Efficiency Gains from Port Reform and the Potential for Yardstick Competition: Lessons from Mexico

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SUMMARY

This paper shows how measures of relative efficiency performance could promote yardstick competition between port infrastructure operators. The illustration is based on a study of the efficiency effects of the Mexican 1993 Port Reform. It covers the 1996-1999 period and relies on a stochastic production frontier to show that Mexico's ports achieved 2.8-3.3% average annual efficiency gains since reform. The port specific measures point to consistent leaders and laggards which would not all be identified by common partial productivity indicators. This information could be built into an explicit incentive based regulatory regime aiming at promoting catch-up by laggards.

Keywords: Latin America, Mexico, efficiency, port, regulation, competition.

1. INTRODUCTION

During the last decade, Latin American ports have changed significantly in all but a few small countries (El Salvador, Honduras, Nicaragua and Paraguay). The region's major ports are no longer state-run public monopolies. Most common user ports have been or are being concessioned to private operators, many more specialized ports and terminals are now privately owned or leased, and regional and international port companies participate in the operation of a large number of relatively small ports and in competing terminals within larger ports.[1]

These reforms have taken place because ports are one of the key components of the logistics chain which weights-in heavily in the final costs of many exported and imported products. Reforms that improve port efficiency are expected to cut total logistic costs and hence improve the overall competitiveness of the reforming economy. The most common instrument relied on to generate cost -cutting efficiency gains is the introduction of some type of competition.

To achieve competition in ports, there are two main approaches. The first is *ex-ante* competition and relies on the auction of the right to operate the port or *in* the port. The second is *ex-post* competition between ports or between terminals within a port. It stems from the assessment of the relative and absolute performance of each port – the basis of yardstick competition or competition by comparison.[2] Both forms of competitions are built-in the Mexican reforms initiated in 1993 which makes Mexico a particularly representative and interesting case study.

A common feature in post-reform monitoring is the focus on partial productivity indicators such as waiting time, labor productivity, use of capacity. These partial indicators are all useful but they can be quite misleading since they do not necessarily generate the same ranking of ports. This is why, in Mexico's reforms just as in most other port reforms, they only have a limited value for the implementation of some of the recent regulatory

mechanisms which require some explicit consistent estimates of efficiency gains.[3] The measurement of the absolute performance stemming from the joint effects of all inputs on outputs is needed for the revision of the price caps adopted by Mexico–another common feature in port reform–and should be analytical–i.e. model or formula driven. These absolute performance measures could also be combined to generate relative performance assessments and promote inter-port competition.

With this background, the specific focus of the paper is twofold. First, we show that even in a set up with limited data availability common to most ports around the world, we could assess through the estimation of a production frontier the efficiency gains achieved since Mexico introduced its reforms. We also discuss some common process issues in port regulation surrounding the use of these efficiency measures in the context of a tariff revisions or any other type of regulatory interaction between operators and regulators. Second, we show why efficiency measurements generated from production frontiers have the seeds of what could become a standard instrument to promote ex-post competition and formal yardstick competition in the sector to give stronger incentives to improve efficiency to the poorest performers.

The paper is organized as follows. Section 2 presents the recent reforms in the Mexican port system. Section 3 summarizes the main results available in the literature. Section 4 discusses the methodology followed to assess the efficiency effects of the reform in Mexico and the results of the analysis. Section 5 offers some concluding thoughts.

2. THE REFORM OF THE MEXICAN PORTS

The reform of the Mexican port system started in 1993 and followed a pattern similar to that of many other reforming countries. In Mexico, as in most countries, the port system was until then managed centrally by a network of public firms. This section describes the Mexican port system and its reform, emphasizing the

institutional framework resulting from the changes and the facts that are most relevant to the assessment of improvements in performance.

(a) Market structure

Mexico is supported by a large port system composed of 108 ports and terminals[4] distributed along the 11,500 km coastline of the country, with a total berth length of 110 km. Half of these facilities are located on the Pacific coast, and the other half on the Mexican Gulf and the Caribbean. There are 39 ports dedicated to commercial activities, and approximately a similar number are fishing ports; 22 ports are specialized in tourist traffics, and eight are specialized in oil traffic. This system handles 85% of total international trade, and more than seven million passengers.

The core of the traffic is however extremely concentrated. Most goes through 27 commercial, industrial and tourist ports, and 10 terminals specialized in oil and mineral ore traffic. In 1999, the main eight ports handled 71% of total cargoes, four of them in the Atlantic coast and the other four on the Pacific. However, if oil is excluded, basically half of total movements of cargo are performed by five ports: Veracruz, Tampico and Altamira on the Gulf of Mexico; and Manzanillo and Lázaro Cárdenas on the Pacific side.

Total movement of cargo by Mexican ports increased from 169 million tons in 1990 to 248 million tons in 1999. Passenger traffic has doubled during the same period, while container traffic has multiplied by three. The main cargo types are oil and its derivatives, with a share of 62%, followed by mineral ores which amounts 23% of total tons handled by Mexican ports. General cargo, including both bulk and containerized goods, represents 8.5% of total tons. The percentage of goods transported in containers over total general cargo (containerization index) exhibits very low values –36% in 1999– compared to international standards—but it is improving. From the total TEUs (Twenty feet Equivalent Unit) handled by the port system, the ports of Manzanillo and Veracruz moved

about 70%. These two ports have the more modern container terminals of the country, and therefore their productivity and efficiency are expected to be higher for than other ports.

(b) Restructuring and privatization

Modernization and reform of Mexican ports started in 1993. As part of the strategy used to reform the port system, two type of actions were followed. First, an adequate legal framework was needed to allow private firms to enter the port industry as operators. This was built in the new Ports Law passed in 1993. The second action was the dismantling of the public agency *Puertos Mexicanos* (PUMEX), responsible up to 1993 for the ports' network and was the only agency in the country authorized to build port infrastructures and to provide port services. The reform rested on three key instruments: decentralization, privatization and introduction of competition in the port system.

Decentralization implies that each port must have an autonomous, self-financing Port Administration, so that the government will have only a supervisory role over the system; it was pursued by creating independent Port Administrations (*Administraciones Portuarias Integrales,* APIs) at each port or group of small ports, which are publicly owned companies to which the administration of ports was directly granted. Thus, for example the API of the Veracruz port is legally established as a company whose shares are owned 99.8% by the federal government, and 0.2% by the development bank BANOBRAS. The board of the APIs must include representatives from the States and municipalities, and some from the private sector. The APIs were granted the rights over the port assets, and authorized to grant concessions over those same assets to private firms, but making it clear that in no case those assets will be permanently transferred to the private sector. APIs pay compensations to the federal government for the use of assets publicly owned. The federal government, through *Secretaría de Comunicación y Transporte* (SCT), keeps the role of port authority, and it is the agency that grants all concessions, and licenses.

Additionally, SCT acts as regulator in those cases where competition is absent or it is not strong enough, by determining maximum tariffs to be charged to users. Matters on safety are performed by the navigation authority (*Capitanía de Puertos*), which is an agency independent from SCT.

Decentralization started in February 1994, when the APIs were created and assumed the functions of planning, building infrastructures and promoting the port, apart from tasks on safety. They act as landlords since the Ports Law precludes them generally to act as port operators and requires them to contract with third parties. However, they are not full port authorities, since that role is legally attributed to SCT. The main 16 ports created APIs accountable to the federal government mostly. Additionally, five ports have APIs which are controlled by State governments, all these are specialized ports (tourism, fishing) or serve small local markets. There is only a private API, in the port of Acapulco, specialized on tourists' traffic. Both the five State-controlled APIs and the one of Acapulco share the characteristic that the API is also the operator of port services, due to the small size of ports, or to their specialization.

Privatization implies that the port industry must be open to the participation of private investors, both nationals and foreign, for the operation of terminals and other facilities, and eventually even the port administration. In almost every port, private participation has now been introduced through auctions for concession contracts between APIs and private firms to provide port services. For simple services, such as towage and pilotage, only a license is required, which can be obtained by any interested party sufficiently qualified. Private participation has induced significant changes in the port industry, in terms of investments on infrastructure, and improvements in quality of service and tariffs. Thus, total investments in equipment and new terminals was around 6,000 million pesos between 1995-1998, 60% of which was private investment. Investments in infrastructure and equipment have already generated substantial capacity increases for the Mexican port system. In 1993, the estimated installed

capacity allowed to handle 59 million tons of commercial cargo (does not include oil, cement and salt). However, ports only moved 24 million tons. The reforms further increased this capacity to over 90 million ton by the end of the 1999 but also increased utilization to over 55 million tons.

The last phase considered for the process of ports' reform is the transfer of APIs to the private sector, by selling their shares to investors. This has no been very successful so far. [5] There are no established dates or conditions for privatizing the port administration (APIs) of the main ports of the country. There is currently only one private API (Acapulco), and two ports are in the process of privatization (Topolobambo and Guaymas). This lack of private interest in the operation of APIs contrasts with the strong penetration of the private sector in port services. Most of these services are in fact now privately operated attesting to the overall success of this phase of the reform.

Liberalization and competition, between ports and between operators within ports, resulted from some restriction in the auctions for concessions and required liberalization of tariffs and elimination of cross-subsidies and barriers to entry. First, according to norms on competition, all request by private firms to participate in public auctions to obtain concessions over port assets were evaluated by the competition agency, the Federal Commission for Competition (CFC using the Spanish initials), to avoid risks of excessive market power after privatization. In practice, this obligation did not impose a relevant restriction over the outcomes, since most applicants were authorized to participate without reservations. However, an important ruling was the initial restriction for firms not to win more than one concession on each coast (Pacific, Atlantic). This geographical restriction was later modified, and now the only restriction is that a firm must not gain a dominating position in the relevant market (this was applied, for example, for the tourist cruise markets).

Second, port tariffs have been generally liberalized. Regulation is only used in those cases where it is

considered that there is not enough competition between operators. The Ports Law establishes that CFC is to examine these questions and to determine when tariff regulation is or is not required. Port tariffs charged by APIs to ships for the use of common infrastructures are subject to price caps. The limits approximate the long-run marginal cost of each port – operating and investment costs –and hence tariffs are different for each port but close to the level that would result from competition. To promote incentives for cost reductions and innovation, the limits are to be revised every five years to reflect any efficiency gains that may have been obtained from competition between the ports. In addition, with respect to the labor market, the reform transformed collective bargaining into firm-level bargaining, thus allowing firms to negotiate with their workers according to local and business conditions. As a result, the number of port workers employed by the public sector has been reduced, but total port employment by private firms is rising, due to an increase in the activity of ports. For example, the port of Manzanillo had 2,100 workers before the reform, and at the end of 1997 the number had doubled. In Veracruz, with an initial number of 6,647 employees, the increased was not so spectacular in relative terms, but it had also risen to 8,260.

Overall, the most relevant fact emerging from this brief overview is that Mexico wants competition between its ports as a way of improving the competitiveness of these ports. To achieve this goal and to make the most of the regulatory tools the reform has granted to its regulator, Mexico needs to be able to measure the improvements in efficiency in each port in absolute and relative terms. It needs an absolute measure because the limits to the regulated tariff will have to reflect every five years the average efficiency gains achieved. It needs a relative measure because the spirit of the reform requires competition to be sustained as a matter of process and that this, in turn, requires a regular assessment of the relative performance of the main ports, therefore creating the basis of a system of yardstick competition. It turns out that five years have just passed since the beginning of the reform and that

enough data are available to make a fair assessment of absolute and relative efficiency improvements in the main Mexican ports.

3. A BRIEF SURVEY OF EFFICIENCY MEASURES IN THE PORT SECTOR

The efficiency literature on ports' performance is relatively modest in comparison to the efficiency literature available on other infrastructure activities. It is evolving however and can be classified into two main groups. The first covers partial indicators of productivity in the port system but presents only a very limited view of efficiency zooming on specific ports. The second, more recent and much less developed, adopts the types of approaches recommended by this paper.[6]

The literature covering partial indicators of port productivity continues to prevail among practitioners as revealed by a random look at annual reports published by port authorities.[7] The more academic literature adopting this approach to focus on specific ports spans over a 15 years period starting in the early 1980s after which a first attempt at using these indicators for inter-port comparisons was suggested by Tongzon (1995) and Talley (1994). Their approach was quite simple and consisted in defining a set of comparable indicators. Heaver (1995) and the Australian Productivity Commission (1998) went further and used comparable indicators to try to see how inter-port competition could be promoted analytically. Similar studies relevant to the concerns of a regulator include the study of scale economies by Jara et al. (1997) or Cullinane and Khanna (1998). Fernández et al. (1999) also covers the effects of privatization. While all these studies generate useful insights on the performance of ports and the factors driving their costs, their main drawback was their partial view which does not yield an analytically consistent approach to the joint contribution of the various inputs to efficiency.

The second generation of studies relying on formal measures of efficiency is an attempt to address this failure. It is still too recent to have generated many publications. However, the diversity of approaches followed by

the relatively modest volume of papers is quite revealing of the lack of concensus on the ideal approach. The main contributions of these studies are summarized in Table 1. A few clear trends appear.

In general, researchers focus on panels of ports cost or production performance to make the most of the information available. Only two papers rely on a simple cross-section. Roll and Hayuth (1993) rely on data commonly available from annual reports in ports and Tongzon (2001) covers 16 ports for which he obtained comparable data for 1996.

Second, the models preferences are evenly distributed between stochastic frontiers and DEA, with one study by Baños, Coto and Rodríguez (1999) also testing a distance function to show the difficulty faced by ports in adjusting in the short run its quasi fix factors. Liu (1995) focuses on production to calculate technical efficiency and compares the influence of public and private ownership in Britain. Coto, Baños and Rodríguez (2000) test a cost frontier. Roll and Hayuth (1993) show how DEA can be useful in assessing the relative effectiveness of various ways of organizing port services when limited data are available. Martínez, Díaz, Navarro and Ravelo (1999) relies on a DEA to assess the evolution of the relative efficiency of Spain's ports. Tongzon (2001) uses DEA to make an international comparison of efficiency in four Australian and 12 other ports from around the world.

A third noticeable feature of the comparison of the studies is that all stochastic frontiers are tested for translogs but the type of technical progress—i.e. neutral vs. non neutral – built-in varies across studies. Moreover, the production or output measures also vary. Coto et al. (2000), Martínez et al. (1999), Baños et al. (1999) and Roll and Hayuth (1993) all adopt a measure of physical quantities of merchandises manipulated. In addition, Roll and Hayuth include service level, service satisfaction and ship traffic as outputs. Martínez et al. and Roll and Hayuth model explicitly the multi-product nature of ports.[8] They aggregate the three main components of the port activity: tons of merchandises moved, passengers loaded and unloaded and number of vehicles with passengers.

The product can also aggregate freight (a weighted sum of containers, general cargo and grain) and service level (ratio of hanlding time to total stay) as done by Roll and Hayuth (1993). Liu (1995), Baños et al. (1999) and Coto et al. (2000) assume a single output technology and the last two authors measure output through the volume of merchandise handled. Liu (1995) measures the output through the revenue generated—excluding revenue from the sale of goods. This approach assumes that the ports are quite competitive and that tariffs reflect costs and hence that revenue reflects output.

All studies model capital and labor as inputs—as expected. The labor input is approximated by the number of employees or the related expenses. Roll and Hayuth (1993), Baños et al. (1999) and Tongzon (2001) adopt the first option and define labor as the average annual number of workers in the port. Liu (1995) and Martínez et al. (1999) assume that the total wage payments are a good approximation of the labor input. The modeling of the capital input gives rise to more approaches. Liu (1995) defines capital as the net value of fixed capital, including land, buildings, docks, berths, roads, storage and equipment. Roll and Hayuth (1993) consider that capital is the annnual average of all capital invested in ports and installations. Martínez et al. (1999) assumes that it can be approximated by depreciation expenditures. Baños et al. consider two types: one variable, approximated as a percentage of the net value and one quasi-fixed definied as the length of the docks/berth with a depth over four meters. Other production factors include "other expenditures" representing intermediate inputs (Martínez et al., 1999); energy consumption, non-recurrent labor inputs (Baños et al., 1999); and the diversity of load to pick up the degree of specialization of the port (Roll and Hayuth, 1993). Tongzon (2001) includes separately the number of cranes, of container berths, of tugs and of terminal areas. In addition, he adds a quality variable approximated by the delay time—which may seem strange since it could be seen as a proxy for an output as well.

Table 1

For the two papers with cost functions, Baños et al. (1999) and Coto et al. (2000), the prices of labor are approximated by the ratio of total labor cost to the number of workers. For the price of capital, they differ. Coto et al. (2000) divide the amortization of the period by the length of docks. Baños et al. (1999) distinguish between the price of variable capital, defined as the ratio of investments realized in one year over investments over the previous year and the price of capital quasi-fixed approximated by the ratio between the use of capacity and the length of docks with a depth over four meters. The price of intermediate inputs is the ratio of consumption, external services and service costs, over port activity defined as the number of tons of merchandise handled by the port. The price of energy is obtained by allocating the energy inputs cost to ports according to the volume handled.[9]

The environmental variables covered are usually included to approximate some institutional or market specific characteristics and are usually built in the second stage of two stages approaches to the measurement of efficiency. Liu (1995) relies on four variables. Ownership is a dummy differentiating between private, trust and municipal ports. The size of ports enters as a dummy distinguishing between large, and, "medium and small" ports. Localization on the Pacific shore vs. Atlantic shore also enters as a dummy. Finally, the intensity of capital is measured as the ratio between the net value of fixed capital and the total wage bill. Coto et al. (2000) rely on a dummy as well to distinguish between autonomous and other ports and on dock length to model the relevance of the size of ports.

While intuitively quite attractive, the idea of using these variables in a second stage to explain efficiency is criticized by some of the top econometricians in the field. Indeed, starting with Kumbhakar et al. (1991), Reifscheneider and Stevenson (1991) and Battese and Coelli (1995), the criticism is based on the fact that the variable used in the second stage should have already been used in the first stage to ensure that inefficiency is measured properly. The failure to do so leads to a mispecified model. To the extent that they are relevant, the

residual of the first stage generate wrong estimates of efficiency. The critique is however not addressed to the general approach since frontiers can indeed provide other policy insights on the functioning of ports.

This leads to a discussion of the estimation methods used. As can be seen in Table 1, the diversity of methods used is quite impressive. Two stages methods relying on instrumental variables and maximum likelihood approaches are quite common to estimate the parametric frontiers. Most of them also look into the fixed effects of each port to ease the relative performance assessment. As for the non-parametric approach, it may be worth pointing out that Martínez et al. (1999) and Tongzon (2001) rely on a methodology proposed by Banker, Charnes and Cooper (1984) to account for scale. They adopt a two stages radial approach to generate the efficient frontier by solving a linear programming model.

While not strictly comparable, the measures of efficiency obtained by the various authors are summarized in the last column of Table 1 since none of the papers rely on methods comparing strictly the same sample with different methods or of the same time period with comparable output variables. Liu (1995) does focus on technical efficiency but does not compute port specific efficiency measures. He computes simply an average which he uses as a variable to explain in a second stage. His comparison of the various ports leads him to suggest that in the UK for the 1983-1990 period, there is no significant advantage to private or public ownership when the policy environment is competitive. He also shows that size matters and being larger helps, that location matters but not a lot and that capital intensity has no significant impact. Coto et al. (2000) assess the economic efficiency of each Spanish port for the second half of the 1980s. The first stage of their analytical works reveals a ranking in which the smallest ports were the most efficient and the largest the least efficient and that autonomy did not necessarily help. When testing in a second stage the relevance of size for the level of efficiency, they conclude that sized does in fact not matter but that autonomy hurts efficieny levels.

Covering a longer period for the same set of ports, 1985-1997, and focusing on technical efficiency, Baños, Coto and Rodríguez (1999) conclude that there is an overcapitalization of the sector and that the Spanish ports are not minimizing costs, hence reinforcing the attractiveness of the distance function—although both the cost and the distance function lead to the same policy conclusions. Relying on DEA, Tongzon (2001) confirms the relevance of the degree of capital and labor utilization in the assessment of efficiency. Also relying on DEA, Martínez et al. (1999) show that a three level grouping of the Spanish ports (large, medium, and small) for the 1993-1997 period refines the earlier results. In recent years, the largest ports have been the most efficient and exhibited the largest efficiency gains. The smallest ports on the other hand have been the victim of a progressive decline in their performance and medium ports seem to catch up. The main additional policy contribution of the Roll and Hayuth (1993) paper is to confirm that location matters, as revealed by a different sample.

Ignoring momentarily the doubts that the Battese-Coelli critique could cast on the results, an overall glance at the last column is however useful to get a rough order of magnitude of the levels of efficiency that can be expected for various types of combinations of models and output variables in sector. It suggests first that the efficiency of the sector is likely to be stronger in terms of production frontier than in terms of cost frontier, confirming that the local monopoly power many ports have is sufficient to generate rent which regulators are failing to redistribute to users. It also shows that the standard policy concerns such as overcapitalization, size or autonomy can be relevant but not always in the expected direction.

Overall, in addition to these fairly generic results, the overview provides some insights on what seems to be the minimum information requirements needed to implement a comparative performance evaluation in the port sector. The multiple output nature of the port business yields a large variety of indicators to pick from which includes non-transport related activities such as the rental of space for any purpose. If allocative efficiency is

important a cost function must be estimated. The challenge of separating costs between variable and fixed is in itself significant but modest in comparison to the challenge of assessing the opportunity cost of capital in many developing countries. This may explain why the production function will probably have to be the preferred option for efficiency measures for developing countries. The main difficulty for labor inputs is obtaining a disaggregation distinguishing white and blue collars and/or permanent and temporary employees. Capital inputs will generally be the most difficult one to assess, in particular in the context of a cost function. The physical inputs or their monetary valuations will often provide good approximations. Intermediate inputs tends to be a residual category. Other factors include anything that the analyst thinks may be relevant to the port activity level. This includes of course its ownership (public vs. private) in international comparisons and in some countries. It can also include market size (in Mexico, the East and West coast markets are different) and the port size, if the data available do not allow to build in economies of scale carefully enough. Finally, a time trend will often have to be tested in most of these models to pick up any technological change.

4. MEASURING THE EFFICIENCY EFFECTS OF MEXICO'S PORT REFORM

This section summarizes the major steps needed to generate the efficiency measures. It covers a somewhat detailed discussion of the data because it turns out that the limitations to the implementation of standard efficiency measurement technique is significantly driven by data restrictions.

(a) The general focus of the efficiency measure and the available data

While the reform was decided in 1993 and the bulk of its implementation took most of 1994, the new autonomous APIs needed another couple of years to put together a reasonable monitoring system demanded by the Transport Subscretariat. The data available are annual and span over four years, from 1996 to 1999, and only covering the 13 APIs (the main ones). This provides a panel of data of 52 observations which is large enough to

rely on parametric methods and in particular on a production frontier. The limited coverage is good enough to allow a fair assessment of the continued progress and efforts made by the APIs to meet the mandate assigned by the reformers. It is also good enough to allow an assessment of the evolution of the relative performance of the main APIs.

The APIs covered by the study are those under federal responsibility: Ensenada, Guaymas, Topolobampo, Mazatlán, Manzanillo, Lázaro Cárdenas and Salina Cruz, on the Pacific coast of Mexico and Altamira, Tampico, Tuxpan, Veracruz, Coatzacoalcos and Progreso, on the Atlantic coast.[10] Excluding oil and its derivatives, these APIs handle 70% of the traffic going through the Mexican port system. This is significant. Among the largest ports, the main ones missing are Puerto Madero, Puerto Vallarta and Acapulco due to lack of enough comparable data. Puerto Madero was closed for a number of years while under repair. Puerto Vallarta is mostly a tourist port and has very little cargo. Acapulco, also a mostly passenger oriented port, has the only API privatized so far (since 1997). Since Mexican law prevents the regulator from requesting any cost information, that could also be used by the fiscal authorities from any tax payer, no data are available on that API. The rest of the ports are generally too small to allocate major resources to meet detailed regulatory informational requirements and furthermore tend to belong to the subnational governments which do not impose the same informational requirements. In the last specifications of the model, we withdrew from the sample of ports Salina Cruz and Lázaro Cárdenas**.** This was done because they are the largest one (and one of them is fully specialized) and several econometric tests suggest that they do not fit well into the technology assumed for the rest of the ports. Ultimately, our production frontier is estimated based on the performance of 11 ports over the four year period.

Since the ports are subject to a price cap and their interactions are designed to be competitive, it would make sense to construct both cost and production efficiency measures to identify possible rents from a comparison

of cost and production efficiency in preparation for the revision of maximum tariff allowed. The econometric techniques available so far however do not allow yet much inference from a comparison of the efficiency estimated from cost and production functions.[11] While an estimation of both the production and cost frontier through stochastic models should, in principle, allow for calculation of technical and allocative efficiency from different but related information bases, the reality is that such comparisons are still almost impossible to conduct in any robust way.

In view of the data restriction on the cost side, the analysis of the efficiency effect of the reforms is based on a production frontier.[12] A production frontier assumes an output maximization rather than a cost minimization effort. This may a reasonable assumption when focusing on the promotion of competition but may not be the most desirable one in view of the fact that the regulated tariffs are under a price cap regime with the explicit purpose of promoting cost reductions. The fact that market shares are a clear concern for APIs' managers and that most of the initial investment decisions were taken for them as part of the restructuring process suggests that the production orientation is overall a reasonable one. Indeed, the efficiency measures generated from the production frontier in a sector with scale economies provide information on the opportunities for expansion of outputs for a given quantity of inputs, for a given level of costs.[13]

The production variable reflecting the output of the infrastructure can be approximated by the volume of merchandise handled (in tons) in each API. This is clearly a second best. Ideally, it would have been desirable to address the multi-product nature of the APIs' activities through a disaggregation of the various types of cargoes handled and through the explicit recognition that APIs also provide other services such equipment rental, commercial building and space rental, water services to the ships, etc. While these activities confirm the multi-product nature of the APIs' activities, the data on these other activities are unfortunately not available for each port

for the period covered. This is why we assume a single output activity which focuses on the APIs' main activity: the operation of an infrastructure which supports the loading and unloading of merchandise and takes the resulting volume of merchandise handled as an approximation of each APIs' production.

The production function builds on two inputs: labor and capital. Labor is measured by the number of workers in each API.[14] The capital input is approximated by the length of docks concessioned by the government to the API. Table 2 summarizes the main statistics and illustrates the diversity of Mexican ports.

Table 2

(b) The specific model

The production frontier estimated is designed to get the best possible assessment of the sector's potential efficiency gains during the period of observation and the average position of each port with respect to these gains. This is important for the regulator since it needs to decide by how much the maximum port tariff can be cut in each port to redistribute efficiency gains achieved since the reform to port users. The model must thus be able to allow the regulator to track down the average evolution of efficiency in the sector but also to track down over time, as effectively as possible, the absolute and relative efficiency ranking of a panel of ports to identify outliers—i.e. systematic laggards or leaders. The estimation of the model is allowed by the access to a panel of data which covers a four year period—1996-1999 – that follows a two year implementation period which should have already built in the frontier shift these reforms tend to introduce. In other words, catch up is the expected outcome measure to come from this sample rather than technological progress at this stage of the reforms.

Following the literature in the field, we tested two functional forms for a stochastic production function, a Cobb-Douglas and a Translog. The estimates are based on the maximum likelihood method relying on the FRONTIER package, version 4.1. The specific functional formal tested are the following:

$$\ln Q_{it} = b_o + b_1 \ln K_{it} + b_2 \ln L_{it} + b_3 t + b_4 \ln(K_{it})^2 + b_5 \ln(K_{it})\ln(L_{it}) + \\ + b_6 \ln(K_{it})t + b_7 \ln(L_{it})^2 + b_8 \ln(L_{it})t + b_9 t^2 + v_{it} - u_{it} \qquad (1)$$

where: the variables are all deviations from the geometric mean and defined as follows:

$i = 1,...,N$ and $t = 1,...,M$

Q_{it} is the volume of merchandise handled in port i during period t,

K_{it} is the capital used by port i in period t as defined in the text,

L_{it} is the number of workers employed in port i in period t,

t is a time trend, and

v_{it} is the random error assumed to be iid distributed as a normal $N(0, s^2_v)$ and independently distributed from u_{it} which is a non negative random variable associated with technical inefficiency and supposed to be distributed independently as a half-normal $N(0, s_u^2)$.[15]

Since the specification of the residual can in fact take various forms, we need a test to chose between the various models. This can be done through a ratio of likelihood test which works as follows:

$$LR = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \qquad \textbf{(2)}$$

where $L(H_0)$ and $L(H_1)$ are the value of the likelihood function under the null assumption (H_0) and the alternative (H_1), respectively. If H_0 is correct, this statistic LR is distributed as a c^2 with as many degree of freedom as there are restrictions imposed.

Applied to the specification of the distribution of the inefficiency term, the tests leads to accept the assumption of a semi-normal.[16] This is consistent with the standard practice in the literature which is characterized by the adoption of flexible functional forms (Stevenson 1980 y Greene, 1990).

(c) The statistical results

Table 3 presents the results of a maximum likelihood estimate of the frontier under these assumptions for three different model specifications: a translog without technological change, and Cobb-Douglas without technological change. The most striking result from Table 4 is given by the likelihood function expressed in terms of the two variance parameters, $\gamma = \sigma^2_u/\sigma^2_v+\sigma^2_u$ as suggested by Battesse and Corra (1977). In every model, the parameter γ has a value not significantly different from one. This suggests that most of the fluctuations in the residual term is due to inefficiency (U_i) and that the random error (V_i) is approximatively zero. This implies that the stochastic frontier is not significantly different from a deterministic frontier for these ports during this period. A reasonable explanation may be that the reforms have significantly leveled the playing field and that at least in the short run, except for inefficiency, there is not much scope for randomness in the system. Considering that the reformers adjusted employment and made most of the investment necessary as part of the reform implementation that preceded immediately the period of estimation, determinism seems to be acceptable intuitively.

Table 3

In addition, the analysis of the significance of the coefficients reported in Table 3 provides useful insights. The coefficients for the capital and labor factors for the functional forms estimated, translog and Cobb-Douglas, are significant and have the exepected signs but the other coefficients for the translog are not significant. Since we estimated the translog as an approximation to an unknown form, the first order coefficients are the elasticities of production at the expansion point and the other coefficients are less important. To be as complete as possible we also need to compare the relative validity of the various specifications. This is achieved through likelihood ratios tests reported in Table 4.

Table 4

Table 4 summarizes the various restrictions tested on each model, the test value calculated and the corresponding critical value of the c^2 distribution at 5% of significance. The last column specifies the decision revealed by the test on each set of parameters restrictions. The first test checks for the presence or absence of technical inefficiency in the port industry. If there is no such inefficiency, U_{it} could be eliminated from the model and it could be estimated through Ordinary Least Squares (OLS).[17] This corresponds to a test of H_0: g=0. The statistical value 8.34 is larger than the critical value and hence the assumption is rejected, meaning that technical inefficiency must be included. The second test suggests that we cannot reject the assumption that a Cobb-Douglas is at least as good as a translog a representation of the production technology of the Mexican port system. This is because the calculated test value (7.38) is lower than the critical value (7.81). In spite of this statiscal indifference between the two specifications, we adopt the translog to generate the specific results discussed next. It turns out that this does not change the ranking of ports in any way but provides us with a more flexible form.

(d) The efficiency scores

With the statistical results settled, we can now assess the technical efficiency of each port in each year. The results reported are based on the translog production function specified earlier. The annual estimates and their average for each port and for the port system as a whole are reported in Table 5. The average technical efficiency of the Mexican ports for the period is *50.5%* when the outlier Ensenada is included.[18] This is within the order of magnitude of other estimates in the sector as seen in Table 1. The average without Ensenada is even higher. The variance across ports is however generally quite high. It varies from 6.9% in Ensenada in 1996 and 100% in

Tuxpan in the same year. From an overall policy viewpoint, the results confirm that the expected gains from reform are becoming reality.

Table 5

During that period, the annual average technical efficiency increased from 49.5% in 1996 to 54.5% in 1999. Ignoring the clear outlier, Ensenada, the efficiency level reaches 58.5% in 1999. The last row of the table gives the annual growth rate for the period under observation (the accumulated rate of change obtained from a comparison of the beginning and end of period efficiency level). The last row shows that some ports lost ground to the frontier over the period. With the exception of Topolobampo and Tampico for which the loss is larger, the rest may simply reflect a demand shock.

The average annual growth rate should also be useful to the regulator in that it gives an educated guess on the range of average efficiency gains the ports should have been able to achieve over the period. This can be used to specify the reduction in price cap to be allowed for the next regulatory period of five years. In other words, the average annual efficiency gains in the sector was around 2.8-3.3% since the reform. This is quite significant. Any port which did not achieve that should provide a good justification in order not to see its maximum tariffs cut by that much.[19]

From the viewpoint of a policymaker, there is, of course, a lot of information underlying these results which can explain good or bad performances and which the regulator should be aware of. For instance, it may be that a port only started handling containers in 1999 or that others are handling a fair load of passenger traffic which is not recognized by the approach adopted here. It is clear that this is relevant information, but the imposition of a method such as this one to assess the joint effect of the various production factors to all regulated firms, has one major advantage for a regulator who know he/she is only likely to have partial information on the firms it is is regulating.

By coming up with a number based on relatively modest information, the regulator places the burden of proof for any wrongdoing or for any explanation on the shoulders of the APIs.

Up to now, in Mexico, as in most other countries, the ports regulators, as most other regulators, have been follower rather than leaders when it came to quantifying such a key regulatory variable as efficiency. Coming up with a methodology which generates a comparable figure across ports places the regulator in the driver seat of the regulatory process. With this kind of information which is much more robust than partial performance indicators would be, a regulator ask the regulated firm for comparable evidence on the efficiency performance of the port and have a default implementable alternative in case the regulated firm is not providing a satisfactory feedback.

(e) Towards yardstick competition in the port sector

The frontiers as estimated here have just as many advantages and disadvantages as many of the other instruments regulators must rely on—asset valuation for instance is one of the key jobs of any regulator and is at least as controversial as efficiency measurement in the context of regulated industries. The disadvantages are obvious once a regulator tries to put together a database from scratch and starts having to make assumptions for almost every input and even for the number of outputs you can take into account. But for most practitioners, in particular in countries in which governance (i.e. corruption) is an issue, the transparency of the information gathering process and of the estimation rules selected here allows an increased accountability for all parties involved and better fairness in regulatory decisions. In particular, it allows a reasonable ranking of ports. This ranking of efficiency scores is likely to be more robust than the specific efficiency estimates and this makes this instrument useful for weak forms of yardstick competition even for those policymakers with concern for the specific efficiency scores.

By way of illustration, Table 6 provides a ranking of the four best and four worst Mexican performers in

terms of efficiency levels every year in an effort to reveal some performance patterns in technical efficiency—the regulator could also look into the ranking in terms of efficiency changes just discussed as a complement. Given this approach to ranking and given the methodology adopted to estimate efficiency, there is no doubt that Manzanillo and Tuxpan are the only ports consistently among the best performers and Veracruz has joined them for the last two years. At the other extreme, the worst performers included Ensenada and Mazatlán. Altamira has managed to pull out of that group in 1998. It turns out that in this case, there are good explanations for the poor ranking of some of the ports. For instance, for three of these worst ports, the poor ranking can be explained by the fact that they are handling also a lot of passenger traffic. But this does not leads to a rejection of the new regulatory process proposed here, it simply means that the regulator would probably have to get into more details in the discussion of the ranking than the obvious comments made here.

Table 6

Once more, it may be useful to make it clear that the process as described is intentionally simple as an illustration of the potential use of robust rankings emerging from efficiency calaculations. The regulators could decide to zoom only on the top and bottom three or to the contrary on the top and bottom five. They should probably discuss the preferred methodology with the regulated firms in transparent public hearings. This could lead them to decide that data envelop analysis or distance functions are more appropriate for this sector because they can deal with multiple outputs. Indeed, since the production level is approximated by the volume of merchandise handled, we saw that the characteristics of some ports may have penalized them more than the others. In the example covered here, Coatzacoalcos only restarted container manipulation in 1999, while Ensenada—in addition to suffering from its proximity to the US ports—and Mazatlán should also have received more credit for their important handling of passenger traffic which is not allowed by the single output assumption of the production

function estimated.

The fact is that within their short-term data constraints, regulators have many choices and must make decisions--ideally in consultation with the regulated operators. Once taken, these decisions define the rules of the game for interactions between the various actors. As these games rules are set, competition to be on the top and reduce the risk of detailed audits for being an underperformer can become effective. The desire to sustain competition in the sector depends on the ability to create the right incentives. Comparative efficiency measures, however they are generated, can help in ports, just like they helped in water or electricity in the UK and Australia for instance. The illustration covered in this paper suggests that it should also be possible to do it in a developing country context.

5. CONCLUDING COMMENTS

There are three main conclusions to the paper. The first is that Mexico's experience suggest that reforms in the management of port infrastructure which promote its autonomous management in each port in a competitive environment –achieved here through decentralization—can generate large short term improvements in the average performance of the sector without privatization of this infrastructure—only services were privatized. The average annual *growth rate* in the Mexican ports efficiency was 2.8-3.3%. This adds up to an almost 5% point increase in the average *efficiency level* over a four years period which starts two years after the reform were implemented. This is quite relevant for Latin America where port reform has been started by about every country with a coast line but where competition within or between ports has not been built-in the overall design of the reforms—with a few exceptions, most notably Argentina, Colombia, Mexico and Panama. [20]

Second, the assessment of the port specific efficiency gains achieved is also important for any regulator mandated to pass on the gains from reform to the port users. The approach and the results discussed here can thus

come in handy in the context of a tariff revision since they provide a well informed indication of a lower bound for what efficiency gains over any period of time can be.

Third, the analytically sound performance rankings allowed by these port specific efficiency measures can help in promoting yardstick competition in the sector. This in turn is crucial to ensure that whatever short term gains are achieved from reform can be sustained and reinforced over the longer run. While not perfect and certainly restricted by the availability of data, this ranking is superior to the one that would emerge from a ranking based on partial productivity indicators which allow easy manipulations of ranks through simple biases in the selection of the performance indicators. The approach suggested here accounts for the joint effects of all inputs on outputs and reduces the odds of getting inconsistent rankings based on different arbitrary choices of partial indicators.

Ultimately, it may be worth pointing out that the main long run benefits of the more encompassing approach to measuring performance proposed here may depend less from its use to promote yardstick competition than from the increased accountability for performance. Indeed, governance issues are typically the main result from lack of information in infrastructure sectors and this tends to be the norm with a strong cost incidence on all infrastructure service users. The generation of the information needed to allow the sustainability of effective competition is what eventually will guarantee the sustainability of the gains achieved through any port reform.

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[1] Argentina, Colombia, Panama and Mexico are the forefront of reforms, Chile, Brazil, Peru, and Venezuela are all in the process of concessioning their common user ports were and Costa Rica, Ecuador, Uruguay, and Guatemala are following closely in increasing private sector participation in the operations of their ports (Hoffmann, 2001).

[2] In countries with multiple ports, this requires their decentralization and an increase in their autonomy to promote inter-port competition within the country—the strategy adopted by Mexico. In smaller countries, this requires international comparisons-which are often more difficult to implement because of the difficulties of comparing prices internationally.

[3] See Trujillo and Nombela (2000) for a longer review of the international experience with port reform.

[4] Facilities located outside port areas, as defined by the government, dedicated to port operations.

[5] The sale of these shares does in fact not imply that the shareholder own the port since the APIs only receive the ports assets in concesion which may explain the lack of success of this last phase of the reform.

[6] For a recent overview of the literature see Campos, Estache and Trujillo (2001). For a more rigorous survey see, Coelli, Rao and Battese (1998). For a survey targeted to infrastructure regulators, see Coelli, Estache, Perelman and Trujillo (2001).

[7] It includes papers by Neufville and Tsunokawa (1981), Suykens (1982), Kim and Sachis (1986) providing simple productivity assessments. The role of investment has been studied by Shneerson (1981) and planning by Bobrovitch (1982), Shneerson (1983) or Goodman (1984).

[8] So does Tongzon but because the two outputs case yields unrealistic results, he ends up focusing on a single output.

[9] Most of the definitions of the variables in this paper are quite complex to implement and may reflect characteristics specific to the way the annual report is presented in Spain by port authorities.

[10] We also have a version of the model including all 13 APIs but the inclusion of the two largest one, Lazaro Cardenas and Salinas Cruz yields somewhat less reliable statistical results, reflecting the fact their significant differences from the others which seem to be more homogoneous in size.

[11] See Coelli, Estache, Perelman, and Trujillo (2001).

[12] In Mexico, the lack of a tradition of regulatory accounting is also a source of concern for the confidence that can be attached to cost data and the estimation of a cost function.

[13] Under constant returns to scale, the results are quite different: Instead of increasing production x%, the firm could get the same output by cutting inputs by 1/x% and the corresponding change in costs can be calculated immediately when factor prices are known.

[14] This number excludes all workers allocated to loading and unloading of ships since that activity is not being measured in this production function. This is an issue only for the four APIs providing merchandise handling e.g. Topolobampo, Guaymas, Mazatlán and Salina Cruz.

[15] The term $-u_i$,cannot be observed in practice. Since the frontier has been estimated, the only thing observable is the difference v_i-u_i, the only solution is to rely on a predictor of this term. The best one is the expected value of v_i conditioned to the value of v_i-u_i. When the models includes explanatory variables for the efficiency of ports , it becomes a $N(m_{it}, s_u^2)$, where $m_{it}=z_i d$, and z_i is the vector of all variables which could influence the efficiency of ports and d is a vector of parameters to estimate in the modes including explanatory variables for port inefficiency.

[16] In this test the Null Assumption ((H_0) refers to the specification of a semi-normal distribution for the inefficiency term (U_i) and the Alternative Assumption (H_1) refers to the consideration of a normal distribution truncated to zero for this inefficiency term.

[17] When H_0:g=0 is right, the production function is equivalent to a regular average response function and OLS estimates will yield efficient estimates.

[18] Ensenada is somewhat of an outlier because it was a fishing port until the early 1990s and is only progressively starting to handle containers for less than 10 years. In fact most of its recent growth seems to be coming from passenger ferries.

[19] Taking the specific figures in every cell of Table 5 for granted would not be a good move for any regulator. Minor changes in the specification of the model could change some of them even if they do not change the ranking or the overall trend.

[20] See Hoffmann (2001)

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Table 1. A survey of the literature on efficiency measures in the ports sector

Author	Data (1)	Model (2)	Functional Form	Variables (3)	Estimation Method (4)	Efficiency concept	Efficiency measure (5)
Liu (1995)	Panel 28 UK ports 1983-1990	SPF	Translog Neutral and non neutral Technological change	Y_1 (X_1, X_2, Z_1, Z_2, Z_3, Z_4, T)	Model 1: OLS, ML Model 2: Within, GLS, ML	Technical efficiency Mod 1 (ML): Mod 2 (GLS): Mod 2 (ML): Mod 2 (ML, with T):	1983-1990 78.0 76.9 68.3 69.7
Coto, Baños and Rodríguez (2000)	Panel 27 Spanish ports 1985-1989	SCF	Translog Non neutral Technological change	TC_0 (Y_0, W_1, W_2, W_3, T)	Within	Economic efficiency Maximum: Minimum Average	1985-1989 100 11 33
Baños, Coto and Rodríguez (1999)	Panel 27 Spanish ports 1985-1997	SCF DF	Translog Neutral Technological change	VC_0 (Y_0, W_1, W_3, W_4, W_5, T) D (Y_0, X_1, X_3, X_4, X_5, T)	Instrumental Variables	Technical efficiency Distance function Maximum: Minimum Average	1985-1997 100 15 41
Roll and Hayuth (1993)	Cross Section Hypothetical data	DEA	Not applicable	Y_0, Y_1, Y_2, Y_3, Y_4, X_1, X_2, X_6	Not relevant	Average Medium Efficiency Total ports: Ports region 1 and 2	1993 78.2 93.4 86.1
Martínez, Díaz, Navarro and Ravelo (1999)	Panel 26 Spanish ports 1993-1997	DEA	Not applicable	Y_0, Y_1, X_1, X_2, X_3	Not relevant	Average global efficiency Group I:, II and III	1993-1997 88.7 80.1 85.7
Tongzon (2001)	Cross Section 16 ports 1996	DEA	Not applicable Tests: Constant returns to scale Variable returns to scale	Y_0, X_1, X_2, X_3, X_4, X_5, Z_1 Delay time	Not relevant	Average efficiency if: Constant return to scale Variable return to scale	1996 59.5 93.1

(1): To indicate sample size
(2): SPF: Stochastic production frontier; SCF: Stochastic cost frontier; DF: Distance function; DEA: Data Envelopment Analysis
(3): TC: Total cost
VC: Variable cost
D: Distancia
Y_0: Production (tons of merchandise or TEUs handled); Y_1: Production (billing for services) ; Y_2: Service level (number of containers mov ed/hour); Y_3: User satisfaction; Y_4: Nº of ships arrivals
X_1: Labor input; X_2: Capital input; X_3: Intermediate inputs; X_4: Variable capital input; X_5: Quasi fixed capital input; X_6: Uniformity of merchandise
W_1: labor price; W_2: capital price; W_3: intermediate input price; W_4: variable capital price; W_5: quasi fixed capital price
T: time trend; Z_1: port size/terminal area; Z_2: port location; Z_3: port ownership; Z_4: capital intensity
(4) OLS: ordinary least squares, ML: maximum likelihood; GLS: generalized least squares
(5): Measured in %; and in some cases calculated by the authors based on published results.

Table 2: Summary statistics for Mexico's main APIs

Variable	Average	Maximum	Minimum
Production (tons)	5,265,930.07	12,487,349	719,459
Labor input (workers)	69.61	226	13
Capital input (m^2)	4,531.52	10,465	1,092

Table 3. Maximum likelihood estimates of the stochastic frontiers

Coefficient	Translog (no technological change)	Cobb-Douglas (no technological change)
Constant	16.209	16.189
	(125.997)	(204.887)
Ln (K)	0.265	0.191
	(2.665)	(3.256)
Ln (L)	0.375	0.406
	(5.800)	(7.078)
Ln $(K)^2$	-0.761	
	(-1.441)	
Ln $(L)^2$	0.105	
	(0.486)	
Ln (K) Ln (L)	-0.283	
	(-1.291)	
σ^2 (*)	0.736	0.771
	(6.987)	(3.503)
γ (*)	0.999	0.999
	(561527.1)	(35.774)
Log likelihood funcion	-34.783	-38.468

Note: The t statistic is given in parenthesis below the corresponding coefficient.

(*) $\sigma^2 = \sigma^2_v+\sigma^2_u$; $\gamma = \sigma^2_u/\sigma^2_v+\sigma^2_u$ (Battesse and Corra, 1977)

Table 4. Likelihood-ratio tests of the various specifications of the frontier

Restrictions (1)	Models	Log likelihood function	Likelihood ratio test	Critical value c^2 (5%)	Decision
	1.Translog (no technological change)	-34.78			
g=0	2.Translog (OLS) (no technical inefficiency)	-38.95	8.34	2.71(2)	Reject
b_3=b_4=b_5=0	3. Cobb-Douglas (no technological change)	-38.47	7.38	7.81	Not reject

(1) The models 3 and 2 (H_0) are compared to the model 1 (H_1)
(2) Kodde and Palm (1986)

Table 5. Evolution of the port specific technical efficiency (in %)

Year	Ens	Gua	Top	Maz	Man	Alt	Tam	Tux	Ver	Coa	Pro	Average without Ensenada	Average with Ensenada
1996	6.9	54.6	61.0	17.8	80.4	21.9	88.6	100.0	68.0	23.0	22.7	53.8	49.5
1997	8.4	54.6	40.3	41.7	67.3	33.0	61.9	85.0	43.7	43.6	23.3	49.4	45.7
1998	9.9	56.7	39.7	41.5	77.1	46.0	67.2	98.9	57.4	55.2	26.3	56.6	52.4
1999	14.3	52.5	36.0	39.8	77.5	51.2	56.7	93.8	60.6	45.0	72.2	58.5	54.5
Average efficiency level	9.9	54.6	44.3	35.2	75.6	38.0	68.6	94.4	57.5	41.7	36.1	**54.6**	**50.5**
Average annual growth rate	27.5	-1.3	-16.1	30.8	-1.2	32.7	-13.8	-2.1	-3.8	25.1	47.1	**2.8**	**3.3**

Note: Ens: Ensenada; Gua: Guaymas; Top: Topolobampo; Maz: Mazatlán; Man: Manzanillo; Alt: Altamira; Tam: Tampico; Tux: Tuxpan; Ver: Veracruz; Coa: Coatzacoalcos; Pro: Progreso.

Table 6. Ranking of technical efficiency[1]

Year	Maximum	Minimum
1996	Tuxpan, Tampico, Manzanillo, Veracruz	Ensenada, Mazatlán, Altamira, Progreso
1997	Tuxpan, Manzanillo, Tampico, Guaymas	Ensenada, Progreso, Altamira, Topolobampo
1998	Tuxpan, Manzanillo, Tampico,Veracruz	Ensenada, Progreso, Topolobampo, Mazatlán
1999	Tuxpan, Manzanillo,Progreso, Veracruz	Ensenada,Topolobampo, Mazatlán,Coatzacoalcos

1 The ranking that would have obtained from a simple analysis of labor productivity would not have implied a major change with a significant exception. Veracruz which according to the technical efficiency measure is one of the best performing port would have fared quite poorly. Indeed, its labor productivity is one of the poorest in the country. The port handles 13% of the output with 26% of the total of workers, 7% of the capital and 12% of total intermediate inputs. Similarly, the analysis of capital productivity also coincides somewhat with the technical efficiency ranking but also shows a few exception. Capital productivity indicators overestimate the ranking of Guaymas while they underestimate the ranking Tampico and Topolobampo.

Note: For the mazimum, the ranking starts with the most efficient and ends with the least efficient among the top performers; for the minimum, it starts with the least effiicient and ends with the most efficient among the worst performers.