SOURCES OF EFFICIENCY GAINS IN PORT REFORM:

A DEA DECOMPOSITION OF A MALMQUIST TFP INDEX FOR MEXICO

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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Contact Details:

Full affiliation: The World Bank, Washington.D.C., USA and ECARES, Universite Libre de Bruxelles, Belgium

Address: The World Bank, Washington.D.C., USA
Tel: 202-458-1442;
Fax: 202-676 98 74
E-mail: Aestache@worldbank.org

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Abstract:

In Mexico, the port system was managed centrally by public firms until the 1993 reforms which involved mainly a liberalization and decentralization of the system into regional port authorities. The main motivation for the reforms was to improve the competitiveness of the Mexican port systems and efficiency gains were expected to be a major contributor. This paper measures the efficiency changes achieved and their main sources. To do so, we estimate and decompose productivity changes in the 11 main ports for the 1996-1999 period with a Malmquist Index. We differentiate between the catching-up effect and the frontier shift effect and unbundle the catching-up effect into pure technical efficiency and scale efficiency effects. We conclude by drawing the main policy lessons of this experience.

I Introduction

A couple of recent papers by Guasch and Kogan (2001, 2003) document the common wisdom suggesting that ports and roads efficiency are among the major determinants of competitiveness through their impact on the level of inventories businesses have to maintain. They show that while in the U.S., businesses typically hold inventories equal to about 15 percent of GDP, in many developing countries these are often up to three times as large simply because the transport infrastructure is not reliable, efficient or sufficient. They estimate the cost to the economies of these additional inventory holdings to be greater than 2 percent of GDP. This figure illustrates the relevance of the great hopes assigned to port reform around the world and gives a benchmark for the potential welfare gains that can be achieved through port reform in developing countries in general.

While this type of benchmark has proven useful to the policymakers concerned with competitiveness, few have made the effort to monitor the actual gains achieved from reform. Worse yet, fewer even seem to recognize that for these competitiveness gains to be realized, the efficiency gains achieved through port reform will eventually have to be shared with the users as part of scheduled tariff revisions, just as in the case of the reform of the major utilities. Indeed, only if these gains are shared with the users will competitiveness improve.

The relevance of the need to ensure an eventual pass-through of some of the efficiency gains is at least gaining ground among port regulators although few (with the notable exception of Australia maybe) show a major commitment to the quantification of these gains in preparation of tariff revisions. This quantification is however crucial since the fairness of the redistribution of efficiency gains depends to a large extent on the fairness with which these gains are quantified. But assessing the gains levels is not enough from a regulatory viewpoint, it is also important to have a good understanding of the sources of the potential gains to be realized. For the port sector, this is particularly sensitive from a political viewpoint since many critics of port reform tend to argue that the efficiency gains achieve through restructuring are mostly due to job reductions.

This paper provides the first systematic analysis of the decomposition of the sources of productivity changes from reform in a developing country.[1] We estimate the productivity change using a Malmquist Total Factor Productivity (TFP) index. From the viewpoint of a regulator, this index has the advantage of not requiring input price nor behavioural assumptions. We then decompose the total change into total technical efficiency and technological change by relying on a non-parametric (DEA) framework outlined by Färe et al. (1990, 1994).[2] This allows to assess the relative importance of the catching-up and the frontier shift effects resulting from the reforms aimed at promoting increased inter-port competition. We then also separate the catching up effect into technical efficiency and scale efficiency effetcs to give a sense of the extent to which the efficiency gains are achieved purely from adjustments to the input use (including a labor reduction) or from better adjustment of the size to the demand.

The paper is organized as follows. In section 2 we present a brief overview of the theory. In section 3 we summarize the Mexican reforms. In section 4 we discuss the data, its limitations. In section 5 we present the TFP results and its decomposition. Section 6 concludes and raises some policy issues. Section 7 concludes.

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1 The paper is in fact one of the few papers to have attempted the assessment of efficiency in the port sector at all. The first paper dates from 1993 and was published by Roll and Hayuth but worked on hypothetical data. Liu (1995) relies on stochastic frontier to assess the performance of 28 UK ports. More recently, Martinez et al. (1999) adopt a DEA to assess the performance of Spanish ports while Tongzon (2001) relies also on a DEA to assess 16 ports from around the world. Banos et al (1999), Coto et (2000) and Estache et al (2002) all estimated port efficiency in Spain for the first 2 and in Mexico for the 3rd paper through a stochastic frontier the overall efficiency gains achieved through reform but did not look into the composition of the changes

2 Malmquist indices have been used to measure efficiency changes in other regulated infrastructure service such as for electricity utilities (Hjalmarsson et al, 1992) and the natural gas industry (Price et al, 1996) or airports (Abbott and Wu, 2002). In the port sector, the only other example to our knowldege is the paper by Martín Bofarrul, 2003.

2 Measuring and decomposing changes in productivity: some conceptual background

The interest in the analysis of efficiency in general has been growing significantly over the last 30 years and has generated major improvements in the techniques available to measure the performance of firms. Over the last 10 years, the regulators of privatized infrastructure services have become major consumers of these techniques where the measure of efficiency is increasingly becoming a basic mandate for regulators-- mostly in developing countries because that is were most of the reforms have taken place outside of the UK, New Zealand and Australia!

One of the major challenges faced in the regulatory debate on the use of efficiency concepts in regulated industries is the need to get the policymakers, interest groups and the operators in the sectors to accept that the concept of efficiency differs from the partial productivity indicators they tend to be familiar with. Indeed, in the port sector maybe more than in other infrastructure sectors, performance tends to be measured simply by relating one output to one input (e.g. containers handled per crane or per workers). This index is however too simple in practice since most operators tend to rely on a combination of inputs (e.g. labor, various types of equipment and other intermediate inputs such as electricity) which can have varying relative importance across operators. Moreover, many regulated industries offer multiple outputs as well (bulk cargo, grain, liquids, containers, storage,...). This suggests that as data bases improve, regulators will eventually have to develop productivity measures which will 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 any given operator and since the relative importance of every input for every output type can differ, the general formula reflecting the common intuition on the concept of productivity should be:

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

where the a_m and b_k are weights and their choice is, as discussed later, quite important in practice. The output weights and input weights must each sum to one, a basic property of any TFP measure and hence standard practice has been to work on the assumption that output and input markets achieve productive efficiency—i.e. output price=marginal cost and input prices=marginal product value) so that the weight are estimated by output and input share in total revenue and cost respectively[3]. 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 across operators at best, picks up changes due to the adoption of new technologies—shift over time in the output generated by evolving combinations and levels of input—but they do so in a biased way because they ignore that productivity improvements can result from technological changes but also 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 the use of inputs) or the capacity to achieve a given level of output at the minimum input use (if the regulator imposes the output levels on the operators and follows an input orientation in the definition of its efficiency concept). Most regulated industries impose service obligations, that is output are exogenous, and hence the input orientation is the most relevant since input choice is endogenous (Coelli et al. 2003). It is the approach followed in this paper. From the viewpoint of a regulator, the main interest in this measure is that its change tracks down 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 from changing the scale of operation in many of the regulated industries. It is hence quite important for a regulator to be able to assess the extent to which the operator adjust the scale of its operations to the demand side of the business trying to optimise the productivity from the available technology. This information is provided by a measure of the scale efficiency.

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3 This is what the Tornquvist index proposes (1936)

In sum, the potential for efficiency gains to be shared with users can come from technological changes but also from improvements to catch-up with best practice as well as from changes in the scale of operations.[4] The main problem from this last source of gains is that it can be driven to a large extent by the demand side on which the operators do not always have lots of control. This means that the potential for scale efficiency is not always something the regulator can force the operator to share with the users. [5] Being able to measure it is however a necessary condition to ensure that the regulator can the do the right thing in assessing the share of the efficiency gains that the operator can share with user in a sustainable way.

To be able to incorporate these various sources of efficiency changes while recognizing the limitations of the assumptions used in the simple index discussed above, the 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 (1).

$$TFP_1 / TFP_0 = \frac{D_1(Y_0, X_0)}{D_1(Y_1, X_1)}, \qquad (2)$$

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

This index has the main advantage of avoiding having to work with input and

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

5 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.

ouput prices and the related output and input market clearing assumptions. It relies on output and input weight estimated directly. In addition, from the viewpoint of regulated industries where many of the productions decisions in terms of timing and levels are driven by the regulatory framework and various types of obligations rather than only self-centered rational behaviour by the operators, the index has the advantage of not requiring the need to work with behavioural assumptions for these operators (e.g. profit maximization or cost minimization). Finally, the Malmquist index makes it easy to compare the catching-up effort with the frontier shift for a given sector or operator. [6]

Increasingly however, the practice is to rely on an alternative Malmquist Index defined by Färe et al. (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:

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

An equivalent way of writing this productivity index is

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

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 the Total Technical Efficiency Change (TTEC).[7] The remaining part of the index in equation is a measure of technical change (TC). It is the geometric mean of the shift in

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6 See Nishimizu et al, (1982); Grifell et al, (1993).

7 "Farrell" measures of efficiency correspond in each case to the expansion, or the reduction, of the ray that pass through the origin. It makes reference to the Farrell' seminal paper (Farrell, 1957).

technology between the two periods, evaluated at the period 0 data point and also at the period 1 data point. That is:

$$\text{TFPC} = \text{TTEC} \times \text{TC} \tag{5}$$

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 one, and hence any scale efficiency gains (or losses) will be missed. Färe et al (1994) used CRS distance functions to calculate the index in equation (5). They also suggested a further decomposition of equation (6), where the CRS technical efficiency change measure (TTEC) could 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

$$\begin{aligned} \text{TFP}_1 / \text{TFP}_0 = {} & \frac{D_0^V(Y_0, X_0)}{D_1^V(Y_1, X_1)} \left[\frac{D_1^V(Y_1, X_1)}{D_0^V(Y_0, X_0)} \frac{D_0^C(Y_0, X_0)}{D_1^C(Y_1, X_1)} \right] \\ & \times \left[\frac{D_1^C(Y_0, X_0)}{D_0^C(Y_0, X_0)} \frac{D_1^C(Y_1, X_1)}{D_0^C(Y_1, X_1)} \right]^{0.5} , \end{aligned} \tag{6}$$

where the V and C superscripts refer to VRS and CRS technologies, respectively[8]. Equation (6) thus gives a technical efficiency change (TEC) measure, a scale efficiency change (SEC) measure and a technical change (TC) measure. That is:

$$\text{TFPC} = \text{TEC} \times \text{SEC} \times \text{TC} \tag{7}$$

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8 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, however none of them are yet to gain widespread acceptance. See Grifell and Lovell (1999) and Balk (1999) for discussion on this issue.

The product of TEC and TC is also sometimes known as total technical efficiency or TTEC.

This is the decomposition looked for in this paper. It is particularly interesting in the port sector 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 level (it is either too small or too big). In that case, there is not much the operator can do in the short run at least and it would be unfair for a regulator to penalize the operator for this scale issue.

A final "logistic" detail associated with this index is that the estimation of the weights relies on a concept of distance which in turns requires the estimation of a frontier from which the distance will be measured. There are two main ways to estimate this frontier, one is through data envelopment analysis (DEA) the non-parametric programming method, the other is through stochastic frontier analysis (SFA).[9] Both methods allow the derivation of estimates of relative efficiency levels for all the operators compared. In this paper we construct the Malmquist TFP index using input distance functions estimated from a DEA.

As seen in the formula, six distance functions must be calculated: 4 defined under constant returns to scale (CRS) and 2 under variable returns to scale (VRS). Equation (8) is one of the standard ways of presenting the underlying optimization program used in this paper:

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

9 For more details, see Coelli et al. (1998, 2003)

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.

3 The Mexican industrial ports system and its 1993 reform

Until 1993, the Mexican port system was managed centrally by a network of public firms like in many other countries historically. The 1993 modernization and reform of the system was organized around a three prong strategy: (i) decentralization; (ii) introduction of competition within the ports and between the decentralized port authorities and (iii) the eventual privatisation of these decentralized authorities and of most of the services provided in these ports.

Decentralization was built around the creation of an autonomous, self financed Port Administration in each port or group of small ports (Administraciones Portuarias Intergrales or APIs). The federal government supervises the APIS created by the main 16 ports and the provincial governments are responsible to monitor 5 provincial APIs. These APIs act as landlords rather than full port authorities since they cannot act as operators. They are managed by a board with representatives of the owners (currently mostly the federal, provincial and municipal governments, the national development bank but also of the private sector users). They enjoy the property rights over the assets they control and can award them in concessions to private operators. They pay a compensation for the transfer of the assets to the federal government in an annual payment.

The Transport Secretary is the de facto regulator of the sector. While port tariff have generally been liberalized, the fee charged by the APIs to ships for use of the common infrastructure is still subject to regulation. This fee, one the main sources of revenue for the 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 the ports. Safety matters are under the supervision by the navigation authority (*Capitania de Puertos*)

While only one of the APIs (Acapulco) has in fact been privatised, the introduction of competition and of private actors within the ports to deliver services quickly generated significant investments and hence capacity increases in the system. In less than a decade, capacity had almost doubled its ability to handle commercial cargo to over 100 million tons and increased capacity utilization in similar proportions. Public employment has however decreased significantly but this decline is now 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 5 years and Veracruz where it has now increased by about 25% since the reform.

All this is happening within a new legal framework needed to allow private firms to enter the port industry as operators built-in the new Ports Law passed in 1993. It also required the dismantling of the public agency *Puertos Mexicanos* (PUMEX), responsible up to 1993 for the ports' network and which was the only agency in the country authorized to build port infrastructures and to provide port services.

The current market structure that emerged from these reforms can be summarized as follows. The APIs and some of the provincial governments share the responsibility of Mexico's 108 ports and terminals 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.[10] There are 39 ports dedicated to commercial activities, and roughly the same number are fishing ports; 22 ports are specialized in passengers, and 8 are specialized in oil traffic.

Total cargo movement in the Mexican port system increased from 169 million tons to 255 millions in 2002 worth most of the increase taking place since the reform. Passenger traffic has more than doubled while container traffic has quadrupled during

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

the same period. 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 handled by the port system, the ports of Manzanillo and Veracruz moved about 76%. 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.

The port system handles 85% of total international trade and its efficiency is hence crucial to the competitiveness of the country. Most of this trade goes in fact through 27 commercial, industrial and tourist ports, and the 10 terminals specialized in oil and mineral ore traffic. In 2002, the main eight ports handled over 72% of total cargoes of over 1.5 million TEU/year, four of them in the Atlantic coast and the other four on the Pacific.[11] In fact, if oil is excluded, 50% of total movements of cargo are performed by 5 ports: Veracruz, Tampico and Altamira on the Gulf of Mexico; and Manzanillo and Lázaro Cárdenas on the Pacific side.

In general, the port reform has generated a reduction of the cargo handling charges, as shown in Table 1. All ports included exhibit substantial reductions in their tariffs charged for moving agricultural and mineral bulk cargoes, and also for palletized goods. Even though there is some case where the price has increased, the general trend is towards lower tariffs, with reductions of more than 20%, apart from containers for which only an average 5% reduction is obtained. This difference could be attributed to the fact that the cost of capital is higher for specialized container terminals, and before the reform this fact might have not been considered when calculating charges.

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[11] TEU: Twenty feet Equivalent Unit.

4 The data sample

The data available are annual and span over four years, from 1996 to 1999, and only covering the main APIs (the main ones) which are not too specialized—specialized APIs would be outliers and provide little added information to the comparative analysis. This provides a panel of data of 44 observations. This coverage allows a fair assessment of the evolution of the relative performance of the main APIs and of the sources of efficiency changes.

The APIs covered by the study are those under federal responsibility: Ensenada, Guaymas, Topolobampo, Mazatlán and Manzanillo, on the Pacific coast of Mexico and Altamira, Tampico, Tuxpan, Veracruz, Coatzacoalcos and Progreso, on the Atlantic coast. Excluding oil and its derivatives, these APIs handle 70% of the traffic going through the Mexican port system and almost 100% of the container traffic as of 2002. 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). The rest of the ports are generally too small to allocate major resources to meet detailed regulatory informational requirements and further tend to belong to the subnational governments which do not impose the same informational 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.[12] We would have liked to be able 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. The quality of the data available on these other activities simply did not

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

allow it.

The data available allows us to focus on the two main inputs only: labor and capital. Labor is measured by the number of workers in each API and this is a fairly standard variable available for most ports and hence used by most studies.[13] The capital input is approximated here by the length of docks concessioned by the government to each API. This was the only variable available for all ports on a systematic basis.[14] We also collected data on intermediate expenditures for all APIs for the period but unfortunately it failed to pass some basic consistency tests and we decided not to use them at this stage. Table 2 summarizes the main statistics.

Table 3 present an overview of the main partial productivity indicators for each port. The left part of the table measures the productivity of capital as a ratio of production (in tons) to capital (in m). The right part measures labor productivity of each API in production (tons) per worker. The emerging big picture can be summarized as follows. On both coasts, in general, capital productivity has increased while labor productivity has decreased. For capital, this reflects that the improvements in the rates of capacity utilization while on the labor side, it reflects that after the initial labor redundancies, employment recovered somewhat at the beginning of the period. In general also, the impact of the Asia crisis is quite obvious on the capital productivity indicators. Indeed, capital productivity continued to improve on the east coast but deteriorated somewhat on the west coast.

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

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

14 This definition is equivalent to the quasi-fixed capital used by Baños et al. (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 et al. (1999) assume that it can be approximated by depreciation expenditures.

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

5 The Malmquist index of productivity change

The approach used allows the assessment of the evolution of the TFP of the main Mexican ports for the first 4 years after the reform had been fully implemented. It compares each port to the best performing ports during the period. Table 4 shows that the best performing ports during that period are Altamira and Ensenada. The table also shows the evolution of the various sources of efficiency for each one of the ports between 1996 and 1999. A value of the Malmquist index or of any of its components larger than one 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 one.

The results suggest an average annual improvement in TFP of 4.1% in the Mexican port sector. Since Tampico is an outlier, we also compute the average without this APIs and show that the TPF change is in fact much larger without this outlier and reaches 5.6%. In addition to Tampico on the Atlantic coast , two the Pacific coast ports, Guyama and Topolobampo, suffer a decline in TFP. If 4.1% were to be used as the "X" factor across ports as part of the tariff review, 6 of the 11 ports would be penalized since their measured efficiency gains would be below the required minimum efficiency gain for the period. On a year to year basis, the average result is driven by the first 3 years of the period when efficiency scores are quite high right after the reform takes place. During the last year in fact, there was a generalized "technological" regression since all ports saw their TFP deteriorate, an expected result since world trade shrank—less traffic is 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 improvement due to the adoption of improved technologies by the operators was dramatic, with and without Tampico in the sample. In other words, the frontier shift effect of the reforms cannot be ignored on average. From the viewpoint of individual ports, the emerging story is more subtle. With the exception of Manzanillo, the catching up effects dominates the shift for all ports on the Pacific coast while the opposite for all ports on the Atlantic coast except for Tampico.[15]

Columns (3) and (4) show the decomposition of the sources of the total technical efficiency into its pure technical effects (TEC) and the scale economy effect (SEC). It reveals that with the exception of Tampico, all the APIs have either maintained or improved their pure technical efficiency during the sample period--in fact, 5 have improved it. In fact, when Tampico is ignored, technical efficiency gains become very significant and drive the total TFP change. The emerging story on the changes with respect to scale efficiency is more complex. The results seems to suggest that on average, the operators have adjusted the scale of their operations for the better. However, 6 of them have adjusted for the worse.

6 Policy issues

The analysis of the data points to a number of important policy lessons for Mexico as well as for other countries considering major reforms of the port sector.

The first main lesson that to emerge from this analysis is that while labour adjustments were clearly a factor in the improvement in TFP for the sector as suggested by many critics of privatization, it is just as clearly not the only one[16].

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15 The fact that difference between the Atlantic and the Pacific sides are so marked begs for a possible explanation. The only obvious one could be that the main trading partners on the Pacific side are East Asian and the sample includes the adjustment to trade that resulted from the 1997-98 East Asia crisis and that there was room after the crisis for a significant catching up effect.

16 Note that employment eventually increased during the sample period as seem from the decline in the partial labor productivity indicator.

Adoption of new technologies and the increases in the capacity resulting from the large investments made right after the reforms were implemented are in fact the main contributors to these improvements as seen from the major share of the TFP change that can be attributed to the technological change and the improvements in scale efficiency.

The second lesson is that the job of the regulator does not stop with these numbers. In the process of developing the data base we identified many data problems that need to be addressed if regulatory estimates of efficiency scores are to be credible. The port industry is indeed typically multiproduct and has many more that two major inputs and yet, the current data base only allows to generate enough data to launch the regulatory debate rather than settling 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 the port sector is not the only data needed. In addition, there are many other "environmental" factors we have not been able to pick up that would contribute to the explanation of the relative performance of the operators. In particular, we have not picked up the changes in quality levels associated with the service levels and type changes adopted by the operators. Quality adjustments are one of the major sources of cost adjustments that regulators tend to fail to take into account well enough in the regulatory decisionmaking processes.

The third main lesson is that the approach adopted in the paper may be too "gentle" from a regulatory viewpoint if the purpose is to promote inter-port competition. Indeed, one of the major problems with DEA is that any operator that is different enough of the others on average or even at any point in time, it is an outlier and can become identified as best practice. More subtly, even when there are no obvious outliers, the operators identified as best practice may be inefficient to some extent. If this is a lasting situation, the regulator is unlikely to be able to pick up the full potential for efficiency gain.

A fourth observation is that while the distribution of the gains has so far been relatively fair when the evolution of prices and efficiency gains are compared, it is important for regulators to continue maintaining the pressure on the APIs, in particular with respect to the pricing of container traffic. Most of the new technologies adopted by the 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 containerisation and yet, container prices has only enjoyed a 5% drop during the period covered by the sample while overall efficiency gains have been 3 to 4 times as much.

The final lesson may be that it is easy to be unfair to operators in industries with increasing returns to scale to penalize the operators for demand shocks. Indeed, the results presented are based on a period which saw major shocks on international trade volumes due to various international crisis, in particular the Asia crisis. During this period, the results show that the scale of operation is indeed sensitive to demand conditions on which the operators can do little. Of course, operators can do port promotion or adopt equivalent policies to stimulate demand but none of these policies tend to be sufficient to quickly mitigate the risks from maor demand shocks. Scale adjustment to these demand shocks are probably just as slow as the responsiveness of demand management policies in the sector. This means that, ideally, the regulator should consider a TFP net of the SEC. Table 5 shows that this would reduce the average efficiency gains to be considered as part of a tariff revision would drop from 4.1 to 2.5%. Only 3 ports would then be below that average. The extreme case of Tampico shows however that under this kind of approach, it would become quite important for the operator to actively use the scale to adjust.

7 Concluding comments

Overall, the results would suggest that the reform was quite successful in terms of contributing potentially to the improvements in the competitiveness of the Mexican economy. The least that can be said is that the reforms did facilitate the adoption of new technologies and for many ports, it also allowed a very significant catching up. A regulator would probably use the result to audit the less effective ports from the viewpoint of TFP such as Guaymas Topolobampo and Tampico although the first have in fact improved their pure technical efficiency during the period, the component of the TFP that operators seem to control the best, while having problems adjusting the scale of operation.

However, the odds are that if these ports were to be audited, their managers would be able to debate the approach quite intensively. 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 is far from ideal. Rather than denying this right to engage the regulator on any efficiency estimate, the authorities could use the opportunity to introduced due processes to interact with the operators and generate more data than currently available. These processes are now relatively standard in the utilities sector in developing countries, there is no reasons not to adopt them in the transport sector.

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Table 1: Change in Cargo Handling Tariffs (1998 pesos)

Ports	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	N.D.	49.3	N.D.	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: SCT

Table 2 Summary Statistics for Mexico's Main APIs

	Production (tons)	Capital (m2)	Labour (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

Table 3: Labor and Capital partial productivity indicators

	1996	1997	1998	1999	1996	1997	1998	1999
	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**

Table 4: Malmquist input based productivity index and its decomposition by API. Annual averages for 1996/1999.

Firm	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
Mazatlan	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

Table 5: What about a TFPC net of SEC as the "X" factor in a tariff revision

Firm	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	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 input based productivity index and its decomposition by API. 1996/1997.

PORT	TTEC	TC	TEC	EC	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 input based productivity index and its decomposition by API. 1997/1998.

PORT	TTEC	TC	TEC	EC	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
Mazatlan	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 input based productivity index and its ecomposition by API. 1997/1998.

PORT	TTEC	TC	TEC	EC	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
Mazatlan	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