Chile: Port congestion and efficient rationing in cargo transfer operations

Claudio A. Agostini and Eduardo H. Saavedra

ABSTRACT

No pricing system is likely to be able to do away with congestion in port cargo transfer operations at peak times, since port use is determined not so much by seasonal factors as, first and foremost, by the simultaneous arrival of vessels, which results in rationing. This article shows that rationing, to be efficient, needs to go by the value of the cargo transferred rather than following a first-come-first-served rule. It demonstrates that efficient rationing gives priority to containerized cargo, followed by break bulk cargo, with bulk cargo in last place. These findings are applied to cargo transfer at the San Antonio Terminal Internacional franchised port in Chile.

KEYWORDS

Ports, maritime transport, goods transport, port charges, port administration, commercial efficiency, mathematical modelling, case studies, Chile

JEL CLASSIFICATION

D22, D45, L23, L90

AUTHORS

Claudio A. Agostini is a professor at the School of Government of Universidad Adolfo Ibáñez, Chile. claudio.agostini@uai.cl

Eduardo H. Saavedra is an associate professor at the Latin American Institute of Social Theory and Social Studies (ILADES), Universidad Alberto Hurtado, Chile. saavedra@uahurtado.cl

I
Introduction

The scale and long payback times of the investment that port cargo handling infrastructure requires mean that this infrastructure can be characterized as an essential input, one that presents severe capacity constraints at times of peak or high demand. Economic theory generally states that congestion should be eliminated or reduced efficiently by means of the pricing system. Unfortunately, this mechanism cannot be applied to ports in the way it can to electricity or drinking water consumption, since port infrastructure usage is driven not so much by seasonal factors as by the almost simultaneous arrival of too many ships. This implies that port use necessarily has to be rationed and thus that some ships have to wait.

The question of how best to ration is disputed, however. Although the first-come-first-served system is the best known, the economic literature has shown it to be highly inefficient, since the willingness to pay of shippers subjected to rationing varies greatly with the value of the cargo they are carrying (Strandenes and Wolfstetter, 2005; Button, 1979), besides which it increases port operating costs (Imai, Nagaiwa and Chan, 1997).

In conformity with the literature, this article shows theoretically and empirically that it is socially desirable to impose all rationing on the activities with the lowest value added. This value is measured in theory as the drop in the value of transported cargo when it is subjected to rationing. The result holds even when the model includes compensation for firms subjected to rationing or if there are effects on the cargo handling capacity of the port that depend on the type of service being rationed. The rationing criterion used in this paper is cargo value, with containerized cargo being distinguished from bulk cargo. The two cargo types present marked differences in value and in their cost to the port operator, chiefly in terms of operating times and port infrastructure use.

This study was motivated by a dispute submitted to the Competition Tribunal (TDLC) in Chile in 2007. A company called Terquim S.A. accused San Antonio Terminal Internacional (STI) and Empresa Portuaria San Antonio (EPSA) of abusing their dominant position by following a priority criterion for serving ships in the port rather than doing it on a first-come-first-served basis. Consistently with the findings of the present study, the TDLC rejected the argument put forward by Terquim and dismissed the charge in January 2010. Its ruling was upheld by the Supreme Court in September that same year,[1] and with it the use of priority criteria rather than first-come-first-served for processing ships in the port.

Looking beyond this specific antitrust dispute, however, the economic arguments for rationing port infrastructure in a particular period of time are applicable to any port, as is the methodology proposed in this article.

The rest of this paper is organized as follows. Section II describes the institutional framework for public-private port ownership in Chile, the features of the port of San Antonio, the two companies operating there (STI and EPSA) and the main bulk cargo handled by STI (sulphuric acid). Section III reviews the literature on port rationing and explains why port infrastructure can be regarded as an essential facility. Section IV presents an economic model that shows why it is more efficient to ration by cargo value than on a first-come-first-served basis. Section V provides comparative estimates for the two methods at the port of San Antonio, using STI information for 2007. Lastly, section VI offers conclusions.

[1] For further details, see Agostini and Saavedra (2008), TDLC ruling 96/2010 and the Supreme Court judgement with the reference Rol 1933/2010. See [online] www.tdlc.cl.

II
Description of the market and institutional framework

1. Public-private port partnerships in Chile

During the 1980s and 1990s, the Chilean Port Enterprise (EMPORCHI) operated the 10 State-owned ports under a multi-operator system. Under this system, the State enterprise administered the port infrastructure and a number of private-sector firms carried out loading and unloading of ships at the ports. One of the great drawbacks of this system was that it divided cargo up among a number of firms at the same port, seriously limiting incentives to invest in cargo handling equipment and preventing port infrastructure from being used efficiently.

As international trade grew strongly in Chile, port management began to turn into a bottleneck, and in the late 1990s the Government took the decision to modernize the State port sector. The key goals of the reform were to stimulate and dynamize investment in port infrastructure, technology and management. To this end it was proposed that the multi-operator system should be replaced by a single operator system in which a single firm took responsibility for operating and maintaining a port terminal. This would make it possible to promote competition both between ports and at the tendering stage when selecting the future single operator. A reform was accordingly proposed to break up EMPORCHI, involve private-sector firms in State port development via the concession mechanism and modernize labour practices at ports.

The reform approved in 1998 created 10 autonomous State port enterprises, each owning a single port, with the explicit objective of administering, operating, developing and preserving their respective ports and terminals. The law also gave each of these enterprises the mission of promoting competition between ports and within their own port and of involving the private sector to increase efficiency and investment. For this, the port enterprises may tender the concession of contracts for private-sector firms to operate and invest in each of the port terminals owned by them. Under the concession system, each State port enterprise continues to own the infrastructure and oversees the concession contract, being paid a minimum annual rent by the concession holder plus a percentage of its revenues.

In 1999, the concessions for Chile's three main port terminals, San Antonio, Valparaíso and San Vicente (Talcahuano), accounting between them for about 50% of all cargo handled by EMPORCHI, were put out to tender. Two criteria were followed in awarding the concessions: (i) a tariff index calculated from the dues for ship wharfage, cargo wharfage, container transfer and break bulk cargo transfer, and (ii) an annual fee or payment to the State.

This article will now focus on cargo activity at the port of San Antonio, the largest in Chile for total cargo handled and the second-largest for containerized cargo, according to figures for 2011 from the Infrastructure Services Unit of ECLAC.

2. Public- and private-sector port enterprises at San Antonio

The State firm EPSA has four berthing facilities with a total of nine berths and a total surface area of 495 hectares, 353 hectares of this being sea and 142 land. The basin has a surface area of 75 hectares and the four terminals are the Molo Sur (berths 1, 2 and 3), the Espigón (berths 4, 5, 6 and 7), the Terminal Norte (berth 8 specializing in dry bulk cargoes) and berth 9, specializing in wet bulk cargoes.

The tendering process for the port of San Antonio covered the Molo Sur and Terminal Norte concessions. The Molo Sur, with the largest-capacity berths, was awarded to San Antonio Terminal Internacional (STI), with a tariff index of US$ 7.05 a ton, an upfront payment of US$ 10 million, an annual fee that came to US$ 11,050,606 in 2007 given the tonnage handled that year, and an additional payment of US$ 121,252,062 split into six equal annual instalments in the first six years of the concession. The Terminal Norte was awarded to Puerto Panul and the other five berths are operated by EPSA. Thus, STI holds the concession to operate and administer the Molo Sur terminal, specializing in containers. For this purpose it had 769 metres of continuous wharf with 12 metres draught right along its docking area at the time of the concession,[2] 31 hectares of dockside area (25 being used for storing containers and bulk cargoes), 6 gantry cranes, 9 forklifts, 41 tractor trucks for handling containers and cargo within the terminal, an area for container consolidation and deconsolidation, 6,000 square metres of roofed cargo storage, 2,000 connections for reefers, railway access to the dockside and container loading areas, and a weighbridge for weighing trucks with bulk or containerized cargo.

The concession contract with STI stipulates loading and unloading speeds and waiting times that must be kept to, failing which the concession holder is fined. It also includes stipulations for a progressive improvement in the service provided by the concession holder over the life of the contract. This provides an incentive for the concession holder to invest as necessary to maintain and improve the standard of service without the need to stipulate specific investments or investment amounts. Basic tariffs are set in the concession contract; however, the concession holder can charge special tariffs for additional services provided at users' request. This encourages the concession holder to invest in accordance with developments both in the technical progress of port operations and demand from its various types of customers, who require different levels of service.

Because container use has substantially reduced cargo handling costs, thereby increasing national and international short sea shipping (Clark, Dollar and Micco, 2004; Blonigen and Wilson, 2008), one of the goals of the tendering process was precisely that there should be investment in increased containerized cargo transfer capacity and efficiency. This trend can also be observed at the port of San Antonio, both in the evolution of the number of dockings at each terminal by vessel type (see figure 1) and in the total amount of cargo transferred by vessel type (see figure 2) and performance by type of cargo transferred (see figure 3).

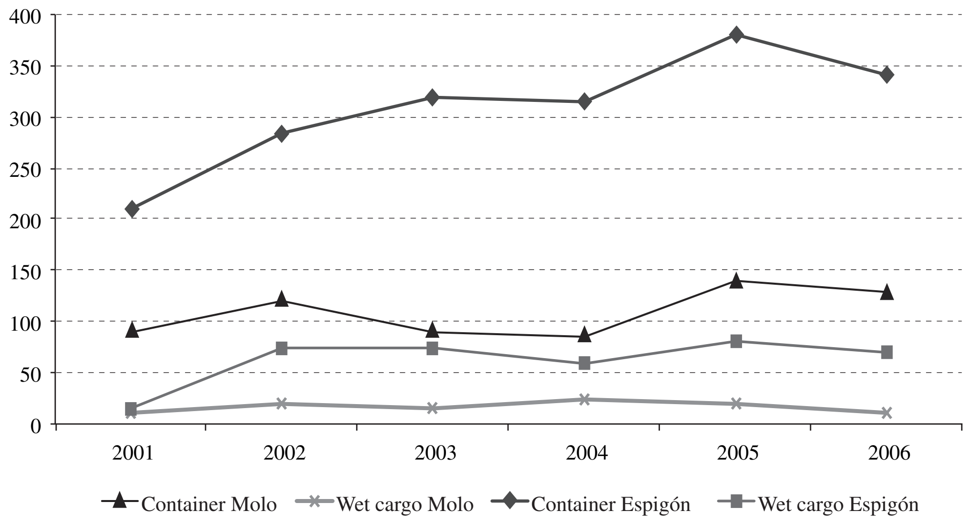
The evolution of cargo in recent years, as reflected in figures 1, 2 and 3, shows not only the tendency towards greater containerization but also the increase in port efficiency brought by containerization. Consequently, having docking facilities that specialize in containerized cargo yields efficiency gains over facilities that mix bulk and containerized cargoes. This is important, as trade volumes can fall off considerably at inefficient ports and the impact can be still greater in small and developing countries (Blonigen and Wilson, 2008).

Berths are a public good, and this implies non-discriminatory public tariffs and an obligation to accept ships and handle cargo. Accordingly, all the landlord

[2] There are currently 380 metres with an authorized draught of 13.5 metres and 389 metres with an authorized draught of 11.34 metres.

FIGURE 1

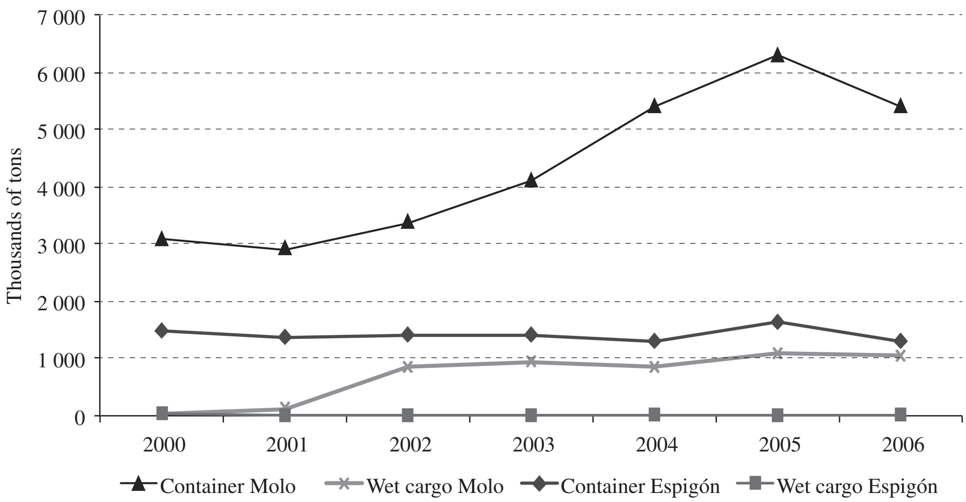
STI: number of dockings by vessel type, 2001-2006



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

FIGURE 2

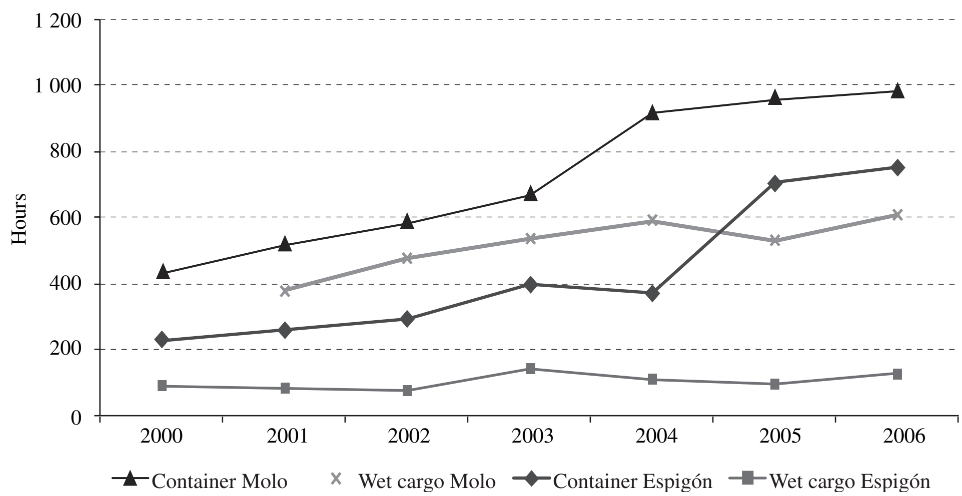
STI: tonnage transferred by cargo type, 2000-2006



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

FIGURE 3

STI: performance by type of cargo transferred, 2000-2006
(Tons/hour)



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

ports have internal regulations on the use of docking facilities that are designed to ensure efficient usage of port infrastructure and freedom of choice for users. The service manual lays down docking priority rules and procedures, establishing that dockings must be scheduled on the basis of an objective technical priority rule. Table 1 shows the priorities established for the three berths operated by STI. These priorities reflect preferences for cargo types with faster transfer speeds and port services that operate vessels regularly.

TABLE 1

Chile: STI berthing priorities

	Berth 1	Berth 2	Berth 3
1	Scheduled container ships	Scheduled container ships	Container ships
2	Scheduled break bulk cargo ships	Scheduled ships loading over 10 000 tons of homogeneous cargo	Ships loading over 10 000 tons of homogeneous cargo
3	Bulk cargo ships	Scheduled break bulk cargo ships	Scheduled break bulk cargo ships
4	Other ships	Bulk cargo ships	Bulk cargo ships
5		Other ships	Other ships

Source: San Antonio Terminal Internacional (STI), Chile.

3. The sulphuric acid storage contract and loading protocol

Transportation of sulphuric acid from the El Teniente mine operated by the Chilean National Copper Corporation (CODELCO) to the port of San Antonio is carried out in three sequential stages: trucks, railway and, once in San Antonio, storage in tanks and loading. This last stage is carried out by Terquim, with 97% of all the cargo transferred by Terquim being sulphuric acid. The firm also has the concession to operate at the Molo Sur, i.e., at the terminals awarded to STI.

While STI does not follow a berth reservation policy and thus does not promise to prioritize particular ships over others beyond what is stipulated in its service manual, the contract between STI and CODELCO makes STI responsible for any environmental problems caused by an overflow at the Terquim terminals due to berth unavailability. The aim of this contractual provision is to minimize the time ships carrying sulphuric acid for CODELCO have to wait out at sea, to which end it limits the time the concession holder can keep these ships waiting before they are unloaded, with the clock running from the time the vessel reaches the pilot station until docking manoeuvres begin. The fine prescribed in the contract as applicable in 2007 was US$ 20,000 a day (calculated pro rata for shorter waiting times). In addition, the cost of taking the ship out to an anchorage has to be met by STI (tugs, time, etc.) if it decides to do this. CODELCO, in turn, pays a fixed tariff per ton of acid, this being US$ 1.05 as of April 2008.

The contract specifies three levels of sulphuric acid in the tanks and maximum waiting times before STI has to service ships, depending on the volume accumulated. The volumes and maximum waiting times are: green level, less than 26,000 tons with a maximum wait of 48 hours; yellow level, between 26,000 and 33,000 tons with a maximum wait of 24 hours; and red level, over 33,000 tons with a maximum wait of 6 hours.

In principle, this contract is an efficient economic solution because it is consistent with the literature on port rationing, as shown in section III, and with the theoretical prediction of an economic model of efficient rationing developed in section IV. On the one hand, this rationing criterion gives CODELCO certain guarantees that the sulphuric acid tanks will not fill up completely but will always have the capacity to store acid produced by its smelter. On the other, there is an opportunity cost to STI when it uses a berth for a container vessel and has to pay to keep an acid ship waiting for longer than stipulated in the contract. The economic effect of this contract is precisely to create the right signals so that the use of a docking facility with limited capacity is rationed efficiently.

III
The economic literature on rationing

The literature on rationing the use of a good, and port infrastructure in particular, will now be reviewed. The section will end with a brief discussion of essential inputs, given the special characteristics of the good subject to congestion in this case.

1. Rationing and the economic rationale

The need to ration the use of a good arises when it is costly to modify prices (waiting time in restaurants), when rationing signals quality (medical care or luxury goods) or when there are temporary increases in demand and consumers face switching costs. As a result, there are markets where excess demand leads not to price increases but to rationing for consumers. This happens in markets as diverse as restaurants, electronic components, semiconductors, personal computers, metals, titanium dioxide, polypropylene, petrochemicals, compact discs and children's toys (MacKinnon and Olewiler, 1980; Ghemawat, 1986; Basu, 1987; Carlton, 1991; Slade, 1991; Ungem-Sternberg, 1991; Haddock and McChesney, 1994; De Graba, 1995).

Going by this evidence in different markets, the economic literature has focused on trying to explain the existence of time rationing as an equilibrium situation, and also on determining the optimal rationing mechanisms when it is not possible or desirable to adjust by raising prices.

In one of the seminal articles of this literature, Barzel (1974) established the economic rationale behind first-come-first-served rationing, noting that the waiting time simply created an extra cost for consumers of a good. When a good is available in limited quantities, the time-price mix plays the same role as the monetary price when there is no restriction on quantity; nonetheless, there is a loss of efficiency relative to the unrationed equilibrium. In the event that there are no constraints on the availability of the good but there is price rigidity, the logic is equivalent to Barzel's and waiting time simply serves the purpose of reducing excess demand until it is in balance with the supply of the good (Alderman, 1987).

Even if there are no price rigidities, however, it can still be optimal for a firm to ration rather than raising prices. Bose (1996) shows that when there are users who differ in their willingness to pay and this characteristic is unknown to the supplier, waiting times become an effective mechanism for discriminating between them, insofar as demand and thus willingness to pay are greater among those who wait. As a result, there is an equilibrium with rationing whereby it is more profitable for the supplier to ration consumers than to charge higher prices to achieve market equilibrium.

Looking past the different theoretical explanations given in the literature to account for the existence of rationing as an equilibrium situation in a market, what is relevant in this case is to consider how optimal the different rationing mechanisms are. An early contribution was made by Greenberger (1966), who noted that the optimal system of priorities depended on the objective, as there is a conflict between minimizing the average waiting time and its variance. Thus, a rule giving priority to consumers who need to be served more quickly can be used to minimize the mean waiting time and the number of consumers waiting, but at the cost of increasing variance. Conversely, a first-come-first-served rule serves to control variance in waiting times.

Both rationing criteria assume that the cost of waiting is the same for all consumers. If it is not, there are more efficient options for setting priorities in accordance with how important or urgent the service is for different types of consumers. Thus, Pestalozzi (1964) and Likens (1976) show that a priority index is more efficient than a first-come-first-served system in airport operations. In particular, Pestalozzi's work shows that if the goal is to minimize the average cost of delay, the optimal approach is to introduce priorities by aircraft type, applying the rule that landings have priority over take-offs. It is important to stress that the first-come-first-served rule is never optimal in any of the cases simulated.

Greenberger (1966) considers different rules for computer time-sharing and establishes that the optimal method is to prioritize users by the waiting cost of each, attending first to those for whom the cost is highest. This is similar to the earlier finding of Cox and Smith (1961), who showed that when service delay costs were heterogeneous, the average cost of delay for consumers was minimized by working down the priority list, defined as the waiting cost per unit of time divided by the expected service requirement.

Subsequently, Naor (1969) showed that the first-come-first-served rule, when applied to a homogeneous population of consumers, led to a degree of congestion in excess of what was socially optimal, making it necessary to raise the price to a level that reduced congestion or charge an extra tariff for the same purpose. This finding was subsequently extended by Balachandran and Schaefer (1979) for a situation in which there were heterogeneous consumers.

The paper by Sherman and Visscher (1982) considers the optimal pricing strategy along with rationing mechanisms when demand for a service is stochastic. Their findings show that a rationing mechanism based on priority for consumers with a greater willingness to pay entails an optimal price that is the same for all consumers. Conversely, a rationing mechanism that prioritizes consumers who value the service less entails discriminatory optimal pricing whereby higher prices are charged to consumers who are more willing to pay.

These findings are relevant to the rationing of port infrastructure use, as they show that when it is not possible to charge different prices for different types of consumer and it is mandatory to charge a single non-discriminatory price, the optimum is to ration excess demand in descending order of willingness to pay.

2. Rationing in port infrastructure use

The great majority of studies in the port rationing literature agree that the first-come-first-served mechanism is inefficient, unless all arriving ships and cargoes are identical. Strandeness and Wolfstetter (2005) state that the first-come-first-served criterion is highly inefficient, as it does not reflect ships' relative waiting costs. Likewise, Imai, Nagaiwa and Chan (1997) conclude that if the aim is to achieve high port productivity, first-come-first-served should never be considered as an option for the optimal allocation of berths.

For reasons of efficiency, then, a port should

to use the port, based on frequency and the amount of time it is used for. Under this system, regular users of the port have priority over infrequent users, since the first-come-first-served system does not reflect each ship's effective demand for port services.

Following this line of argument, Ghosh (2002) shows that it is optimal to give priority to the ships that most value the service and suggests a system of sequential berth auctions for this purpose. Setting out from this idea, and applying the Vickrey-Clarke-Groves mechanism, Strandenes and Wolfstetter (2005) propose a system of berth auctions using a mechanism that ensures that the bids reveal the true value to each ship of docking at the place and time being auctioned.

Looking beyond theoretical considerations and the consensus in the literature regarding the inefficiency of the first-come-first-served system of berth allocation, in practice different prioritization systems have been increasingly employed at different ports all over the world. For example, Imai, Nishimura and Papadimitriou (2004) argue that allocating berths in a way that takes considerations of priority into account is very important for port operators working in a competitive environment, particularly in view of the greater flexibility it gives them in their decisions about infrastructure use.

Consequently, some ports establish ship size or cargo volume as a priority criterion. For example, port authorities in Japan, Singapore and Norway give priority in some ports to the ships with the largest volume of containers (Imai, Nagaiwa and Chan, 1997; Imai, Nishimura and Papadimitriou, 2004; Svendsen, 1967).

3. Ports as an essential facility

Conceptually, an essential facility or essential infrastructure can be understood as the basic input for supplying firms that participate in competitive segments (even if competition is imperfect) of an industry, where this basic input is provided under conditions of monopoly or