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Costs, Benefits and Pricing of Dedicated Container Terminals

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This paper analyses some of the implications of the emergence of dedicated container terminals (DCT) in the past 10 years. It presents a general overview of DCTs and stresses, through the use of a generalised port cost function, that one of the main factors that could explain this development is the increasing gap between the objectives of ports and those of shipping lines. The main implications of a DCT, from a port viewpoint, are analysed next through the employment of a simple queuing model. It is shown that under certain assumptions, a carrier with exclusive access to facilities and the port providing them could both benefit through such a strategy. At the same time, the model underlines that eventual losses would be born mainly by those carriers who, as a result, can now use only a restricted number of servers (berths). The paper shows that such losses could be even higher in the presence of direct (club effect) or indirect (hardware/software paradigm) externalities and that the choice of DCT is similar to the access pricing of a bottleneck in a network industry. Finally, the paper develops a hypothetical pricing rule (Efficient Component Pricing Rule) that could be used to internalise such external effects.
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INTRODUCTION

The first section of the paper focuses on the implications, for ports, of horizontal integration in liner shipping; a most noticeable trend indeed nowadays taking the form of alliances and mergers and acquisitions. The paper suggests that the exploitation of economies of density in ocean routes and the development of Hub-and-Spoke systems place more pressure on ports and sometimes justify the need for a DCT.

The second section analyses the consequences of the existence of DCTs in port areas. Through the use of a queuing model, it is shown that, under certain assumptions, DCTs can pose significant barriers to entry to new competition in liner shipping. Carriers' investments in DCTs may thus entail a strategic element that goes well beyond the often proclaimed technical efficiency gains in global supply chain management. The paper argues that such barriers could be reinforced if direct and/or indirect externalities exist in the production of port services. Port pricing should therefore be considered as a case of *interconnection pricing* in network bottlenecks and, ideally, it ought to internalise the technical and economic gains and losses of *all* port users.

THE EMERGENCE OF DEDICATED CONTAINER TERMINALS

Specialised terminals are not something new. The need for dedicated infrastructure, many times for reasons of safety, has often led to the segmentation of port areas between liquid, bulk and container terminals. Within the latter, the emergence of DCTs is a more recent trend that started in Asia and North America. In Europe, it was introduced by Maersk in the early nineties, in the transhipment facility of Algeciras (Figure 1).

As a rule, DCTs are interconnecting points in the East – west and North – south trades, offering carriers greater flexibility, reliability, short turnaround times, and enhanced efficiency in the management of global supply chains. They emerged amidst a general trend of worldwide port development, privatisation, and reduction of public investment in ports. In many cases, new terminal concessions required generation of substantial new traffic by port operators, thus in a way obliging them to develop stronger links with carriers.

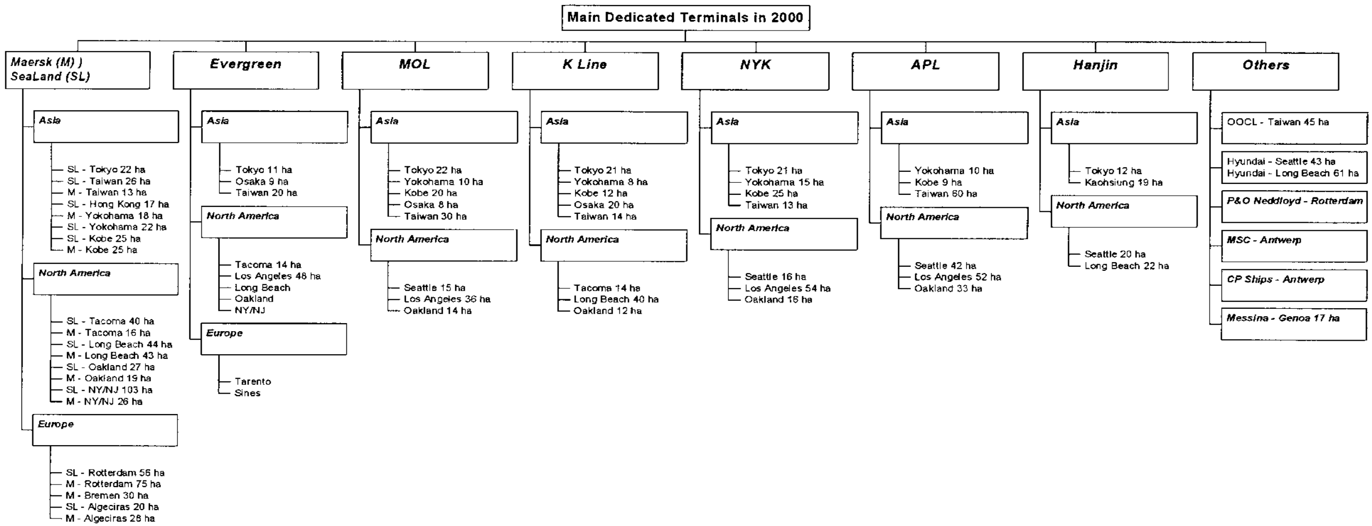

Figure 1: Main dedicated container terminals in Northern America, Asia and Europe (in hectares).
Source: Bank of Japan, Containerisation International, Lloyd's List

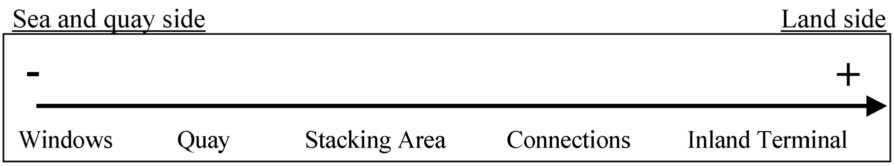

Figure 2: Scope of Dedicated Container Terminals

The level and scope of accessibility to a DCT is determined by private agreement between one or more carriers and a port operator or authority. The deal usually involves exclusivity in the use of a berth, but this can be extended to include other parts of the terminal such as stacking areas and railway connections (Figure 2). A carrier can have direct control on the stevedoring company, through a joint-company such as that of Maersk with Maersk España in Algeciras, or indirect control of terminal operations, ie allowing the stevedoring company to run the terminal, as in the case of MSC and CP Ships with Hessenatie in Antwerp. Finally, DCTs entail both a spatial dimension – the use of facilities in a defined part of the terminal – and a temporal one, ie the use of facilities for a certain period of time.

DEDICATED CONTAINER TERMINALS AND VERTICAL INTEGRATION

Dedicated Terminals have also been seen, however, as the consequence of strategic behaviour of carriers that *inter alia* has taken the form of mergers, joint-ventures and alliances (Clarke, 1997; Hoffman, 1998; Ryoo and Thanopoulou, 1999; Meersman *et al*., 1999 and 2000; Midoro and Pitto, 2000; Gilman, 1999; Cullinane *et al*., 1999; Cariou and Haralambides, 1999; Haralambides *et al*., 2000). Allegedly, these developments have followed shipper requirements for higher geographic coverage and better 'supply chain management' (Slack *et al*., 1996; Heaver, 1994 and 1996; Evangelista and Morvillo, 2000; Caves *et al*., 1984; Bittlingmayer, 1989; Trethway and Oum, 1992; Brueckner and Spiller, 1991 and 1994; Oum *et al*., 1995).

In contrast to the above however, DCTs are a form of *vertical integration* that can create substantial sunk costs and thus make liner shipping a less contestable market. In addition, investment in DCTs could well be seen as a form of *limit pricing* whereby the operating costs of potential entrants are raised to such a level that entry is no longer profitable. Both strategies can be particularly effective as long as shippers are 'convinced' that this is the one and only way of organising international ocean transport and global supply chain management.

GENERALISED COSTS: PORT EXCESS CAPACITY AND VESSEL SIZE

The responsiveness of ports is of crucial importance for the success of carrier consolidation strategies (Cariou, 2000a). *Ceteris paribus*, whenever increasing returns to scale are present, a port should normally opt for a common user arrangement in order to maximise capacity utilisation and thus minimise unit costs. High levels of terminal capacity utilisation however can quickly lead to longer turnaround times, something not acceptable nowadays by carriers in their finely tuned logistical systems. Obviously, the organisation of liner services in indirect hub-and-spoke networks can only succeed if the economies of density achieved at sea are not negated by diseconomies of scale in ports.

The problem is exacerbated with the increasing deployment of ever larger containerships. As has been shown earlier (Cariou and Haralambides, 1999; Cariou, 2000; see also Figure 3), in general, the cost per TEU of ship-time in port is an increasing function of ship size. This has mainly to do with the availability of cargo-handling equipment (cranes) that can be put to work on a ship, and the problem of course intensifies at higher levels of terminal capacity utilisation (Figure 4). Still, four and sometimes five crane operations are standard today in many major ports for post-Panamax ships. One cannot envision however eight or 10 cranes working a concurrent sustained operation

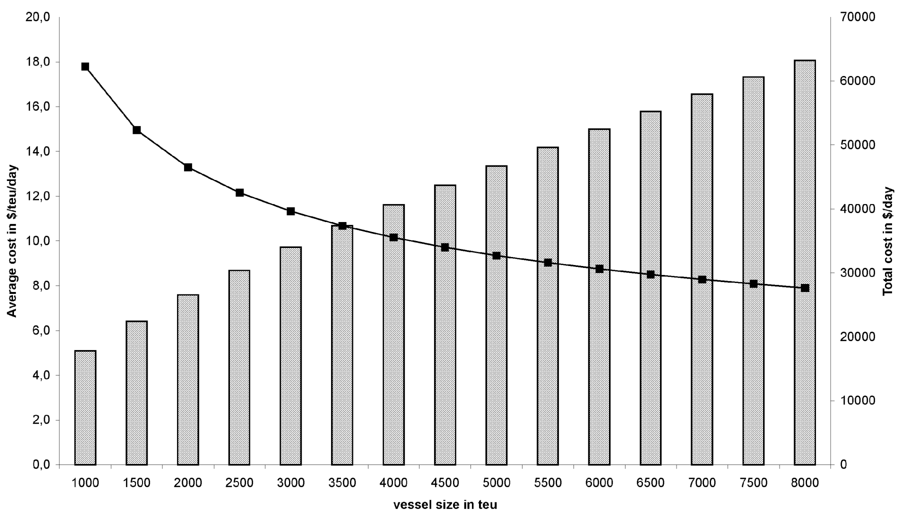

Figure 3: Increase in total costs (histogram) and decrease in average costs (line) per day as a function of containership size in 1997
Source: Cariou and Haralambides (1999), Cariou (2000)

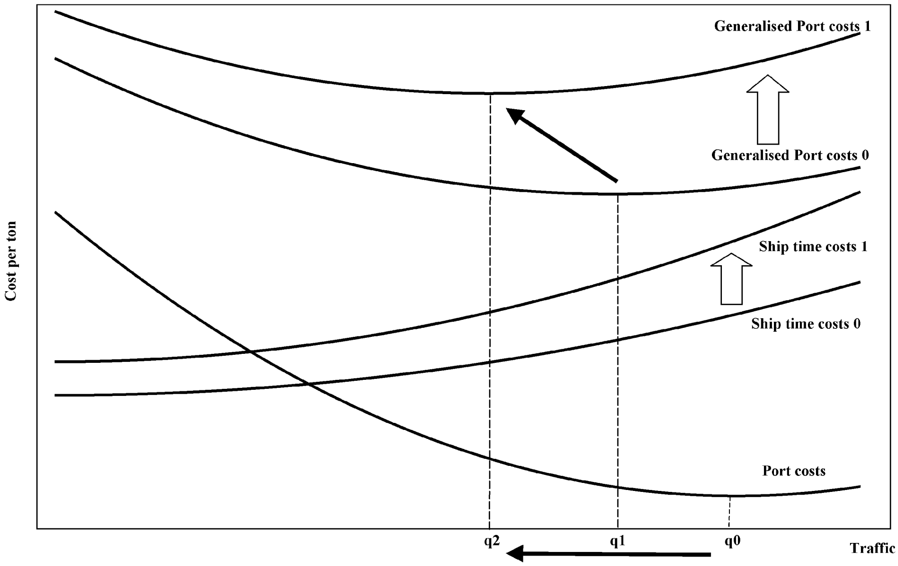

Figure 4: Impact of an increase in vessel size on the generalised port cost function

on a 10,000 TEU vessel in Hong Kong, Singapore, Rotterdam or Los Angeles any time in this decade (Haralambides *et al.*, 2002). Thus, other things being equal, the utilisation of larger vessels requires more excess capacity in ports (Figure 4).

The generalised cost idea of Figure 4 illustrates the by now classical conflict of interest between ports and carriers (UNCTAD, 1975; Jansson and Shneerson, 1982; Musso *et al.*, 1999), augmented in a way that also highlights the impact of ship size on excess port capacity.

Due to high fixed costs in port production, port costs per ton decrease up to the point (q_0) where congestion starts to set in. For the carrier, after a certain point,[1] ship-time costs per unit increase with port traffic (ship time costs 0 curve) (De Langen, 2000). The vertical summation of the port cost and ship-time curve gives the generalised cost curve (generalised port costs 0 curve) which determines the optimum level of port production at q_1. However, increase in ship sizes has the effect of shifting the ship-time curve upwards to a new position (ship time costs 1). The result is a new optimum level of port production at q_2, necessitating a lower level of terminal utilisation (q_1-q_2).

Clearly, other things being equal, efficient servicing of larger vessels involves higher port costs, in terms of excess port capacity and availability of cargo-handling equipment. This should be kept in mind when setting port charges, negotiating concessions or DCTs, as well as when considering the financing of port infrastructure, particularly when an appeal for public funding is being made.

EFFECTS OF DEDICATED CONTAINER TERMINALS ON PORTS

In the queuing model employed here, the *occupancy rate* is determined by the ship arrival rate λ and *service time* μ (Poisson and negative exponential distributions respectively) (Saaty, 1961; De Monie, 1988; Jansson and Shneerson, 1982; Evans and Marlow, 1990). The lay out of the terminal is assumed to be a one stage process and the length of the queue is infinite with a First In First Out ruling. The question of a port is under what conditions it is beneficial to maintain a multi-user terminal in its initial configuration with m servers, or to split it in (d) dedicated servers and (m-d) multi-user servers (Figure 5).

From the port's point of view, the effect of moving from the first (pure multi-user) to the second situation (multi-user and dedicated) can be assessed by comparing the respective occupancy rates (ϕ_1) and (ϕ_2):

$$\phi_1 = \frac{\lambda_m}{\mathrm{m}\mu_m} \text{ and } \phi_2 = \left(\frac{\lambda_{m-d}}{(\mathrm{m}-\mathrm{d})\mu_{m-d}}\,\frac{\mathrm{m}-\mathrm{d}}{\mathrm{m}}\right) + \left(\frac{\lambda_d}{\mathrm{d}\mu_d}\,\frac{\mathrm{d}}{\mathrm{m}}\right) = \frac{1}{\mathrm{m}}\left(\frac{\lambda_{m-d}}{\mu_{m-d}} + \frac{\lambda_d}{\mu_d}\right) \quad (1)$$

assuming that:

$$\begin{cases} \lambda_{m-d} = \theta_{m-d}\lambda_m \\ \mu_{m-d} = \sigma_{m-d}\mu_m \end{cases} \quad \mathit{and} \quad \begin{cases} \lambda_d = \theta_d\lambda_m \\ \mu_d = \sigma_d\mu_m \end{cases} \quad (2)$$

with:

θ: arrival rate change for a server from the first to the second situation;
σ: service rate change for a server from the first to the second situation,

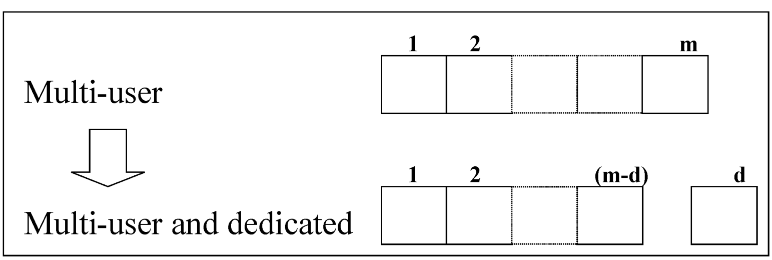

Figure 5: A hypothetical choice of DCT in a port

the occupancy rate will:

1. decrease ($\phi_1 > \phi_2$) if $\left(\frac{\theta_{m-d}}{\sigma_{m-d}} + \frac{\theta_d}{\sigma_d}\right) < 1$;
2. remain the same ($\phi_1 = \phi_2$) if $\left(\frac{\theta_{m-d}}{\sigma_{m-d}} + \frac{\theta_d}{\sigma_d}\right) = 1$;
3. increase ($\phi_1 < \phi_2$) if $\left(\frac{\theta_{m-d}}{\sigma_{m-d}} + \frac{\theta_d}{\sigma_d}\right) > 1$.

Ceteris paribus, the third situation is generally assumed optimal (increase in port occupancy rate) from a port perspective, as long as it involves a higher utilisation of capacities. The first situation (decrease in global port occupancy rate) could also be acceptable as long as the decrease is matched by extra traffic.

The choice between the three alternatives is often difficult. According to a case study on 16 multi-user and six dedicated terminals in Seattle (Turner, 2000), the arrival rate remains unchanged ($\theta = 1$), while some increasing returns exist with the number of servers ($\sigma < 1$). It can thus be assumed that the splitting of servers would imply an increase in the global occupancy rate of the port (case 3), but the problem is that this increase is mainly the result of a poorer level of service rather than an increase in port traffic. It could thus be interesting to analyse the assumptions under which the previous case is not relevant ($\theta \neq 1$and $\sigma \gtrless 1$).

To do so we first consider the DCT case and the assumption of increasing returns in port production ($\sigma_d < 1$). In a pure transhipment terminal, for instance, increasing returns could be achieved through a reduction in the variance of service time (Jansson and Shneerson, 1982).

In general, for any arbitrary distribution of the service time *s*, the mean queuing time, *q*, can be expressed as a function of the mean and the variance of the service time and the arrival rate (Saaty, 1961):

$$q = \frac{\lambda(s^2 + \text{var}(s))}{2(1 - \lambda s)} \tag{3}$$

substituting ϕ for λs, equation (3) becomes:

$$q = \frac{\phi(s + Var(s)/s)}{2(1 - \phi)}. \tag{4}$$

If *s* is distributed according to the negative exponential distribution, its variance is equal to s^2 and the mean queuing time becomes:

$$q = \frac{s\phi}{(1 - \phi)}. \tag{5}$$

Now, if the variance of service time could be reduced significantly as a result of, say, better coordination between mother and feeder vessels and harmonisation of ship calls (learning capacity), a case of constant service time becomes applicable. The variability of service time is eliminated and the mean queuing time is reduced by half. The attractiveness of a DCT is thus obvious. Simply, when Var(s)→0, equation (4) becomes:

$$q = \frac{s\phi}{2(1-\phi)}. \tag{6}$$

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OVERALL EFFECT AND INTERCONNECTION PRICING IN DEDICATED CONTAINER TERMINALS

From the point of view of *all* users in the system, the desirability (overall effect) of a DCT can be derived from the value of queuing time with ($W_d V_d + W_{m\text{-}d} V_{m\text{-}d}$) and without ($W_m V_m$) a DCT (where: W_i is queuing time and V_i its value per unit of time).

$$\phi_m = \frac{\lambda_m}{m\mu_m} \qquad \phi_d = \frac{\lambda_d}{d\mu_d} = \frac{\theta_d \lambda_m}{d\sigma_d \mu_m} \qquad \phi_{m-d} = \frac{\lambda_{m-d}}{(m-d)\mu_{m-d}} = \frac{\theta_{m-d}\lambda_m}{d\sigma_{m-d}\mu_m} \tag{7}$$

$$\begin{aligned} W_m V_m &= \frac{1}{\mu_m}\frac{\phi_m}{(1-\phi_m)} V_m \qquad W_d V_d = \frac{1}{\mu_d}\frac{\phi_d}{(1-\phi_d)} V_d \\ W_{m-d} V_{m-d} &= \frac{1}{\mu_{m-d}}\frac{\phi_{m-d}}{(1-\phi_{m-d})} V_{m-d} \end{aligned} \tag{8}$$

Three cases can be considered for carriers choosing for a DCT:

1. if $\frac{W_m}{W_d} < \frac{V_d}{V_m}$ the DCT implies an increase in the value of queuing time;
2. if $\frac{W_m}{W_d} = \frac{V_d}{V_m}$ the DCT implies no change in the value of queuing time;
3. if $\frac{W_m}{W_d} > \frac{V_d}{V_m}$ the DCT implies a decrease in the value of queuing time.

In cases where d < (m-d) < m, and assuming no change in the arrival rate ($\theta_d = 1$), as well as economies of scale in port production ($\sigma_d < \sigma_{m-d} < 1$), the final effect of a DCT would be to increase the value of queuing time for carriers. In the previous section it has been shown that this assumption can be challenged by certain properties of the service time variance. However, for carriers not using the DCT, this assumption holds and, therefore, it will be they who will bear the consequences of the DCT. For as long as DCTs are afforded to some carriers at a 'price' less than social opportunity costs[2], something quite common in port authorities' eagerness to privatise and build up traffic of new facilities, other carriers not using the DCT are placed at a competitive disadvantage. This can be measured by the increase in operating costs (longer waiting times) as a result of having to switch from a multi-user system of m servers to one of only (m-d) servers. From a different viewpoint, such a situation could be construed as a barrier to entry (or exit) due to the exclusivity on an essential facility.

To internalise such costs, the price a DCT carrier will have to pay must also include the potential 'losses' born by all other carriers calling at the port due to increase in waiting time. This internalisation process is similar to that of other network industries, such as railways, aviation and telecommunications (Baumol, 1983; Baumol and Sidak, 1994; Economides and White, 1995; Armstrong *et al*., 1996; Armstrong and Vickers, 1998; Laffont, 1994; Enacoua *et al*., 1996).

The main issue of *access* or *interconnection pricing* in network industries is the existence of direct and indirect externalities. Usually, two types of network externalities are considered (Katz and Shapiro, 1986, 1995, and 1998; Economides and Salop, 1992; Economides, 1994):

1. direct externalities, or 'club effect', are demand-side effects indicating that the utility of a consumer depends on the number of consumers connected to the network. For instance, in the case of port activities, it can be safely assumed that if there are many carriers calling at a server, the cost of port services will decrease, or the number of value-added services offered by the port (eg inland connections) will increase; and
2. indirect externalities, or 'Hardware-Software Paradigm', are supply-side effects indicating that the utility derived from the consumption of a good depends on the availability of complementary goods. For example, in the case of port activities, it can be argued that shippers and freight forwarders will choose a certain port because they know that many carriers call at this port.

In the case of ports with DCTs, it is thus possible that both the port and non-DCT carriers 'lose' due to a reduction in some potential externalities such as those described above. Those factors are actually difficult to quantify. The Efficient Component Pricing Rule (ECPR) is one of the most commonly applied rules in access pricing. The rule states that the price to charge for an exclusivity to an essential facility has to consider both Direct Access Costs (DAC) and Opportunity Costs (OC). Direct access costs (DAC_d) are the costs of providing a DCT to a carrier (inland connection, dredging, land costs, etc.). Opportunity costs (OC) can be surmised by the sum of potential losses and gains born by the port and the carriers.

$$\textit{Optimal Access Price}_d = [\mathrm{DAC_d}] + \left[\frac{\mathrm{CT}_{port}}{\phi_1 - \phi_2}\right] + \left[\frac{1}{\mu_1}\frac{\phi_1}{1-\phi_1} - \frac{1}{\mu_2}\frac{\phi_2}{1-\phi_2}\right] \times \mathrm{VT_{users}} \quad (9)$$

with:

DAC_d: direct cost of providing exclusive access;
CT_{port}: total cost for the port;
ϕ_1: initial occupancy rate of the port;
ϕ_2: occupancy rate of the port following the choice of DCT;
μ_1: initial global service rate of the port ;
μ_2: service rate of the port following the choice of DCT; and
VT_{users}: value of time of users.

The second term in the right hand side of equation (9) gives the losses or gains born by the port, and the third term, the losses or gains for all port users.

Although the access pricing rule is still in its early stages of development, at least in port pricing, it has a clear bearing on the pricing of DCTs. It stresses, for instance, that the pertinent question is not whether a DCT is a good or a bad thing for a port, but whether its pricing is done in a way that does not lead to barriers to entry (or exit).

CONCLUSIONS

For carriers large and powerful enough to own and/or operate a dedicated container terminal, the benefits are rather obvious and, at any rate, for them only to assess. For the port, its financiers, and the rest of its users, however, the picture is not equally clear. The implications of DCTs in terms of occupancy rates, efficiency and carriers' waiting times are yet to be examined, mainly by those who provide finance for general port development. From a societal and collective welfare perspective, the gains to carriers through vertical integration (higher service rate and smaller service variance) must be contrasted with potential losses from the reduction of competition and from the presence of negative externalities. The determinants of the bargaining power (in DCT deals) of certain carriers has yet to be analysed, as well as the extent to which such power may lead to a DCT 'price' not reflecting overall impacts and social opportunity costs of dedicated container terminals. The role of port and regulatory authorities in this process is still an open issue.

Aviation provides lucid examples of potential effects of DCTs in terms of market distortions. Barnard (2000) reports in the Journal of Commerce: '… *access to airport is becoming more and more important. As large hub airports are regarded as being among an airline's most valuable assets, established carriers enjoy a long-standing right to retain them under the so-called 'grandfather' system. Airlines often hold on to slots, even though they are not using them, to protect their market share and prevent rivals from launching competing services* … '.

ENDNOTES

[1] In practice, up to a certain point, the ship-time in port curves should be parallel to the horizontal axis. Their rising curvature here is introduced for expository purposes and for highlighting the impact of ship size.

[2] Defined here as the costs of the factors of production (exclusive of possible economic rent) required to produce the port service. This definition, particularly the word 'social' does not have to necessarily include external costs of production, something that has often been a cause of confusion.

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