DEPARTMENT OF ECONOMICS

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Port activities, hinterland congestion, and optimal government policies: the role of vertical integration in logistic operations (*)

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Abstract

We study the implications of vertical integration in logistics and transport operations for welfare-optimal port access charges and hinterland congestion tolls. We show that, first, vertical integration of terminal operators and transport firms does not affect the optimal congestion toll rule for the hinterland, but it does imply higher optimal port access charges. Second, the government not only has an incentive to promote competition between downstream firms, it may also be beneficial to approve of vertical mergers in the logistic chain. Third, the government's failure to respond to changes in industry market structure may have large welfare effects. Fourth, both under separation and integration, optimal port fees may imply subsidies if downstream firms enjoy a high degree of market power.

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1.0 Introduction

Recently, substantial changes have taken place in the industrial organization of port operations and logistic activities, both at the port itself and on the hinterland. First, as noted by, e.g., Notteboom (2007) and Slack and Fremont (2005), the terminal and stevedoring industry is confronted with bigger and fewer shipping lines that have become increasingly demanding with respect to productivity, priority servicing and flexibility. To meet these new demands, the industry has recently witnessed a tendency towards consolidation, leaving 40% of the market in hands of the four biggest terminal operators (Hutchinson, APM terminals, PSA and P&O ports). Moreover, companies are developing various strategies to control larger parts of the supply chain by transforming into logistics organizations and/or organizers of inland transport.[1] Second, in many countries the interaction between port activities and congestion on the hinterland has become more pronounced over time. Road traffic flows in the neighborhood of port cities such as Rotterdam and Antwerp have become increasingly congested, partially due to the expansion of port activities.[2]

The purpose of the current paper is to study the implications of vertical integration in the shipping and logistics industry, taking into account the interaction between port activities and hinterland congestion. We analyze a simple serial network consisting of two congestible facilities, viz., a port and its hinterland. In the initial situation, a number of

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[1] For example, German terminal operators are directly involved in intermodal rail transport, and some terminal operators have set up their own road haulage firms. In the UK, Hutchinson Port Holding controls the transport companies Maritime Haulage Limited and Port of Felixstowe Transport Services. In the port of Rotterdam, the terminal operator ECT, a member of the Hutchinson Port Holding, has established Maasvlakte Transport for organizing transportation between its terminals and the Maasvlakte Districentres in Rotterdam. See Notteboom (2002) for details.

[2] For example, the construction of the new Deurganckdock in Antwerp is responsible for a substantial increase of container trucks on the highway surrounding the centre of Antwerp. Plans to increase the capacity of the port of Antwerp by building the Saefinghedock encounter a lot of public resistance; it is feared that mobility problems in the Antwerp region might aggravate substantially.

competing private terminal operators are active at the port level, and private profit maximizing trucking firms are responsible for shipping goods over the port's hinterland to their end destination. Moreover, port-related traffic interacts with local traffic on the hinterland road network. Given the often highly complex ownership structure of some European ports, we assume a simplified but highly transparent institutional structure as a benchmark: we assume that a welfare-maximizing government can affect both port-related traffic and hinterland traffic using two major policy instruments, viz. a port access fee and a hinterland road toll. Within this setting, we first analyze optimal government policies and optimal pricing of terminal operators and road transport firms in a vertically separated market structure. We then study in detail the effect of vertical integration in the logistic chain, viz., between terminal operators and trucking firms, for optimal hinterland road tolls and optimal port access fees.

The analysis leads to the following insights. First, vertical integration in the logistic chain implies higher optimal port access charges. The intuition is that the optimal port fee corrects for inefficient pricing behavior in the logistics industry, and vertical integration eliminates double marginalization by terminal operators and transport firms. Indeed, confirming and generalizing earlier results (Verhoef, Nijkamp and Rietveld (1996), Brueckner (2002), De Borger, Proost and Van Dender (2008)), we find that pricing by imperfectly competitive terminal operators and trucking firms implies double marginalization of markups and a fraction of external congestion costs. Second, the optimal hinterland congestion toll is independent of the market structure in the logistic process and equals the full marginal external cost of congestion, as experienced by local as well as port-related traffic. Third, both under separation and integration, optimal port fees may imply subsidies if downstream firms enjoy a high degree of market power. Fourth, the government not only has an incentive to promote competition between downstream firms (because it leads to lower prices), but under specific conditions it may be beneficial to approve of vertical mergers in the logistic chain. Finally, failure to respond to changes in industry market structure has adverse welfare effects.

This paper is related to recent work on port pricing and the interaction with hinterland congestion. First, Yuen and Zhang (2007a) consider the pricing behavior of oligopolistic port operators, and analyze optimal port access charges and hinterland congestion tolls, assuming that port charges and hinterland road tolls are controlled by a different regional government. However, they do not consider the trucking industry and, by implication, do not study the effects of vertical integration between port terminal operators and trucking companies. Second, De Borger, Proost and Van Dender (2008) study competition between two ports and the interaction with hinterland congestion, assuming an exogenous congestion toll. An externsion of this setting (Yuen, Basso and Zhang (2008)) does allow for oligopolistic port operators and introduces optimal congestion tolls on the hinterland. However, neither of these papers considers issues of vertical integration. Third, De Borger, Proost and Dunkerley (2007) study tax and capacity competition between two governments, each operating one link of a serial network. However, they do not allow for competition between firms using the road links, and they are not interested in issues of vertical integration. Finally, Yuen and Zang (2007b) develop a model of international trade between two countries, focusing on the implications of local congestion that is associated with the shipment of goods. They find 'double' internalization of congestion costs, due to the lack of coordination between the two countries, but they neither look at issues of market structure and vertical integration, nor do they consider the policy instruments analyzed in the current paper.

The remainder of the paper is organized as follows. Section 2 describes the structure of the model. In Section 3, we analyze the case of vertical separation, in which terminal operators and trucking companies are independent firms; we determine the optimal port access fee and the optimal hinterland congestion toll under those conditions. Section 4 analyzes the implications of vertical integration between terminal operators and trucking companies for private sector pricing and for the optimal design of government policies. The implications of vertical integration are carefully discussed. A final section concludes.

2.0 Model structure

The structure of the model is depicted on Figure 1 below. A simple serial network is considered: commodities are shipped from a foreign origin through a local port and further to the final destination, making use of the port's hinterland. Ports charge an access fee for use of the infrastructure; moreover, port users employ the services of one of n terminal operators[3]. Following Yuen and Zhang (2007a), we assume the terminal operating industry at the port consists of n identical firms, offering a homogeneous service. After passing through the port, the cargo is brought to its destination by one of m symmetric trucking companies that use the road infrastructure of the port's hinterland. This infrastructure is used both by port-related trucks and by local traffic, and it may suffer from congestion. The model assumes that a benevolent government decides on the access fee at the port and it levies a congestion toll on the hinterland. Both port and hinterland capacity are assumed to be fixed; hence, we look at optimal pricing of given capacity.

[3] The port access fee can, in line with Yuen, Basso and Zhang (2008), be considered as a congestion toll at the port. In their terminology, it is a "gateway congestion toll".

The decision making process is modeled as a typical leader-follower game, where the government is assumed to take the lead. It sets its control variables before the terminal operators and the trucking companies set their prices. The government thus takes into account the reaction of the terminal operators and the trucking industry when deciding on congestion tolls and port access fees. Terminal operators and trucking companies take the government's decisions as given when determining prices. Moreover, the terminal operators and the trucking companies are assumed to make their decisions simultaneously and take prices in the next/previous facility into account[4].

Turning to the formulation of the model, we denote transit traffic (transport passing through the port and using the hinterland) by *X*, and local hinterland traffic by *Y*. For example, *X* can be interpreted as the number of containers shipped through the port. The demand for transit traffic is given by the inverse demand function $P^X\left(X\right)$; similarly, demand for local traffic is described by $P^Y\left(Y\right)$. These inverse demand functions are strictly downward sloping and twice differentiable. It is assumed that both the organizers of shipments through the port and local users of the hinterland network are basing their decisions on the generalized price of their trip, hence $P^X\left(X\right)$ and $P^Y\left(Y\right)$ are generalized prices. For port users, the generalized price consists of three components: the money and time cost of overseas transport to the port under consideration, the monetary and time cost at the port and the monetary and time cost incurred on the hinterland roads. As in De Borger, Proost and Van Dender (2008), the first cost component will be ignored because it does not

[4] The assumption of simultaneous decisions of operators and trucking firms is not entirely innocuous and may have important implications for the results. Indeed, it is well known from the recent 'self-internalization' debate at airports that quite different results may be obtained if one assumes a Stackelbergh leader (see, e.g., Brueckner and Van Dender (2008)) instead of Cournot interaction. We return to this issue below, see Section 3.4.

influence any of the results. The organizers of transit transport pay all the costs incurred on the whole serial network: they hire terminal operators and trucking firms in order to get the cargo delivered and pass the bill on to their clients.

Algebraically, the generalized cost at the port can be expressed as follows:

$$p_s + f + C_p(X) \qquad \frac{\partial C_p}{\partial X} > 0 \tag{1}$$

The terminal operator's price is denoted by p_s , the port access fee by f . Moreover, C_p is the time cost function, relating time at the port to total port traffic. Similarly, the generalized cost of port-related and local road transport on the hinterland (including tolls) is, respectively:

$$p_t + C_h(X+Y) \tag{2a}$$

$$\theta + C_h(X+Y) \tag{2b}$$

In these expressions, $C_h(.)$ is the hinterland congestion (or time) cost function: since more traffic raises the time cost, the first derivative is assumed to be positive[5] The equilibrium price on the trucking market is denoted by p_t, and the hinterland congestion toll by θ . It is assumed that the congestion toll is paid directly by the local users of the hinterland and by the trucking firms carrying port-related commodities; the congestion toll is therefore treated like an input cost for the trucking companies. Note that port-related transit traffic and local traffic also both incur monetary costs like fuel, maintenance and insurance costs, etc. Because these costs are not relevant here, they are normalized to zero.

[5] The specification of the hinterland congestion function implicitly assumes that the value of time is the same for local traffic Y and port-related traffic X. This may not be true in practice, because cargo from the port may have higher time values on average than local shipments. However, as differences in time values do not affect the main conclusions of the current paper, we stick to equal time values for simplicity.

Equilibrium on the various transport markets (local, transit) requires the generalized prices of a trip (($P^X(X), P^Y(Y)$) to equal the generalized cost. Denoting the latter by g^X, g^Y, respectively, we have:

$$P^X(X) = p_s + f + C_p(X) + p_t + C_h(X+Y) = g^X \tag{3}$$

$$P^Y(Y) = \theta + C_h(X+Y) = g^Y \tag{4}$$

It is shown in Appendix 1 that the solution of these equilibrium conditions leads to (reduced-form) demand functions $X(p_s, p_t, f, \theta)$, $Y(p_s, p_t, f, \theta)$ with the following properties (also see De Borger, Proost and Dunkerley (2007)):

$$\frac{\partial X}{\partial p_s} = \frac{\partial X}{\partial p_t} = \frac{\partial X}{\partial f} = \frac{1}{\Delta} < 0 \qquad 5)$$

$$\frac{\partial X}{\partial \theta} = \frac{1}{\Delta}\frac{\partial Z}{\partial X} > 0 \tag{6}$$

where

$$\Delta = \frac{\partial P^x}{\partial X} - \frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right) < 0 \tag{7}$$

The term $\frac{\partial Z}{\partial X}$ in (6) and (7) captures the effect of an increase in port-related transit traffic on local demand *Y*. It is easily shown that this effect is negative and that, in absolute value, it is situated between zero and one (see Appendix 1). This makes sense: more port-related traffic raises hinterland congestion and hence reduces local traffic demand, but the net effect is still an increase in traffic.

Expression (5) implies that higher prices for terminal operations, for trucking services and a higher port fee per unit all have the same effect on port demand: they reduce demand as the monetary cost of transit transport increases. A higher congestion toll (see (6)) raises, ceteris paribus, the demand for transit traffic: it lowers the demand for local traffic and, hence, congestion on the hinterland.

Similarly, one easily shows:

$$\frac{\partial Y}{\partial p_s} = \frac{\partial Y}{\partial p_t} = \frac{\partial Y}{\partial f} = \frac{\partial Z}{\partial X}\frac{\partial X}{\partial p_s} > 0 \tag{8}$$

$$\frac{\partial Y}{\partial \theta} = \frac{\partial Z}{\partial \theta} + \frac{\partial Z}{\partial X}\frac{\partial X}{\partial \theta} < 0 \tag{9}$$

Higher prices charged to transit traffic by the terminal operators and the trucking companies reduce the demand for transit transport, and hence reduce the time cost of local traffic, which has a positive effect on the demand for local transport. The same reasoning applies to the port access fee. An increase in the congestion toll lowers the demand for local traffic.

3.0 Vertical separation

In this section, we analyze the case where terminal operators and trucking firms are vertically separated. The government moves first and sets the port access fee and the hinterland congestion toll; then prices for terminal operator services and for road transport are determined on these respective markets, conditional on the government's decisions. This sequential decision making process is solved by backward induction.

3.1 The market for terminal operations

We assume there are *n* identical terminal operators supplying a homogeneous service and competing with each other à la Cournot[6]. This implies all output choices by other

[6] Cournot competition is commonly assumed in papers dealing with airline competition, see e.g. Brueckner (2002, 2005), Pels and Verhoef (2004) and Basso and Zhang (2007). It also makes sense in our model. Indeed, Notteboom (2002) argues that the terminal operating business is characterized by a lack of service differentiation.

terminal operators are taken as given by the firm. Moreover, the firm is assumed to take government policy instruments (the port access fee and the road congestion toll) as well as the price on the trucking market as given. The cost structure is kept simple: marginal costs are constant and there are no fixed costs. Profit maximizing behavior then implies that the *i*-th terminal operator considers the problem:

$$\max_{X_{is}} \pi_{is} = p_s X_{is} - c_s X_{is} \qquad \text{where } i \in [1, n]$$

The terminal operator's marginal cost is denoted by c_s, assumed equal for all n firms, and X_{is} represents the quantity of services delivered by the firm. Now substitute (3) in the objective function and note that $X = \sum_i^n X_{is}$, so that our symmetric setup implies $X_{is} = \frac{X}{n}$.

Under the assumptions mentioned above, the first-order condition for maximal profit can then be written as follows:

$$p_s + \frac{X}{n}\left[\frac{\partial P^x}{\partial X} - \frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - c_s = 0 \tag{10}$$

Expression (10) is independent of *i* by our assumptions. Rearranging gives:

$$p_s = c_s + \frac{X}{n}\left[\frac{\partial C_p}{\partial X} + \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - \frac{1}{n}\frac{P^x}{\varepsilon_x} \tag{11}$$

where $\varepsilon_x = \left(\frac{\partial X}{\partial P^x}\right)\left(\frac{P^x}{X}\right)$ is the price elasticity of demand for transit transport with respect to the generalized price. Note that we have $(1 + \frac{\partial Z}{\partial X}) > 0$ [7].

[7] This follows because the effect of more transit demand on local transport ($\frac{\partial Z}{\partial X}$) is less than one in absolute value (see the discussion in Section 2 above).

Expression (11) describes the implications of optimal behavior of terminal operators. The price charged for logistic services at the port terminal adds various markups to the private marginal production cost. First, the price captures the congestion costs incurred by the customers of an individual operator (each operator handles (X/n) at its terminal), both at the port and on the hinterland. Second, it includes a mark-up that depends positively on the operator's market share and negatively on the price elasticity of demand.

Note that operators only internalize the congestion costs incurred on the hinterland and at the port to the extent that it affects their own customers. This 'partial' internalization of congestion costs has been observed before in various different settings where firms have at least some market power (see, e.g., Verhoef, Rietveld and Nijkamp (1996), Brueckner (2002), Van Dender (2005), Yuen and Zhang (2007a), and De Borger, Proost, Van Dender (2008)). A pure monopolist (*n=1*) would charge the full congestion cost at the port and those imposed on port-related road traffic on the hinterland, plus a maximal mark-up due to market power. As $n \to \infty$, the terminal operating business becomes perfectly competitive. In that case, neither congestion costs nor mark-ups will be reflected in the price.

3.2 The market for trucking services

The trucking companies are also assumed to be profit maximizing private firms. There are *m* trucking firms delivering a homogeneous service; all firms have identical costs: marginal costs are constant, fixed costs are zero. The *j*-th trucking company's maximization problem can then be written as:

$$\max_{X_{jt}} \pi_{jt} = p_t X_{jt} - c_t X_{jt} - \theta X_{jt} \qquad \text{where} \quad j \in [1, m]$$

The marginal costs incurred in the trucking business are denoted by c_t. Price and quantity are denoted by p_t (the same for all firms) and X_{jt}, respectively. Finally, θ is the road toll paid by trucking firms for transport services on the hinterland.

Going through a series of similar steps as in Section 3.1, i.e., substituting (3) and using $X_{jt} = \frac{X}{m}$, the first order condition can be expressed as:

$$p_t + \frac{X}{m}\left[\frac{\partial P^X}{\partial X} - \frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - \theta - c_t = 0 \qquad (12)$$

Alternatively:

$$p_t = c_t + \theta + \frac{X}{m}\left[\frac{\partial C_p}{\partial X} + \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - \frac{1}{m}\frac{P^x}{\varepsilon_x} \qquad (13)$$

The price on the trucking market equals the constant marginal cost of the trucking firm plus the congestion toll, augmented by various markups reflecting partial internalization of port and hinterland congestion costs, and pure market power[8]. Moreover, these mark-ups are again maximal for $m = 1$, and they vanish for $m \to \infty$.

Comparison of the price structure on the terminal operating and trucking markets shows that both industries charge part of the congestion costs at the port and on the hinterland incurred by transit traffic. Moreover, on both markets a mark-up due to market power is charged. There is thus a double marginalization problem, not only due to market power but also due to congestion-related charges on the serial network. The former

[8] The analytical result of trucking firms charging congestion costs at the port might seem a little odd at first. However, empirical evidence suggests that it is not unrealistic. For example, as reported in the Dutch magazine "Nieuwsblad Transport (2007)", Dutch trucking firms indeed charge a mark-up related to waiting time at the port.

phenomenon is well known from the industrial organization literature[9]. Excessive overall charges for congestion are in line with previous analyses of pricing in a serial network by, among others, De Borger, Dunkerley and Proost (2007) and Yuen and Zhang (2007b). The latter authors consider trade between two countries and show that each country internalizes congestion occurring in the other country, due to a lack of coordination. They refer to this phenomenon as double internalization. The extent to which the problem of overcharging for congestion plays in our model depends on the market structures in both industries. At one extreme, if both markets are characterized by a monopoly, the congestion costs incurred at the port and on the hinterland would be charged exactly twice to the organizer of transit transport. At the other extreme, if both markets would be perfectly competitive, the problem would disappear.

3.3. The effect of government policies on private sector pricing behavior

Prices in the industries operating in the logistic chain (terminal operators and trucking firms) are determined, conditional on the government's policies with respect to port access fees and congestion tolls. In this subsection, we briefly study the reaction of prices in the trucking and terminal business to changes in government tolls and fees. To get transparent results, we will do so for the special case of linear congestion cost functions. Although this implies the algebraic effects derived are not generally valid, it simplifies the analysis without losing important insights.[10]

[9] The phenomenon of double marginalization dates back to Lerner (1934); also see, e.g., Spengler (1950), Bresnahan and Reiss (1985), Tirole (1995) and Motta (2005). It is well known that the problem is sensitive to the assumption of linear pricing. As Hart and Tirole (1990) point out, appropriate two-part pricing can eliminate the vertical externality. Following most recent transport literature (e.g. Yuen, Basso and Zhang (2008) and Yuen and Zhang (2007a)), we stick to linear pricing schemes in this paper.
[10] In fact, convex congestion costs can be shown to reinforce most of the effects derived.

To determine the effect of port fees and hinterland congestion tolls on prices of trucking and terminal services, reconsider (10)-(12). These can be rewritten as:

$$p_s + \frac{X}{n}\left[\Delta\right] - c_s = 0$$

$$p_t + \frac{X}{m}\left[\Delta\right] - c_t - \theta = 0$$

where Δ was defined by (7). Differentiating this two-equation system, noting that the assumption of linear demand and cost curves implies that Δ is constant, and using the derivatives of demand derived before (see (5)-(6)), we easily show the following effects:

$$\frac{dp_s}{df} = -\frac{m}{n\left(m+1\right)+m} < 0 \qquad \frac{dp_t}{df} = -\frac{n}{n\left(m+1\right)+m} < 0 \tag{14}$$

$$\frac{dp_s}{d\theta} = -\frac{m}{n\left(m+1\right)+m}\left(1+\frac{\partial Z}{\partial X}\right) < 0 \qquad \frac{dp_t}{d\theta} = \frac{m\left(n+1\right) - n\frac{\partial Z}{\partial X}}{n\left(m+1\right)+m} > 0 \tag{15}$$

The terminal operators and the trucking companies will both lower their prices in response to an increase of the port access fee. The higher fee raises the generalized price of transit transport and reduces demand; firms compensate by reducing prices. Similarly, an increase in the hinterland congestion toll reduces prices of terminal operators, but raises marginal costs of the trucking firms, directly increasing their prices.

Of course, all price effects strongly depend on the market structure in both industries. To see the effect of changes in the number of firms, differentiate to find:

$$\frac{\partial(\frac{dp_s}{df})}{\partial m} < 0 \qquad \frac{\partial(\frac{dp_s}{df})}{\partial n} > 0 \qquad \frac{\partial(\frac{dp_t}{df})}{\partial m} > 0 \qquad \frac{\partial(\frac{dp_t}{df})}{\partial n} < 0$$

The extent to which prices of terminal operators decline in response to an increase in the port access fee depends negatively on the number of terminal operators active on the market.

This is intuitive, as the negative demand effect for an individual firm caused by an increase of the port access fee depends negatively on its market share. Moreover, prices of terminal operators decline more the more trucking firms are active on the hinterland. This can be explained by the fact that the downward adjustment of prices in response to an increased port access fee by the trucking firms depends negatively on the number of trucking firms on the market. Hence the terminal operator industry will 'compensate' more for the falling demand as they get less 'help' from the trucking firms. An analogous interpretation can be given for the effect of the number of firms on the impact of the port fee on trucking prices.

Finally, in exactly the same manner it is found that:

$$\frac{\partial \frac{dp_s}{d\theta}}{\partial m} < 0 \qquad \frac{\partial \frac{dp_s}{d\theta}}{\partial n} > 0 \qquad \frac{\partial \frac{dp_t}{d\theta}}{\partial m} > 0 \qquad \frac{\partial \frac{dp_t}{d\theta}}{\partial n} < 0$$

This shows that an increase in the congestion toll will raise the price for trucking services more the less concentrated the trucking industry is. Terminal operators will lower their prices relatively more in response to an augmented congestion toll when the trucking industry gets more dispersed. Along similar lines the impact of the number of firms on the effect of the toll on terminal prices can be explained: the negative effect of an increase of the congestion toll on the equilibrium price on the terminal operating market depends negatively on the market share of an individual terminal operator.

3.4 Optimal access fees and congestion tolls under vertical separation

As stated earlier, the government is assumed to act first in the sequential pricing process; hence, it takes the reaction of the followers to its decisions into account when setting its policy variables. The government is assumed to maximize a social welfare function that, in its most general form, can be written as follows:

$$W = \int_0^Y p^Y(y)dy - g^y Y + \sigma \left[\int_0^X p^X(x)dx - g^x X \right]$$
$$+ fX + \theta(X+Y) + \left[(p_s - c_s)X\right] + \left[(p_t - c_t - \theta)X\right]$$

where, see (3)-(4):

$$g^X = p_s + f + C_p(X) + p_t + C_h(X+Y)$$

$$g^Y = \theta + C_h(X+Y)$$

The structure of the welfare function is, with one minor exception, in line with previous models in the literature (see De Borger, Proost and Dunkerley (2007), Yuen and Zhang (2007a)). The government cares about the net surplus of local traffic on the hinterland, it cares about all government revenues (of the port access fee and the congestion toll), and it cares about all industry profits (in both the terminal operating business and the trucking industry). However, we assume it also takes into account a fraction (σ) of the net surplus of port-related transit traffic. Although this is a rather ad hoc formulation, we justify this by noting that a share of transit traffic is destined to the home country and directly contributes to local economic activity. We will discuss the role of σ for the results below.

Optimization of the welfare function with respect to the port access fee and the congestion toll, results in the following rules (see Appendix 2):

$$\theta = (X+Y)\frac{\partial C_h}{\partial V} \tag{16}$$

$$f = X\frac{\partial C_p}{\partial X}\left(1 - \frac{1}{n} - \frac{1}{m}\right) - X\frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\left(\frac{1}{n} + \frac{1}{m}\right) + \frac{P^X}{\varepsilon_x}\left(\frac{1}{n} + \frac{1}{m}\right) + (\sigma - 1)\frac{P^X}{\varepsilon_x} \tag{17}$$

The optimal congestion toll is just equal to the full marginal external cost traffic incurs on the hinterland. As the government is assumed to also control the port access fee, it can correct for downstream inefficiencies using this instrument; there is no need to deviate from marginal social cost pricing on the hinterland road network (also see Yuen and Zhang (2007a)). Interestingly, note that the toll rule is independent of σ, the share of net surplus of port-related transit traffic that is explicitly captured in social welfare. The reason is that σ is related to the government's trade-off between the net surplus in the market and the profit of trucking firms, and this trade-off has already been captured in the optimal access fee, as discussed below.

To interpret the optimal port access fee, note the four separate terms on the right-hand side of (17). The first term, $X\frac{\partial C_p}{\partial X}\left(1-\frac{1}{n}-\frac{1}{m}\right)$, leads to full internalization of the congestion cost at the port itself. To see this, note that if it is positive (this will be the case, unless one of the industries is a monopoly or both are duopolistic), then the congestion cost is not fully internalized by port operators and trucking firms (see (11) and (13)), and the port access charge incorporates a positive congestion toll component. If the term is negative (this will be the case when one sector is a monopoly and the other is less than perfectly competitive), congestion is over-internalized and a subsidized access fee corrects for this. The second term, $X\frac{\partial C_h}{\partial V}\left(1+\frac{\partial Z}{\partial X}\right)\left(\frac{1}{n}+\frac{1}{m}\right)$, similarly leads to full internalization of hinterland road congestion costs (again, see (11) and (13)). The third term, $\frac{P^X}{\varepsilon_x}\left(\frac{1}{n}+\frac{1}{m}\right)$, is a subsidy to correct for the distortion due to market power, which is harmful for final consumers. It disappears if both industries are perfectly competitive. Finally, the last term on the right hand side, $(\sigma-1)\dfrac{P^X}{\varepsilon_x}$, captures the trade-off between consumer surplus and profits for port-related traffic in the terminal operator and trucking businesses. If σ is one, the term vanishes. If it is zero, then a tax is imposed to solve the coordination problem; if it is between zero and one, there is a trade off between profit and surplus.

Obviously, (17) implies in general that the port access charge strongly depends on the market structure in the two industries considered. To simplify the discussion, we therefore consider a number of special cases, summarized in Table 1. It shows that when both downstream industries (trucking, terminal operators) are monopolistic (*n,m=1*), the optimal port access fee is necessarily a subsidy. This can be easily understood: under monopoly, the terminal operator and the trucking firm both charge the marginal external cost of congestion at the port and on the hinterland (corrected for the interaction with local traffic), see (11) and (13). This full 'double' charging of congestion costs and markups are, from a social point of view, inefficient. The welfare-maximizing government reacts by returning the socially inefficient overcharging by the private sector to the organizer of transit transport. Note that, as the government already charges the full marginal external cost of congestion on the hinterland by means of its congestion toll, it optimally reimburses all extra hinterland congestion charges incorporated in downstream firms' prices.

The role of σ for the size of the subsidy is clear. If the government cares for all consumer surplus of port-related traffic on the hinterland *(σ=1)*, it reimburses the markups of both industries through the access fee. If it does not care about transit surplus at all *(σ=0)*, it 'allows' one mark-up to be charged to the organizer of transit traffic, as it is not directly interested in the net surplus of this transit traffic.

Of course, when downstream markets are perfectly competitive ($n, m \to \infty$), the downstream firms do not charge any marginal external congestion costs nor any mark-ups (see (11) and (13)). A benevolent government that cares about the surplus of port-related road users (*σ=1)* then just charges for the marginal external cost of congestion at the port. The port access fee is then strictly positive. Moreover, if the government does not care for the congestion suffered by transit traffic on the hinterland (*σ=0),* but it does care for toll revenues this brings in, then it will engage in tax exporting and charge a markup over marginal congestion cost.

The results described above shed some light on the implications of introducing more competition in both industries. First, more competition leads to lower prices in the terminal operator and trucking business, see (11) and (13). Second, however, more competition raises the optimal port access charge (see (17)). This gives the government a direct budgetary incentive to promote competition. Third, interestingly, as long as the government has all the relevant information to set the port access charge optimally, from a welfare viewpoint it becomes indifferent between different market structures of port operators and truckers. Indeed, the access fee allows correcting for whatever market distortions arise in the downstream industries[11].

The previous discussion shows that both the importance of potential overcharging of markups and congestion costs by terminal operators and transport firms, and the government's optimal reaction by adapting the port access charge strongly depend on the market structure of the two industries. The current terminal operating business is probably best described as a highly concentrated oligopoly. For example, there is evidence that it is characterized by a duopoly in main European ports like Antwerp (PSA and DP world) and

[11] We owe this last point to a referee.

Rotterdam (APM terminals and Hutchinson HP), and the number of operators is not much larger outside Europe (Notteboom (2007)). For the trucking industry, empirical estimates of the cost structure (see, e.g., Harmatuck (1991), Giordano (1997)), the large number of firms in the industry, and the coexistence of large and small firms operating on the market have all been used to argue that, in general, the industry may come close to perfect competition[12]. However, as the supply of port-related transport services is in many ports dominated by a limited number of very large trucking firms and long-term contracts serve as an entry barrier, perfect competition may not strictly hold for the relevant market segment.

Despite this qualification let us assume, as a final special case, that the terminal business is duopolistic and the trucking industry is perfectly competitive. Prices of trucking services will then include the congestion toll, but no extra markup or self-internalizing charge for port and hinterland congestion is included (see (13)). Using *n=2* and $m \to \infty$ in (17), we find that the optimal port access fee equals:

$$f = \frac{1}{2} X \left[\frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V} \left(1 + \frac{\partial Z}{\partial X} \right) \right] + \left(\sigma - \frac{1}{2} \right) \frac{P^X}{\varepsilon_x} \tag{18}$$

The port fee depends on the relative importance of port congestion costs vis-à-vis hinterland congestion and on the value of σ. The fee will be positive if port congestion is more important than hinterland congestion (the government charges through the fee for port congestion but reimburses overcharging of hinterland congestion by downstream firms) and the less the government cares about congestion of transit transport on the hinterland network. The latter may, in our logic, depend on the size of the country in which the port is located.

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[12] Many empirical studies find close to constant returns to scale in the trucking industry. Exceptions do exist, however see, for example, Xu et al. (1994)). Moreover, Allen and Liu (1995) suggest that correcting for service quality into the estimation of motor carrier’s cost functions increases estimates of returns to scale.

Two important remarks conclude this section. First, we have assumed that terminal operators and trucking firms make simultaneous decisions. Of course, one might ask what would happen if the terminal operator business, where the flexibility to introduce price changes may be less pronounced than for trucking services, acts as a Stackelbergh leader vis-à-vis the trucking industry. The recent literature on airport congestion pricing suggests that self-internalizing behavior is much weaker when a Stackelbergh leader interacts with a competitive fringe than under Cournot competition (see, for example, Daniel (1995) and Brueckner and Van Dender (2008)). Although this alternative setup would complicate the analysis substantially, this suggests that assuming Stackelbergh interaction might well affect our results. A second and related remark is that, unlike for the airline industry, there is no direct empirical evidence on the pricing behavior of terminal operators and transport firms that would allow judging the extent to which self-internalization of congestion, and double marginalization along a logistic chain, actually take place[13]. More empirical research is needed here because, if self-internalizing behavior does not occur, there is no need for the government to correct for it when setting the port access fee.

4.0 Vertical Integration

In this section we analyze the implications of vertical integration in the logistic chain. Specifically, we study the impact of a merger of terminal operators and trucking firms (as recently witnessed in the industry, see the introduction) on prices, congestion, optimal access fees and roads tolls, etc[14]. The mergers imply a market structure in which there is

[13] The evidence for the airline industry is actually far from conlusive, see Daniel and Pahwa (2000, and Daniel and Harback (2008)).

[14] The physical vertical integration between terminal operators and trucking firms is not strictly necessary to obtain our results. Increased cooperation and coordination between the two types of firms or the possibility to impose vertical restraints (see e.g. Rey and Tirole (1986)) will lead to similar outcomes.

competition between vertically integrated companies. The industrial organization literature suggests that vertical integration between an upstream and a downstream firm will, in general, reduce prices. In the setting of this paper, however, vertical integration is likely to induce further effects. Specifically, the government will reconsider the optimal design of its fee and toll structure, taking into account the change in market structure in the private sector. Moreover, lower prices will reduce the generalized cost of a trip and, therefore, one expects transit demand to rise, yielding more port and hinterland congestion.

4.1 The decisions of the vertically integrated firms

To keep the problem as transparent as possible, and assuming that in the initial situation there are more trucking firms than terminal operators ($m > n$), we suppose that each of the *n* individual terminal operator merges with *(m/n)* trucking companies. This assumption leaves the symmetry assumption intact: the *n* vertically integrated firms are identical ex post. They are private companies that maximize profits conditional on government policies. Assumptions with respect to the cost structure are as before, but we do allow for potential economies of scope between operators and trucking industries.

Specifically, the *l*-th vertically integrated firm is assumed to maximize:

$$\max_{X_{lvi}} \pi_{lvi} = p_{vi} X_{lvi} - c_{vi} X_{lvi} - \theta X_{lvi}$$

where $l = 1, \dots. n$, and the subscript *vi* refers to vertical integration. The constant marginal cost of the vertically integrated firm is denoted by c_{vi}, and X_{lvi} is the quantity of firm *l* under vertical integration. We allow for economies of scope by assuming that $c_{vi} = (1-\beta)\left(c_s + c_t\right)$ with $\beta \in [0,1]$, reflecting the cost savings induced by vertical integration with respect to administration, coordination, etc.

Equality of generalized price and cost of transit transport now reads (where we have used the notation X_{vi} to indicate equilibrium output under vertical integration):

$$p^X(X_{vi}) = p_{vi} + f + C_p(X_{vi}) + C_h(X_{vi} + Y_{vi}) = g^X$$

Use this relation into the objective function, differentiate profit and note that, under our assumptions, $X_{lvi} = \frac{X_{vi}}{n}$. The first-order condition can then be written as:

$$p_{vi} + \frac{X_{vi}}{n}\left[\frac{\partial P^x}{\partial X} - \frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - c_{vi} - \theta = 0 \qquad (19)$$

Rearranging, we obtain:

$$p_{vi} = c_{vi} + \theta + \frac{1}{n} X_{vi}\left[\frac{\partial C_p}{\partial X} + \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - \frac{1}{n}\frac{P^x}{\varepsilon_x} \qquad (20)$$

Interpretation of (20) goes along the same lines as in the case of (13) above. The price in the vertically integrated industry reflects its private marginal costs plus the congestion toll (which is an input cost), augmented with the relevant fraction of external congestion costs and a mark-up for market power.

To see the implications of integration most clearly, note that the pricing rules under separation imply that the total price charged for terminal and trucking services is (see (11) and (13)):

$$p_s + p_t = c_s + c_t + \theta + X\left(\frac{1}{n} + \frac{1}{m}\right)\left[\frac{\partial C_p}{\partial X} + \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right)\right] - \left(\frac{1}{n} + \frac{1}{m}\right)\frac{P^X}{\varepsilon_x} \qquad (21)$$

Comparing expressions (20) and (21), two differences immediately follow. First, if there are economies of scope ($\beta > 0$) then the marginal cost of the integrated firm is smaller than the sum of the marginal costs of the separated firms, $c_{vi} < (c_s + c_t)$, reducing the overall price. Second, the integrated firm eliminates the double marginalization problems that existed under separation (assuming $m \neq \infty$). The integrated firm charges for congestion costs in as far as it affects its own (X_{vi}/n) customers. Under separation, both links in the logistic chain partly self-internalize port and hinterland congestion. A similar argument holds for the markup related to market power. Ceteris paribus, these factors tend to further reduce prices under integration.

4.2 The impact of government policy instruments on private sector pricing behavior

By analogy with section 3, we can easily derive the reaction of prices in the integrated industry when the government adjusts toll or port access fees. Using the same techniques as before, it follows:

$$\frac{\partial p_{vi}}{\partial f} = -\frac{1}{n+1} < 0 \qquad \frac{\partial p_{vi}}{\partial \theta} = \frac{n - \dfrac{\partial Z}{\partial X}}{n+1} > 0 \tag{22}$$

As expected, an increase in the port access fee reduces the equilibrium price on the market for combined terminal operating and trucking services, because it raises the generalized price of transit transport. This induces the vertically integrated firms to lower their charges to compensate for the falling demand. An increase in the congestion toll raises the price charged by the vertically integrated firm as it raises its input costs.

4.3 Optimal government policies under vertical integration

Under vertical integration in the logistic chain, the government's social welfare optimization problem reads:

$$\max_{f,\theta} W = \int_0^{Y_{vi}} P^Y(y)dy - g^Y Y_{vi} + \sigma\left[\int_0^{X_{vi}} P^X(x)dx - g^X X_{vi}\right] + fX_{vi} + \theta(X_{vi} + Y_{vi}) + (p_{vi} - c_{vi} - \theta)X_{vi}$$

Following the same steps as in the previous section (also see Appendix 2) and using (22), we find the following optimal pricing rules:

$$\theta = \left(X_{vi} + Y_{vi} \right) \frac{\partial C_h}{\partial V} \qquad (23)$$

$$f = X_{vi} \frac{\partial C_p}{\partial X} \left(1 - \frac{1}{n} \right) - X_{vi} \frac{\partial C_h}{\partial V} \left(1 + \frac{\partial Z}{\partial X} \right) \left(\frac{1}{n} \right) + \frac{P^X}{\varepsilon_x} \left(\frac{1}{n} \right) + (\sigma - 1) \frac{P^X}{\varepsilon_x} \qquad (24)$$

The optimal congestion toll rule is identical as under separation: the toll equals the full marginal external of congestion on the hinterland. The expression for the optimal port access fee again consists of four clearly identifiable terms; the interpretation is the same as before, see the discussion following (17) in the previous section.

Comparing (24) with (17) gives insight into the main effects of vertical integration for the optimal port access fee. The differences are easily interpreted. The access fee is used by the government to correct for the distortions of market power, double marginalization and partial self-internalization of congestion costs. Since integration eliminates double marginalization and limits self-internalization to one link of the logistic chain, (24) and (17) imply that access charges decline under vertical integration, ceteris paribus.

In Table 2 we consider some special cases. Under monopoly, the results show three remarkable differences with the situation under vertical separation (compare with Table 1). Consider, for example, the case of $\sigma = 0$. First, under vertical integration port congestion costs do not appear in the optimal access charge; the reason is that they are already fully internalized by the monopolist, see (22). Second, hinterland congestion is only reimbursed once in the integration case, as the double marginalization of congestion cost in the separation case does not arise here. Third, under separation, the monopoly case implied the reimbursement of the monopoly markup via the access fee. We now see that integration does not contain a markup term. The difference between the cases $\sigma = 0, \sigma = 1$ has the same logic as before. Finally, note that, if the integrated structures tend to competition ($n \to \infty$) results are, of course, identical to the case under separation: integrated competitors or a sequence of competitive chains yield similar optimal government policies. Numerically, results may still differ, of course, because economies of scope would imply lower prices under integration.

To conclude this subsection, consider a duopolistic market structure for the integrated logistic industry as an intermediate case. It follows from (24) that in that case we have:

$$f = \frac{1}{2} X_{vi} \left[\frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V} \left(1 + \frac{\partial Z}{\partial X} \right) \right] + \left(\sigma - \frac{1}{2} \right) \frac{P^X}{\varepsilon_x}$$

Interestingly, this is identical to (18). Upon reflection, this makes sense: since there is no distortion due to the trucking industry under competitive conditions, in both cases there is just a single distortion the government has to correct for.

4.4 Policy implications of vertical integration

In previous subsections, we noticed important differences in behavior of the private logistic operators and in the government's optimal policies with respect to hinterland tolls and port access fees. The private sector charges lower prices for the overall logistic chain because the double marginalization of markups and congestion is avoided. Integration did not affect the government's optimal congestion toll on the hinterland, but it did strongly affect the optimal port access charges. Because the private pricing behavior in the vertical integration case avoids the double marginalization problem, this eliminates the need for the government to correct this overcharging distortion through lower access fees. The access charge will therefore be higher under integration.

What does this imply for the overall welfare implications of vertical integration, provided the government charges the optimal congestion tolls and port access fees? To see this, let us compare the sum of all monetary charges paid by the organizer of port-related transport under separation and vertical integration. The total price includes payments for terminal operations, for trucking services, and the port access fee. Note that under separation, using (11), (13), (16) and (17), we have:

$$p_s + p_t + f = c_s + c_t + X\frac{\partial C_P}{\partial X} + \left(X + Y\right)\frac{\partial C_h}{\partial V} + \left(\sigma - 1\right)\frac{P^X}{\varepsilon_X} \tag{25}$$

Inspection of (25) readily shows that the government, through its fee setting, makes sure that the marginal private costs of the terminal operators and trucking firms and all marginal congestion costs are charged exactly once. If it does not fully incorporate the surplus of transit traffic ($\sigma < 1$) in the objective function, then it will in addition engage in tax exporting and charge an elasticity related mark-up. Similarly, under vertical integration we have, using (20) and (24):

$$p_{vi} + f = c_{vi} + X_{vi}\frac{\partial C_P}{\partial X} + \left(X_{vi} + Y_{vi}\right)\frac{\partial C_h}{\partial V} + \left(\sigma - 1\right)\frac{P^X}{\varepsilon_X} \tag{26}$$

Comparison of (25) and (26) shows that the overall charges to transit traffic are identical, except for potential differences in marginal production costs of the vertically integrated versus separated firms, due to economies of scope. This just reflects the fact that the only motivation of government policy through adjustment of the port access fee is to correct for distortions induced by private sector behavior. Provided the government correctly responds to changes in market structure, the impact of vertical integration for congestion will, therefore, be fairly limited. Although economies of scope imply lower prices under integration, optimal government behavior implies there are no further effects on generalized prices.

The following conclusions then easily follow. First, vertical integration is welfare-improving, provided two conditions are satisfied. There must be economies of scope associated with the integration process ($\beta > 0$), so that prices of terminal and trucking services jointly decline. Moreover, the government must charge optimal congestion tolls as well as port access fees. Second, vertical integration is also likely to be good news for the government's budget, especially if there are economies of scope. We noted before that the optimal access fee is higher under vertical integration. If economies of scope reduce prices and traffic flows through the port rise, this leads to further increases in government revenues. This suggests that the government may have a double motivation for promoting vertical integration in logistic chains. If economies of scope exist that lead to lower prices for end users, it is not only welfare-improving but also raises the revenues of optimal government policies.

The analysis of this paper points further at two clear policy implications associated with the tendency towards vertical integration in the logistics chain. The first one is that optimal government policies have to be adjusted to take account of this evolution in the logistics business. Although road toll rules for the hinterland are unaffected, optimal port fees increase under vertical integration. As argued above, if the government optimally responds, welfare effects can be expected to be positive, and the government budget is likely to improve. Second, however, the downside is that, if the government does not respond to changes in market structure in the logistics industry, welfare losses are likely to be substantial. Too low port fees will in that case raise port-related traffic X, and it will generate excessive congestion both at the port and on the hinterland, the burden of which largely falls on local hinterland users.

5.0 Conclusion

The purpose of the current paper was to get some insight into the implications of vertical integration for the design of optimal government policies, taking into account the interaction between port activities and hinterland congestion.

The analysis leads to the following insights. First, vertical integration in the logistic chain (integration of terminal operators and transport firms) implies higher optimal port access charges. The intuition is to be found in the pricing behavior of the private sector. Imperfectly competitive terminal and trucking industries imply double marginalization of markups and a fraction of external congestion costs, leading to ‘overcharging’ for logistic services. The government uses the optimal port access charge to correct for this inefficient pricing behavior in the logistics industry. With vertical integration between successive stages in the logistic chain double marginalization by terminal operators and transport firms is eliminated, requiring less compensation through the port fee. Second, the optimal hinterland congestion toll is independent of market structure and equals the full marginal external cost of congestion, as experienced by local as well as port-related traffic. Third, both under separation and integration, optimal port fees may imply subsidies if downstream firms enjoy a high degree of market power. Fourth, if there are economies of scope associated with the integration process, vertical integration is welfare-improving, provided the government’s policies with respect to congestion tolls and port access fees are optimal. Moreover, under the same assumptions, vertical integration is also likely to raise government revenues. Finally, optimal government policies strongly depend on the evolution in the market structure of the logistic industry. Failure to respond to changes in industry market structure may have large welfare effects. Too low port access fees will in that case raise port-related traffic and generate excessive congestion both at the port and on the hinterland, the burden of which largely falls on local hinterland users.

References

Allen, W.B., and D. Liu (1995): ‘Service quality and motor carrier costs’, *Review of Economics and Statistics*, 77, 499-510

Basso, L.J., and A. Zhang A. (2007): ‘Congestible facility rivalry in vertical structures’, *Journal of Urban Economics*, 61, 218-237

Bresnahan, T., and P. Reiss (1985): ‘Dealer and manufacturer margins’, *Rand Journal of Economics*, 16, 253-268

Brueckner, J.K. (2002): ‘Airport congestion when carriers have market power’, *American Economic Review*, 92,, 1357-1375

Brueckner, J.K. (2005): ‘Internalization of airport congestion: a network analysis’, *International Journal of Industrial Organization*, 23, 599-614

Brueckner, J.K., and K. Van Dender (2008): ‘Atomistic congestion tolls at concentrated airports? Seeking a unified view in the internalization debate’, *Journal of Urban Economics*, 64, 288-295.

Daniel, J. (1995): ‘Congestion pricing and concentration at large hub airports: A bottleneck model with stochastic queues’, *Econometrica*, 63, 327-370.

Daniel, J., and M. Pahwa (2000): ‘Comparison of three empirical models of airport congestion pricing’, *Journal of Urban Economics*, 47, 1-38.

Daniel, J., and K. T. Harback (2008): ‘(When) do hub airlines internalize their self-imposed congestion delays?’, *Journal of Urban Economics*, 63, 583-612

De Borger, B., Dunkerley, F., and S. Proost (2007): ‘Strategic investment and pricing decisions in a congested transport corridor’, *Journal of Urban Economics*, 62, 294-316

De Borger, B., Proost, S., and K. Van Dender (2008): ‘Private port pricing and public investment in port and hinterland capacity’, *Journal of Transport Economics and Policy*, 42, 527-561.

Giordano, J.N. (1997): ‘Returns to scale and market concentration among the largest survivors of deregulation in the US trucking industry’, *Applied Economics*, 29, 101-110

Harmatuck, D.J. (1991): ‘Economies of scale and scope in the motor carrier industry. An analysis of the cost functions for 17 large LTL common motor carriers’, *Journal of Transport Economics and Policy*, 25, 135-151

Hart, O., and J. Tirole (1990): ‘Vertical integration and market foreclosure’, *Brookings papers on economic activity: microeconomics*, special issue, 205-276

Motta, M. (2005): *Competition policy: theory and practice*, Cambridge University Press, Cambridge, UK

Notteboom, T.E. (2002): ‘Consolidation and contestability in the European container handling industry’, *Maritime Policy and Management*, 9, 257-269

Notteboom, T.E. (2007): ‘*The changing face of the terminal operator business: lessons for the regulator’*, paper presented on the ACCC regulatory conference, Gold Coast Australia, 26-27 July

Lerner, A.P. (1934): ‘The concept of monopoly and the measurement of monopoly power’, *Review of Economic Studies*, 1, 157-175

Pels, E., and E.T. Verhoef (2004): ’The economics of airport congestion pricing’, *Journal of Urban Economics*, 55, 257-277

Rey, P., and J. Tirole (1986), ‘The logic of vertical restraints’, *American Economic Review*, 76, 921-939

Slack, B., and A. Frémont (2005), ‘Transformation of port terminal operations: from the local to the global’, *Transport Reviews*, 25(1), 117-130

Spengler, J. (1950): ‘Vertical integration and anti-trust policy’, *Journal of Political Economy*, 58, 347-352

Tirole, J. (1995): *The theory of industrial organization*, MIT Press, Cambridge, Massachusetts.

Van Dender, K. (2005): ‘Duopoly prices under congested access’, *Journal of Regional Science*, 45, 343-362

Verhoef, E., Nijkamp, P., and P. Rietveld (1996): ‘Second-best congestion pricing: the case of an untolled alternative’, *Journal of Urban Economics*, 40, 279-302

Xu, K., Windle, R., Grimm, C., and T. Corsi (1994): ‘Re-evaluating returns to scale in transport’, *Journal of Transport Economics and Policy*, 28, 275-286.

Yuen, A., Basso, L.J., and A. Zhang (2008): ‘Effects of gateway congestion pricing on optimal road pricing and hinterland, *Journal of Transport Economics and Policy, 42*, 495-526.

Yuen, A., and A. Zhang (2007a): ‘*Port pricing in a congestible intermodal transport system*’, paper presented on the International Conference on Logistics, Shipping and Port management, Kainan University Taiwan, 29-30 March

Yuen, A., and A. Zhang (2007b): ‘Strategic trade and transport policies with congestible facilities’, *Asia Pacific Journal of Accounting and Economics*, 14, 235-257.

Figures

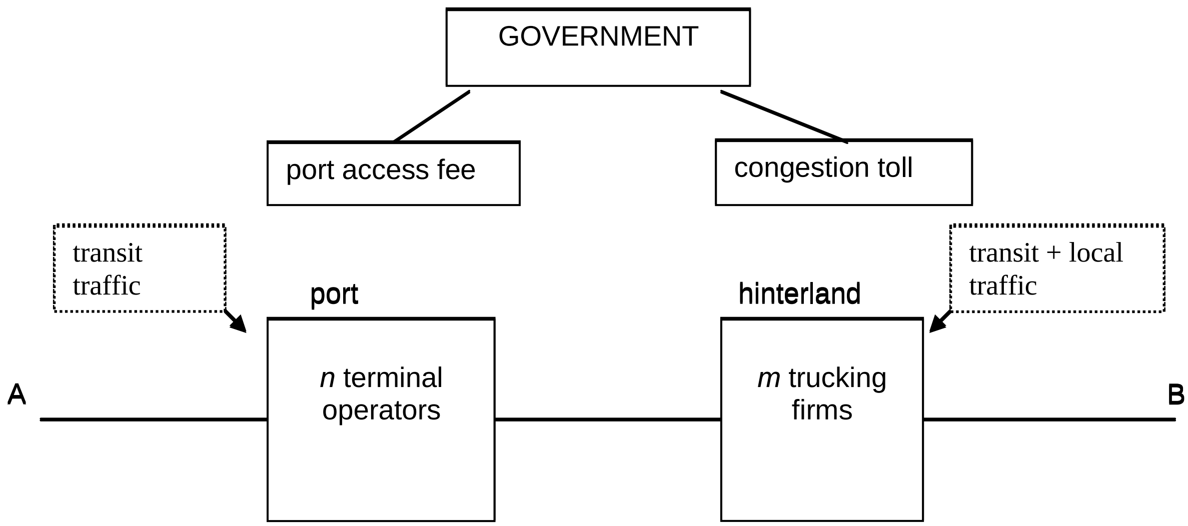

Figure 1: Structure of the model

Tables:

	$n, m = 1$	$n, m \to \infty$
$\sigma=0$	$f = -X \frac{\partial C_p}{\partial X} - 2X \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right) + \frac{P^X}{\varepsilon_X} < 0$	$f = X \frac{\partial C_p}{\partial X} - \frac{P^X}{\varepsilon_X} > 0$
$\sigma=1$	$f = -X \frac{\partial C_p}{\partial X} - 2X \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right) + 2\frac{P^X}{\varepsilon_X} < 0$	$f = X \frac{\partial C_p}{\partial X} > 0$

Table 1: Optimal port access fee under vertical separation

	$n=1$	$n \to \infty$
$\sigma = 0$	$f = -X \dfrac{\partial C_h}{\partial V}\left(1 + \dfrac{\partial Z}{\partial X}\right) < 0$	$f = X \dfrac{\partial C_p}{\partial X} - \dfrac{P^X}{\varepsilon_X} > 0$
$\sigma = 1$	$f = -X \dfrac{\partial C_h}{\partial V}\left(1 + \dfrac{\partial Z}{\partial X}\right) + \dfrac{P^X}{\varepsilon_X} < 0$	$f = X \dfrac{\partial C_p}{\partial X} > 0$

Table 2: The optimal port access fee under vertical integration

Appendix 1: Demand characteristics

Start from the following equilibrium conditions:

$$p^x(X) = p_s + f + C_p(X) + p_t + C_h(X+Y) = g^x \qquad \text{(A.1.1)}$$

$$p^y(Y) = \theta + C_h(X+Y) = g^y \qquad \text{(A.1.2)}$$

Now solve (A.1.2) for Y as a function of transit demand and the congestion toll:

$$Y = Z\left(X, \theta\right) \qquad \text{(A.1.3)}$$

Applying the implicit function theorem to (A.1.2) implies:

$$\frac{\partial Z}{\partial X} = \frac{\frac{\partial C_h}{\partial V}}{\frac{\partial p^y}{\partial Y} - \frac{\partial C_h}{\partial V}} < 0 \qquad \text{(A.1.4)}$$

$$\frac{\partial Z}{\partial \theta} = \frac{1}{\frac{\partial p^y}{\partial Y} - \frac{\partial C_h}{\partial V}} < 0 \qquad \text{(A.1.5)}$$

Next substitute (A.1.3) into (A.1.1) to obtain:

$$p^x(X) = p_s + f + C_p(X) + p_t + C_h(X + Z(X, \theta))$$

This implies, again using the implicit function theorem:

$$\frac{\partial X}{\partial f} = \frac{\partial X}{\partial p_s} = \frac{\partial X}{\partial p_t} = \frac{1}{\Delta} < 0 \qquad \text{(A.1.6)}$$

$$\frac{\partial X}{\partial \theta} = \frac{1}{\Delta}\frac{\partial Z}{\partial X} > 0 \qquad \text{(A.1.7)}$$

where $\Delta = \frac{\partial p^x}{\partial X} - \frac{\partial C_p}{\partial X} - \frac{\partial C_h}{\partial V}\left(1 + \frac{\partial Z}{\partial X}\right) < 0$ (A.1.8)

The sign of Δ is easily derived because, making use of (A.1.4):

$$1+\frac{\partial Z}{\partial X}=\frac{\frac{\partial p^{y}}{\partial Y}}{\frac{\partial p^{y}}{\partial Y}-\frac{\partial C_{h}}{\partial V}}>0 \tag{A.1.9}$$

Interpretation of (A1.6)-(A1.7) is straightforward. An exogenous increase in the port access fee, the price charged by the terminal operators and the price charged by the trucking firms reduces transit demand as these price rises increase the generalized cost of the trip. An exogenous increase in the congestion toll raises, ceteris paribus, the demand for transit transport as it reduces congestion on the hinterland through its effect on local traffic.

Finally, the impact of the various prices on local traffic on the hinterland is:

$$\frac{\partial Y}{\partial \theta}=\frac{\partial Z}{\partial \theta}+\frac{\partial Z}{\partial X}\frac{\partial X}{\partial \theta}<0 \tag{A.1.10}$$

$$\frac{\partial Y}{\partial f}=\frac{\partial Z}{\partial X}\frac{\partial X}{\partial f}>0 \tag{A.1.11}$$

$$\frac{\partial Y}{\partial p_{s}}=\frac{\partial Z}{\partial X}\frac{\partial X}{\partial p_{s}}>0 \tag{A.1.12}$$

$$\frac{\partial Y}{\partial p_{t}}=\frac{\partial Z}{\partial X}\frac{\partial X}{\partial p_{t}}>0 \tag{A.1.13}$$

An exogenous increase in the port access fee, the terminal operators’ price or the trucking companies’ price, has a negative impact on transit traffic and thus reduces congestion on the hinterland. As a response to this lowered time cost on the hinterland, local traffic will surge. An increase in the congestion toll raises the monetary cost of transport for local traffic and thus reduces demand for it. Moreover it raises transit traffic what raises congestion on the hinterland and hence time costs for local traffic, what also reduces demand for local transport.

Appendix 2: Derivation of optimal port access fee and congestion toll

Start from the welfare function:

$$W = \int_0^Y p^y(Y)dY - g^y Y + \sigma\left[\int_0^X p^x(X)dX - g^x X\right]$$
$$+ fX + \theta(X+Y) + \left[(p_s - c_s)X\right] + \left[(p_t - c_t - \theta)X\right]$$

where, see (1.4)-(1.5):

$$g^x = p_s + f + C_p(X) + p_t + C_h(X+Y)$$

$$g^y = \theta + C_h(X+Y)$$

Differentiating the welfare function with respect to the road toll, using the above definitions of g^x, g^y, and noting the equality between generalized price and generalized cost, we can write the first-order conditions as:

$$-Y\left[\frac{\partial C_h}{\partial V}\left(\frac{dX}{d\theta}+\frac{dY}{d\theta}\right)+1\right] - \sigma X\left[\frac{\partial C_p}{\partial X}\frac{dX}{d\theta}+\frac{\partial C_h}{\partial V}\left(\frac{dX}{d\theta}+\frac{dY}{d\theta}\right)+\frac{\partial p_s}{\partial \theta}+\frac{\partial p_t}{\partial \theta}\right]$$
$$+ f\frac{dX}{d\theta} + (X+Y) + \theta\left(\frac{dX}{d\theta}+\frac{dY}{d\theta}\right) + (p_s - c_s)\frac{dX}{d\theta} + X\frac{\partial p_s}{\partial \theta}$$
$$+ (p_t - c_t - \theta)\frac{dX}{d\theta} - X + X\frac{\partial p_t}{\partial \theta} = 0$$

Rearranging yields:

$$f\frac{dX}{d\theta} + \theta\frac{dY}{d\theta} =$$
$$(Y+\sigma X)\frac{\partial C_h}{\partial V}\left(\frac{dX}{d\theta}+\frac{dY}{d\theta}\right) + \sigma X\frac{\partial C_p}{\partial X}\frac{dX}{d\theta} - \left[(p_s - c_s) + (p_t - c_t)\right]\frac{dX}{d\theta} + (\sigma - 1)X\left(\frac{\partial p_s}{\partial \theta}+\frac{\partial p_t}{\partial \theta}\right)$$

Going through the same steps, the first-order condition with respect to the port access fee can be written as:

$$f\frac{dX}{df}+\theta\frac{dY}{df}=$$

$$(Y+\sigma X)\frac{\partial C_h}{\partial V}\left(\frac{dX}{df}+\frac{dY}{df}\right)+\sigma X\frac{\partial C_p}{\partial X}\frac{dX}{df}-\left[(p_s-c_s)+(p_t-c_t)\right]\frac{dX}{df}+(\sigma-1)X\left(1+\frac{\partial p_s}{\partial f}+\frac{\partial p_t}{\partial f}\right)$$

Writing the two-equation system in matrix notation and solving we get:

$$f=\frac{1}{D}\left[r_\theta\frac{dY}{df}-r_f\frac{dY}{d\theta}\right]$$
$$\theta=\frac{1}{D}\left[r_f\frac{dX}{d\theta}-r_\theta\frac{dX}{df}\right]$$

where $D=\frac{dX}{d\theta}\frac{dY}{df}-\frac{dX}{df}\frac{dY}{d\theta}$.

$$r_\theta=(Y+\sigma X)\frac{\partial C_h}{\partial V}\left(\frac{dX}{d\theta}+\frac{dY}{d\theta}\right)+\sigma X\frac{\partial C_p}{\partial X}\frac{dX}{d\theta}-\left[(p_s-c_s)+(p_t-c_t)\right]\frac{dX}{d\theta}+(\sigma-1)X\left(\frac{\partial p_s}{\partial\theta}+\frac{\partial p_t}{\partial\theta}\right)$$
$$r_f=(Y+\sigma X)\frac{\partial C_h}{\partial V}\left(\frac{dX}{df}+\frac{dY}{df}\right)+\sigma X\frac{\partial C_p}{\partial X}\frac{dX}{df}-\left[(p_s-c_s)+(p_t-c_t)\right]\frac{dX}{df}+(\sigma-1)X\left(1+\frac{\partial p_s}{\partial f}+\frac{\partial p_t}{\partial f}\right)$$

Let us first work out the toll rule. Note that substitution and simple manipulation yields:

$$r_f\frac{dX}{d\theta}-r_\theta\frac{dX}{df}=(Y+\sigma X)\frac{\partial C_h}{\partial V}\left(\frac{dX}{d\theta}\frac{dY}{df}-\frac{dX}{df}\frac{dY}{d\theta}\right)+(\sigma-1)X\left[\left(\frac{\partial p_s}{\partial f}+\frac{\partial p_t}{\partial f}\right)\frac{dX}{d\theta}-\left(1+\frac{\partial p_s}{\partial\theta}+\frac{\partial p_t}{\partial\theta}\right)\frac{dX}{df}\right]$$

This implies

$$\theta=(Y+\sigma X)\frac{\partial C_h}{\partial V}+\frac{1}{D}\left[(\sigma-1)X\left[\left(\frac{\partial p_s}{\partial f}+\frac{\partial p_t}{\partial f}\right)\frac{dX}{d\theta}-\left(1+\frac{\partial p_s}{\partial\theta}+\frac{\partial p_t}{\partial\theta}\right)\frac{dX}{df}\right]\right]$$

Next, note that,

$$\frac{dY}{df}=\frac{\partial Y}{\partial f}+\frac{\partial Y}{\partial p_s}\frac{\partial p_s}{\partial f}+\frac{\partial Y}{\partial p_t}\frac{\partial p_t}{\partial f}$$

$$\frac{dX}{df}=\frac{\partial X}{\partial f}+\frac{\partial X}{\partial p_s}\frac{\partial p_s}{\partial f}+\frac{\partial X}{\partial p_t}\frac{\partial p_t}{\partial f}$$

$$\frac{dX}{d\theta}=\frac{\partial X}{\partial\theta}+\frac{\partial X}{\partial p_s}\frac{\partial p_s}{\partial\theta}+\frac{\partial X}{\partial p_t}\frac{\partial p_t}{\partial\theta}$$

$$\frac{dY}{d\theta}=\frac{\partial Y}{\partial\theta}+\frac{\partial Y}{\partial p_s}\frac{\partial p_s}{\partial\theta}+\frac{\partial Y}{\partial p_t}\frac{\partial p_t}{\partial\theta}$$

Now use the various demand derivatives given before, and note that:

$$\frac{dp_s}{df}=-\frac{m}{n(m+1)+m}<0 \qquad \frac{dp_t}{df}=-\frac{n}{n(m+1)+m}<0$$

$$\frac{dp_s}{d\theta}=-\frac{m}{n(m+1)+m}\left(1+\frac{\partial Z}{\partial X}\right)<0 \qquad \frac{dp_t}{d\theta}=\frac{m(n+1)-n\frac{\partial Z}{\partial X}}{n(m+1)+m}>0$$

We then find:

$$\frac{dY}{df}=\frac{\partial Z}{\partial X}\frac{1}{\Delta}\left(\frac{nm}{nm+m+n}\right)$$

$$\frac{dX}{df}=\frac{1}{\Delta}\left(\frac{nm}{nm+m+n}\right)$$

$$\frac{dX}{d\theta}=\frac{1}{\Delta}\left(\frac{nm\left(1+\frac{\partial Z}{\partial X}\right)}{nm+m+n}\right)$$

$$\frac{dY}{d\theta}=\frac{\partial Z}{\partial\theta}+\frac{\partial Z}{\partial X}\frac{dX}{d\theta}$$

It follows by simple algebra:

$$D=\frac{dX}{d\theta}\frac{dY}{df}-\frac{dX}{df}\frac{dY}{d\theta}=-\frac{\partial Z}{\partial\theta}\frac{1}{\Delta}\left(\frac{nm}{nm+m+n}\right)$$

$$\left(\frac{\partial p_s}{\partial f}+\frac{\partial p_t}{\partial f}\right)\frac{dX}{d\theta}-\left(1+\frac{\partial p_s}{\partial\theta}+\frac{\partial p_t}{\partial\theta}\right)\frac{dX}{df}=\frac{\partial Z}{\partial X}\frac{1}{\Delta}\left(\frac{nm}{nm+m+n}\right)$$

Substituting into the toll rule ultimately yields:

$$\theta=(Y+X)\frac{\partial C_h}{\partial V}$$

Finally, a series of completely analogous steps produces the optimal port fee:

$$f=X\frac{\partial C_p}{\partial X}\left(1-\frac{1}{n}-\frac{1}{m}\right)-X\frac{\partial C_h}{\partial V}\left(1+\frac{\partial Z}{\partial X}\right)\left(\frac{1}{n}+\frac{1}{m}\right)+\sigma\frac{P^X}{\varepsilon_x}-\frac{P^X}{\varepsilon_x}\left(1-\frac{1}{n}-\frac{1}{m}\right)$$