DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS

Port Capacity Extension
A trade-off between public investment and shipping companies' time losses

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Port Capacity Extension

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Abstract

Port capacity and especially free port capacity plays a crucial role in the competition struggle between ports. During the last decades port authorities decisions have been made to enlarge and renovate existing port infrastructure or to build new infrastructure, in several ways: deepening rivers and maritime channels; building new locks, new terminals and berths; facilitating new and better hinterland connections. Most infrastructure capacity expansion has been financed by public money.

This paper investigates whether and in what way port capacity investments can be considered a trade-off between new free (over)capacity paid for by public money, and potential time losses by private shipping companies due to a lack of capacity and corresponding waiting lines or congestion.

[1] The authors would like to thank Christa Sys and Thierry Vanelslander for their constructive comments and suggestions.

1. INTRODUCTION

The port landscape is evolving very quickly. This is partly due to developments exogenous to the ports, such as the scale increases in the container business which has implications for the shipping routes and the ports of call. But also within the port perimeter there have been new developments. A major one is the way in which ports deal with existing and new infrastructure. In the past, port authorities could rely upon the government and upon public money for financing their large scale infrastructure plans, resulting often in the creation of huge amounts of excess capacity. Shipping companies welcomed this free capacity because it reduced the turnaround time in a port, and hence also the costs of their ship operations.

This situation is changing rapidly. For budgetary reasons, often in combination with ecological and spatial aspects, each new demand for port infrastructure expansion is subject to a thorough study not only of all the social costs and benefits, but also of all the risks and returns for the actors involved. Traditionally capacity shortages and the resulting congestion and queuing can be handled by efficiency improvements, congestion pricing and capacity expansion. Due to the complex nature of ports and port competition, the uncertainty of future demand for port services in combination with the large scale and highly irreversible nature of the required investments, it is not straightforward to find the optimal port capacity.

The literature on optimal port capacity considers either a partial aspect such as terminal or berth capacity or simplifies the analysis to a limited number of port actors. From research in airport pricing and capacity, it is clear that the following elements have to be taken into consideration when defining the optimal capacity: the ownership structure, the market situation and competition of all the actors involved, the different types of services offered, the vertical structure, the uncertainty of the future demand, the timing of the decision and building process of new infrastructure, the huge amounts of capital needed for new or additional capacity, the irreversibility of some of the projects.[2]

In this contribution we will frame this issue in the first instance within the context of port competition and the different port actors. Then it goes into detail on the concept of port capacity, its composition and the crucial variables . This capacity is then linked to port infrastructure investment and possible conflicts of interest.

2. PORT COMPETITION AND PORT ACTORS

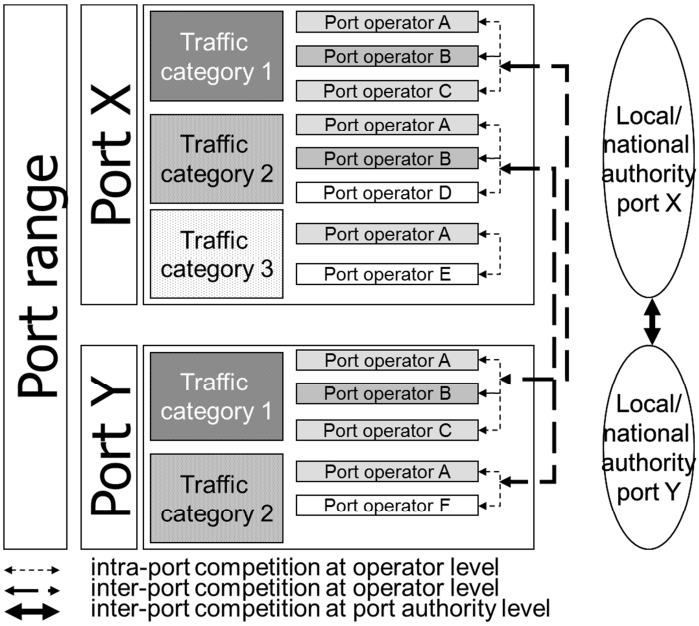
Modern ports are complex structures with a multitude of functions. Where the traditional views on ports focussed on the transfer of goods and/or passengers from ship to land or onto other vessels, the modern view distinguishes between on the one hand the core services, such as terminal services, towage, pilotage, ship repair, infrastructure provision and information management, and on the other hand the value added services such as stripping and stuffing, warehous-

[2] A good overview is given by Zhang and Czerny (2012) and Basso and Zhang (2007).

ing, distribution centres, logistics chain integration services, bunker facilities, container repair and maintenance, weigh bridges, parking facilities and other value added services (Meersman, Van de Voorde, Vanelslander, 2011, p. 823-824). As a consequence, a multitude of actors, often interconnected vertically or horizontally, operate within a seaport, each with their specific management and cost structures, pricing strategies and market conditions. They can roughly be divided into three groups: the port users such as the shippers, the shipping companies, and industrial enterprises; the service providers such as the terminal operating companies, the pilots, the towage services, the agents, the forwarders, the ship repairers, the suppliers of food and spare parts, waste reception facilities, and bunker providers; and the port authorities.

The heterogeneous and complex nature of a seaport, with a multitude of interconnected market players requires a thorough knowledge at a disaggregate level. Not only the ports as an entity compete with each other, but also the manufacturing companies and the service providers based in the port can be in competition within or outside the port. This led to the traditional view on port competition which is illustrated in figure 1. Within a port range port authorities can compete for some types of cargo. At a lower level port operators can compete within a port for some or all of the traffic which passes through that port. But they can also compete with operators in other ports for goods flows in their range.

Figure 1 Traditional view on port competition

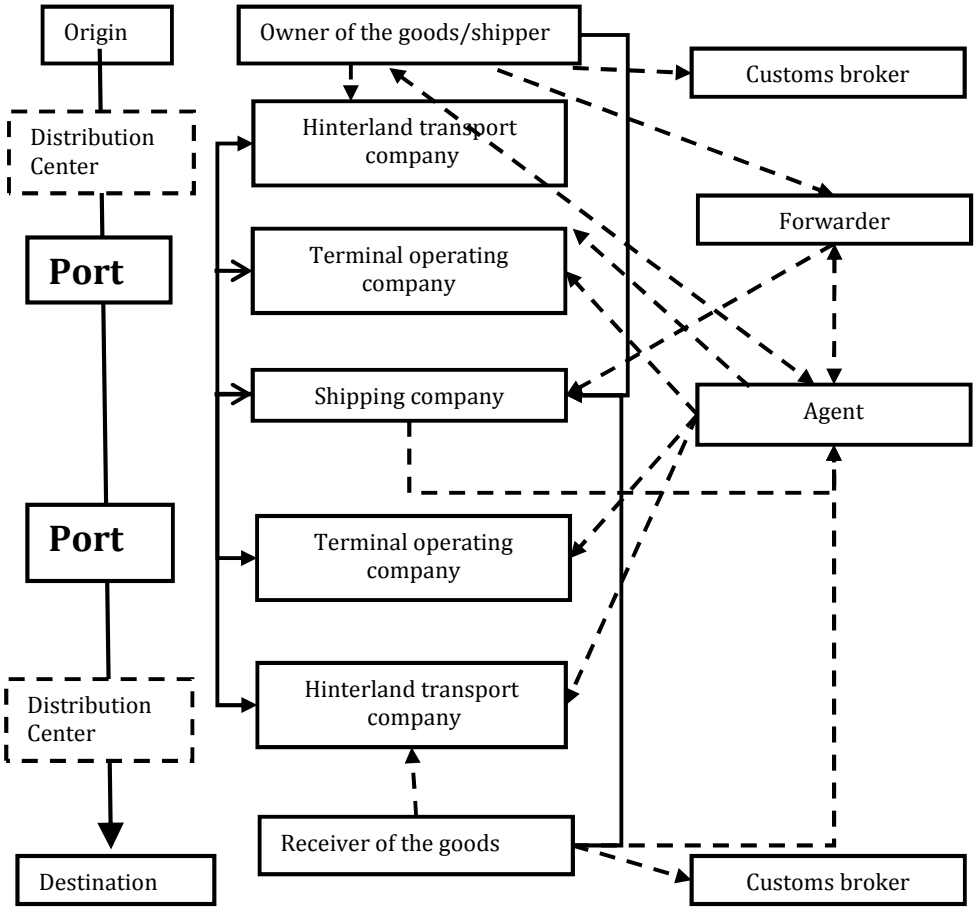


Source: based on Van de Voorde, E. and W. Winkelmans, 2002, p.12

However, in recent years there was a remarkable evolution of competition between individual ports to competition between logistics chains. This is consistent with the idea of Suykens and Van de Voorde (1998) that the port product can be considered as a chain of interrelated functions, while the port itself is a node in the global supply chain. This implies the existence of dif-

ferent levels of competition both horizontally and vertically between actors with their own objectives and instruments (Meersman et al , 2010, p. 217-219). As a result the competitiveness of a port is no longer solely dependent on its infrastructure and organization. It will also be subject to numerous internal and external market forces depending on its position in the maritime supply chain (figure 2).

Figure 2 Ports as nodes in the maritime supply chain



Source: Meersman, Van de Voorde and Vanelslander, 2010

As a consequence of this process, the port authorities and also the terminal operating companies will often not be in direct contact with the shipper and the producer or consumer of the goods which pass through the port. Depending upon the logistics structure of their companies, shippers can decide to outsource fully or part of their logistics operations and will be only interested in how and for what price their goods can be brought to their final destination. In this case, they are not directly involved in the choice of the shipping line, the terminal operating company, the hinterland transport provider, the port of origin and the port of destination. In general, it are the shipping lines which are the clients of the port and the terminal operating companies.

The question is which actor in the supply chain will take or participate in which decisions. Some of the decisions are autonomous but some are intertwined horizontally or vertically having consequences for the entire chain and its actors. In this process, each actor has specific objectives and instruments to realise its objectives (see table 1).

Table 1 Port actors, objectives and instruments[3]

Actors	Objectives	Most important instruments
Shipper and/or owner of the goods	Minimizing the generalized cost (including time)	Negotiating power (e.g. depending on volume)
Forwarders	Minimizing the generalized cost plus profit margin	Negotiating power (e.g. depending on volume)
Shipping company	Maximizing profits, or, alternatively: maximizing market share and/or control over the supply chain	Rates Cost control
Port authority	Private: maximizing profit (Semi)-public: maximizing social welfare and/or cost recovery	Port dues Concession policy Investments (e.g. dredging, infrastructure)
TOC – Terminal Operating Company	Maximizing profit	Handling fees Technological choice
Hinterland operator	Maximizing profit	Rates Capacity Speed

Source: Musso, Piccioni and Van de Voorde, 2013, based on Meersman, Van de Voorde and Vanelslander, 2010

Port choice is an interactive and simultaneous process, largely driven by the fundamentals of supply and demand. The demand is a function of variables such as the flow of goods, the merchant or haulage character of such flows and the generalized costs associated with the supply chain to which the relevant port belongs. The supply is a combination of different activities which as a whole define the port product and which are delivered by different actors. Each actor contributes to the generalized cost of the supply chain (Meersman et al, 2010). The port belonging to the cheapest logistics chain will have, at least in theory, the best competitive position.

It is necessary to emphasize the importance of the generalized costs for port competition in this debate. Especially potential time losses due to congestion in the port and the rest of the chain, can for some shipowners be a reason to reschedule their routes, their ports of call or the order of their ports of call. Therefore, the reduction of congestion is an important issue in port competition. Musso et al. (2013) selected three endogenous variables that can be influenced directly by port operators: price, capacity and productivity. In what follows, we focus on the capacity aspect. It is evident that this capacity can/will be partly determined by decisions in terms of pricing and productivity policy.

[3] See also Coppens et al., 2007; Heaver et al., 2001; Meersman et al., 2009; World Bank, 2007.

3. PORT CAPACITY

Port capacity is a difficult concept to grasp. First, one must distinguish between the physical capacity and the economic capacity. The physical capacity is simply the maximum possible output which could be produced using the available technology, capital, and the full and technically efficient utilization of the variable inputs. The economic capacity is the potential output that can be produced with the highest economic and commercial return given the capital stock, the technology, inputs prices, output prices when outputs are not fixed, and technically efficient and fully-utilized factors of production. There exist two different definitions of economic capacity. The first, suggested by Cassels (1937) and Hickman (1964) corresponds to the output at which the short run average total cost curve reaches its minimum. The second, suggested by Klein (1960) corresponds to the output at which the long run and short run average total cost curves are tangent and allows for situations where there is no perfect competition. Under the assumption of constant returns to scale, the two definitions are equivalent. As such capacity is clearly a short run and an output-based measure. It is a potential output which may be equated to a maximal output or an economically-derived output given the stock of capital, the state of technology, the market situation and the input and output prices. Although a change in any of those components will have an impact on the economic capacity, the available capital stock plays an important role.

Figure 3 Economic and maximum capacity in perfectly competitive markets

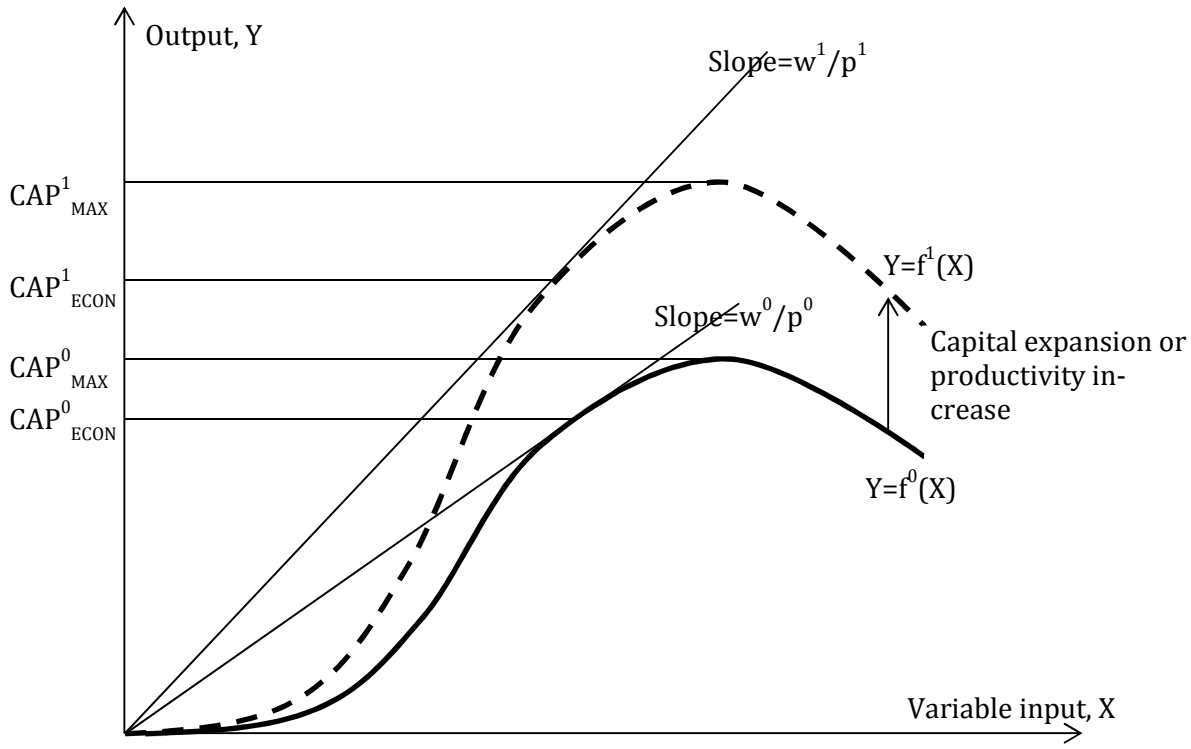
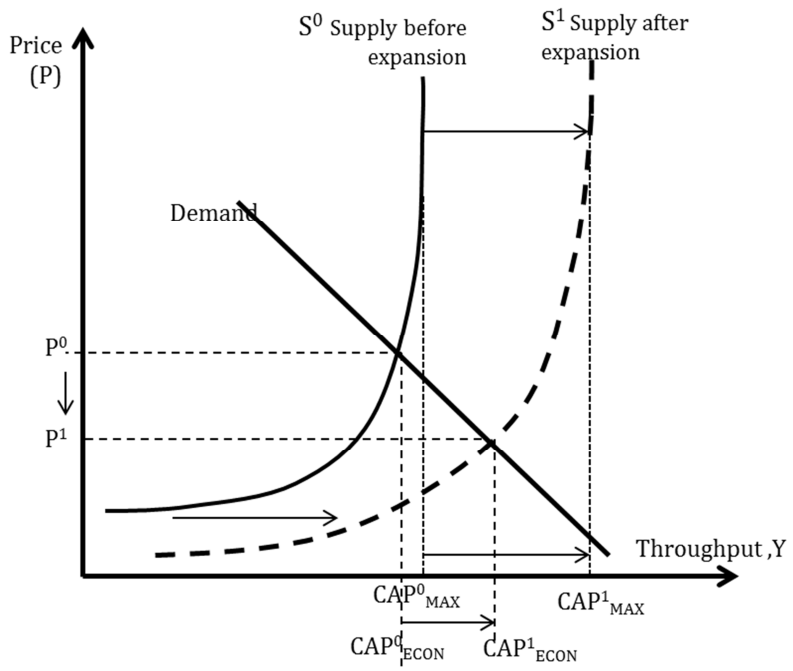


Figure 3 illustrates the economic and maximum capacity. Initially the capital stock and the technology define a production function f^0 relating output Y to the variable input X. The maximum level of output for this situation is CAP^0_{MAX}. The output price p and the input price w are determined in competitive markets for given demand functions. Under perfect competition, profit will be maximized if the marginal product and average product are both equal to w/p. Therefore, the economic or optimal capacity is given by CAP^0_{ECON} at the ratio w^0/p^0. It is clear that in the absence of perfect competition the actual output can be less than the capacity output if for instance the port or terminal has a monopoly. In that case, given the same capital stock, the maximum capacity will remain the same but the economic capacity will be smaller.

An upward shift of the production function will result in an increase of both the maximum and economic capacity to the levels CAP^1_{MAX} and CAP^1_{ECON}. This can be realized by an increase of the capital stock but also by an increase of the productivity of the existing capital stock. For example, the number of terminals and/or berths can be increased, the throughput capacity per berth can be increased by expanding the backup area and improving the storage facilities, and the handling capacity can be increased by introducing modern gantry cranes, straddle carriers and other modern technology.

When there is perfect competition, the increase of the supply will lead to a decrease of the prices of port activities from P^0 to P^1, resulting in a new equilibrium with a higher economic capacity CAP^1_{ECON} as illustrated in figure 4.

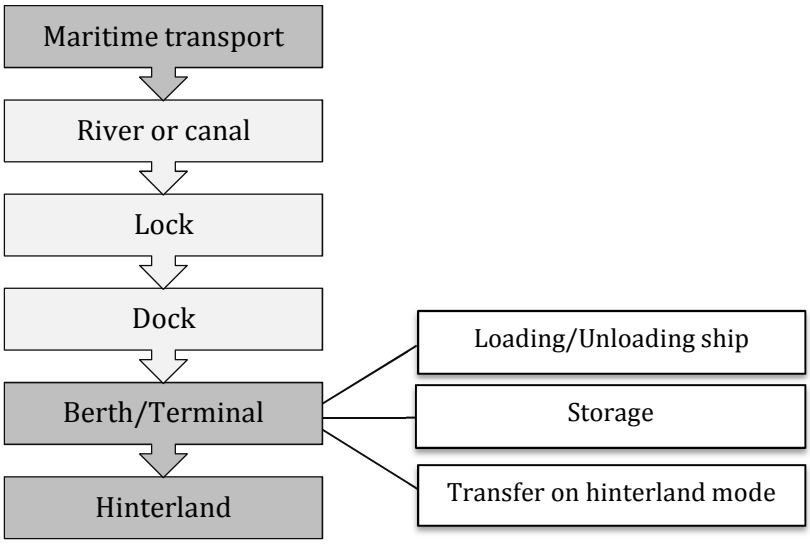
Figure 4 Impact of a capacity expansion on prices



Although it is clear from this basic theoretical analysis that the capacity of a port is related to the actual capital stock, the technology, the prices and the market situation, in reality the exact determination of port capacity is far more complex. One of the reasons is that the capital stock of a port, and hence also port capacity consists of a number of very diversified elements: the maritime access infrastructure such as channels, breakwaters, locks, lights and buoys; the port infrastructure such as berths, docks, basins, storage areas, internal connections; the port superstructure such as cranes, pipes, terminals, sheds; and the land access infrastructure such as roads, railways, inland navigation channels. In general, a large part of this infrastructure is financed with public money which is recuperated fully or partly by terminal concessions and port charges. But there is also a part, mainly the superstructure, which is financed privately.

Figure 5 gives an overview of a theoretical port entrance, where a ship from a certain point at sea, for instance a buoy, starts entering a port. For an inland port, this will mean that the ship will have to sail upon a river or canal to reach the port. The terminal or berth is either behind a lock or in a tidal dock. This means that a port call can be divided into a number of sequential processes depending upon the type and location of the port: entering the port via river of canal; passing one or more locks; sailing into a dock; mooring the ship at the berth; unloading the cargo to the terminal; storing the cargo at the terminal; loading the cargo on the hinterland transportation modes[4]. At any of these processes, ships can be confronted with events resulting in waiting times: waiting for higher tide, a pilot or a tugboat in the vicinity of the buoy; waiting for a slot in a lock, also taking into account slower sailing on river or canal in function of that slot; waiting for a berth, cranes and personnel for the loading/unloading of the ship; waiting for hinterland connections. Those delays will result in extra costs for the ship owners.

Figure 5 General structure of the process to enter a port



Source: Meersman et al., 2010, p.212

[4] A port call may consist of two movements, one inbound and one outbound.

From the above analysis, it is clear that the capacity of a port will depend upon a number of factors, but it is the capacity of handling facilities at terminals and berths which is crucial. They determine how much ships and freight can be handled at what speed and at what prices. When ship owners talk about free capacity it is primarily about this capacity component. Obviously terminal capacity should be matched to the remaining physical port capacity at the level of access channels, the locks, and the hinterland connections. Services such as towing and piloting will have to adapt. If not, this will damage the image and competitiveness of a port and affect negatively the profitability of the physical capacity.

4. PORT INFRASTRUCTURE INVESTMENT, CAPACITY AND CONFLICTS OF INTEREST

Free capacity is a crucial variable for port authorities, witness the ever emerging discussions about building new terminals and/or increasing the number of available berths. The expansion of capacity and the optimization of capacity have as major objective to meet the demand of the shipping companies being the main customers of the port. As they want to limit as much as possible time losses, their port choice is often based on the availability of free capacity.

That means that decisions on the future physical capacity should help achieve long term goals of the port depending upon the expected demand for port services and expected operational costs. In the short term, once the physical capital stock is fixed, it may be optimized through pricing and improvement of productivity. At that moment, conflicts (may) arise between major port actors. Shipping companies are looking for ports and terminals with free capacity to avoid costs due to any loss of time. They favour low prices and no waiting time. Terminal operating companies have to decide on their capacity and the price they will charge taking into account their concession fees, their concession conditions and their profits. Port authorities aim at the competitive strength of the port which has to be reflected in their concession policies and port dues which should guarantee a sufficient return on investment from a business perspective, as well as from a socio-economic welfare perspective if public money is involved.

In the short run, the terminal operator has a concession to operate a terminal with a maximum physical capacity and a certain economic capacity depending upon the configuration, the operational costs and the demand for port activities. When the demand is increasing faster than expected, the terminal operating company will not always be able to expand immediately its infrastructure or change the conditions of its contracts with the shipping lines. As a result there will be congestion which manifests itself in long queues at the locks and the berths at a terminal. The terminal operator will only be able to handle the larger volumes at higher costs, resulting in lower profits if he is facing contractually binding prices. Even if the ship owners will have the possibility to have their ships loaded and unloaded at the contractual prices, the queuing and waiting time will result for them in a higher cost. The risk is therefore not inconceivable that the owners either change operator but still remain in the same port, or stay with the same terminal operator but in a different port, or opt for another operator and port. They can also change the sequence of the ports of call to avoid the waiting time[5]. The terminal operator and/or the port

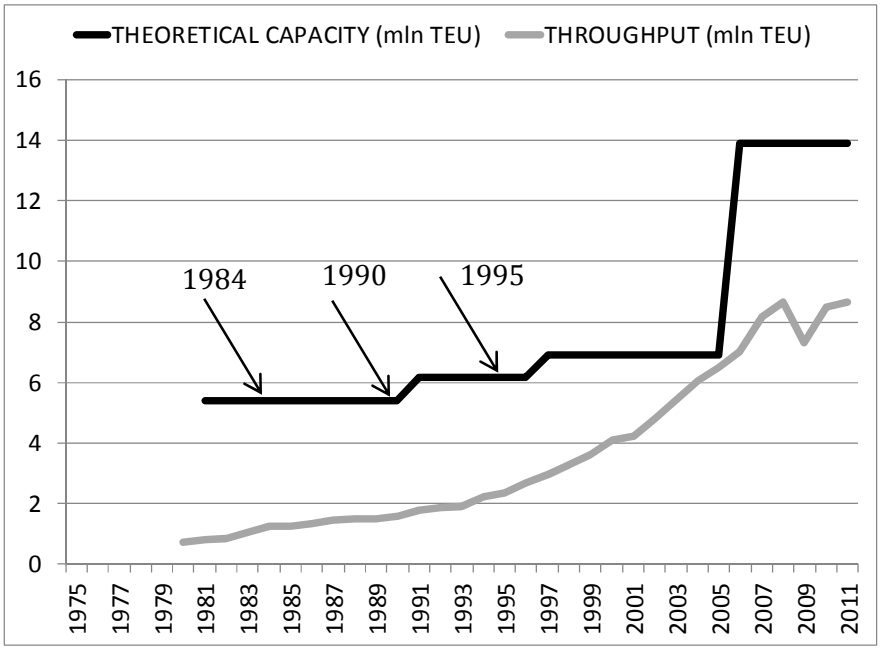
[5] This can be an important issue especially in the container business since ports prefer to be the first and/or the last port of call in a range.

may thus lose customers which may solve the problem of insufficient capacity but at the price of idle capacity, higher average costs and lower profits.

If confronted with systematic and increasing congestion, shipping companies require actions from terminal operators and port authorities to eliminate time losses and inefficiencies. They are thinking primarily in terms of additional infrastructure investment and therefore additional capacity, mainly because in a large number of ports this type of investments is still fully or partially funded by the government.

Due to the nature of port infrastructure investments, there will always be some periods with an excess of physical capacity. This is related to the uncertainty of future demand evolutions, the large scale and the indivisibility of the infrastructure, and the irreversibility of some of the port investments. Historically, port authorities have conducted with the support of national and/or regional authorities a policy which ensured that there was always sufficient physical capacity. Investments were made to guarantee that the economic capacity could always be materialized and that congestion could be avoided as much as possible. However, as the annual container traffic increased at a high rate, terminals evolved over time in size. New container docks in the 80s had a physical capacity of 600,000 TEUs. At present new container facilities have much larger capacities as for instance the 6-7 million TEUs of the Deurganck Dock in the port of Antwerp and the 12 million TEUs of the Maasvlakte 2 of the port of Rotterdam. As a consequence, there can be substantial differences between the actual throughput, the economic capacity and the potential capacity. This is illustrated for Antwerp by figure 6 where the potential is compared with the actual throughput (Meersman and Van de Voorde, 2014).

Figure 6 Comparison of realised TEU-throughput and potential or theoretical capacity of container terminals in the port of Antwerp



Source: update based on Meersman et al., 2007

The black line shows the amount of TEU that can be theoretically handled with the available infrastructure of the port of Antwerp. It is the physical upper limit of what can be materialized if this infrastructure would be fully operational. The grey line is a representation of the effective realized throughput. The three arrows indicate the moment at which the decision was taken to expand the port infrastructure. It is striking that those decisions were made well in advance. The rapid succession of new decisions stemmed from the rapidly decreasing margin between the effective and theoretical throughput. In 1989, just before the opening of the Europa Terminal, the existing terminals as a whole had a utilization rate of 72%. In 1995, the year the North Sea Terminal came in use, the capacity utilization stood at 86%. It is only when the Delwaide Dock became operational in 2006, that there is significant spare capacity.

There is certain rationality in the decision to invest in apparent overcapacity. A new terminal or a new dock are usually built in a single movement and as such add a lot of physical capacity to the existing one. The advantage of investing in the total infrastructure needed to manage future demand over a more staged and gradual investment policy is inspired by the economies of scale that might exist in the infrastructure construction process. As port throughput is closely related to economic activity and international trade, future growth in combination with the lumpy character of port infrastructure investment can rationalize partly an over-supply. One has then indeed to take the additional costs at lower traffic volumes, but can avoid congestion at higher traffic volumes.

It is obvious that for investments in port infrastructure with a life span of more than thirty years, it is difficult to determine the optimal size of the infrastructure. Xiao, Fu and Zhang (2013) have analysed the impact of demand uncertainty on investments in airports under different financial and market conditions. Although there are considerable differences between ports and airports, it is interesting to note that they conclude that substantial demand uncertainty will lead to more capacity investment, although there are differences between profit-maximizing and welfare-maximizing airports, and between monopoly and competing airports.

In the past, there have been additional incentives for over-investment in port infrastructure due to the nature of the decision process. The port authority took the initiative to start a procedure for additional port infrastructure investment, a proposal was submitted and discussed at several levels, and when finally approved it was often financed for a large part by the government. In such a construction, the port authority had an incentive to create overcapacity not only to increase their own attractiveness, but also to reduce the centrally available investment funds for other ports.

It is clear that ports try to supply, often under pressure of the shipping companies, at least a level of capacity which is sufficient to avoid congestion, queuing and time losses. However, there are alternatives. The existence of congestion is an indicator of scarcity and could be solved by using congestion pricing mechanisms. The strategy is clear and has already been formulated by Bennathan and Walters (1979, p 63): “Clearly, the rule is to find the port tariff (including congestion levies) that causes the marginal benefit of the port to be just equal to the additional money required to compensate domestic traders and consumers for the increase in port charges (the compensating variation)”. Although simple in its formulation, this rule is not that simple to apply due to a number of complicating factors such as the relations between all the port actors, the

financial structure of the port, the interactions with the entire logistics chain, the different market structures, the relation between pricing and optimal capacity, etc.

5. A SCENARIO-BASED FUTURE

The issue of a potential conflict of interest between port authorities and ship owners was sharply delineated by Jansson and Schneerson (1982, p. 30) : "Due to the non-storability of port services the inevitable fluctuations in ship arrivals will either make considerable port standby capacity necessary or result in long queuing times for the ships. The trade-off between the cost of port capacity and the queuing costs of ships is at the heart of the choice of port design".

That brings us to the third actor in question, the government as a potential financer of port infrastructure. Traditionally ports are classified on the basis of the owner of the capital as a service port which is fully publicly owned and operated, a tool port where infrastructure and superstructure are publicly owned but the actual cargo handling is executed by private cargo handling companies, a landlord port where the infrastructure is publicly owned but leased to private companies who are responsible for the organisation and management of the cargo handling operation, and a private port with no direct government interference (Meersman, Van de Voorde, Vanelslander, 2011) . Where in the past port investments were financed by the government, this is no longer evident because there are arguments against it. The growing cost-recovery requirement for the port authorities is an incentive to keep costs and expansion plans under control. In the absence of such restrictions port authorities will be tempted to build new infrastructure and create overcapacity instead of improving the productivity of the existing infrastructure or using the price mechanism to allocate scarce resources.

The major question is how the debate on new port infrastructure will evolve in the future. Assume that the decisions on the expansion and use of port infrastructure will be taken with or without consultation by the two main actors, i.e. the port authority and the shipping companies. Port authorities have some power within their perimeter, but little or no influence outside it. Shipping companies are not bound to a single port but they have several alternatives within the same port range. For other actors, even for the terminal operators, the infrastructure decisions are exogenous. The issue is how for such a market environment, the strategic behaviour of the main actors can be described and what will be the consequences for the competitive position of the port.

The port choice of a shipping company is based on a multitude of factors: the type of transport (bulk, containers,…), the origin and destination of the goods, the price to be paid in the port for all the port activities, the cost of the maritime leg, the price paid by the shippers, etc. They will determine the demand for port activities and are, from the point of view of the shipping companies, the basis for the negotiations with the terminal operators and the port authorities.

In most ports the supply of infrastructure and of capacity can become complicated. In the landlord-type ports the port authority provides the port infrastructure but part of it will be franchised to third parties. Typical examples are the container terminal concessions. At that moment two providers of infrastructure and capacity are involved. The port authority receives the port dues and the concession fee that the terminal operator pays. The height of the concession fee,

the capacity utilization, the operational costs and the profit or return on capital that should be materialized, form the lower limit of the terminal operator's own price of the transhipment services to the shipping company.

The question is how in this context the decision on port calls is made. The shipping companies seem to be in the strongest position because they have the choice out of several possible ports facing port authorities that are eager to attract them. Shipping companies have built over the years a strong negotiation strategy and knowledge. The only variable that can limit to a certain extent the strong bargaining position of carriers is the way in which freight volumes are brought together. In the case of merchant haulage, as contrast to carrier haulage, shipping companies will be forced to call on that port where those flows are created and/or consolidated.[6]

This shows that the future decisions on new port infrastructure and the use of existing port infrastructure cannot unambiguously be fixed. Therefore, it is more appropriate to work with scenarios. Assume a situation with a strong demand for port services together with a limited free capacity resulting in congestion. Port authorities and terminal operators can generate additional profits by introducing or increasing congestion charges. The higher prices should result in better use of the scarce resources and lead to a reduction of the congestion. However in practice, even when the capacity utilization is high, port authorities and terminal operators keep their prices usually low, let alone charge congestion charges. One possible reason lies in the fact that sometimes an objective of maximizing tonnage or employment is more important than profit maximization. Moreover, higher port and terminal prices carry the risk of traffic diversion to other ports resulting in a loss of market share.

In the absence of congestion charges, shipping companies will have to face waiting lines and loss of time in congested ports. Shipping companies are not happy about it, but will accept them as long as they can pass on the associated costs to their own customers.

Hitherto the implications of congestion charges by a port authority or terminal operators have been insufficiently explored. Is a tax payer in a country with a congestion charge better off than under a scenario of low port prices with congestion and queuing? Congestion charges generate extra income. The additional income can be used to invest in additional port infrastructure. Moreover, the consistent use of congestion charges targeting the congested points or time slots can also lead to a better use of infrastructure and as such also increase the port throughput.

The combination of optimal infrastructure investment, economic capacity and an efficient use of existing capacity fits perfectly within the transport economic principles. Jansson and Schneerson (1982, p. 4) argued that, in order to maximize social welfare, the basic economic principles of pricing and investments can be summarized in two golden rules. In the short run, the utilization of the fixed capacity of a facility should be such that the social marginal cost equals the marginal benefit of the users of the facility. In the long run or the planning stage, infrastructure investment should be planned so that the long-run social marginal cost is equal to the marginal benefit.

[6] The port on the Bill of Lading is decisive.

6. CONCLUSION

The debate on investment in new port infrastructure has evolved rapidly in recent years. The ease with which national or regional authorities could fund the total investment or a major portion thereof, has disappeared due to budgetary constraints. The decision on new port infrastructure can no longer be separated from its funding. Whereas in the past port infrastructure expansion seemed limitless, nowadays there is more and more a focus on the balance between the costs and benefits of offering excess free capacity and the costs and benefits of some congestion. This has consequences for the strategic investment behaviour of the major port actors

Port authorities are increasingly responsible for investment and will be less inclined to create excess capacity because they have to finance it themselves. Shipping companies will have their port calls and loops more carefully planned. With sufficient merchant haulage, they will accept some time loss, especially if they can pass on the additional costs to the customer - owners of the goods. Ports with excess capacity and a low probability of delays and loss of time will be called at if there is an adequate amount of freight. The role of the terminal operating companies is to transform the available infrastructure in economic capacity taking into account their market position, the operational costs, the concession conditions, the productivity and the terminal charges. The owner of the goods is targeting a low generalized cost of the overall transport and logistics chain and is relatively indifferent with respect to the port selection. National and/or regional authorities will be less involved in port investments and if so, they will require a welfare return which is positive and at least as high as other alternative investments even outside the port sector.

To conclude with Bennathan en Walters (1979, p. 4) it is clear that "without the right economics, ports will be plagued by problems of long queues or empty berths".

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