PORT INVESTMENTS IN AN UNCERTAIN ENVIRONMENT

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ABSTRACT

This contribution focuses on some specific aspects of port investments related to the large amounts of capital needed for some types of port investments and the long payback time of the projects. The first part treats the problem of private and/or public involvement and the impact on the competitiveness of a port. Next, the consequences of uncertainty in combination with large sunk costs for the rules which guide the decision to invest are examined. The last part considers the problem of forecasting port traffic and its volatility because they are crucial for an accurate evaluation of the investment projects.

1. INTRODUCTION

The success of a port in attracting investors will depend to a large extent not only on its current, but also its future competitive position. Good and well-planned investments can help to strengthen the competitive position of a port. Investment in a port may create additional capacity, increase productivity, generate added value and income, boost international trade, and

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create economic growth within the port and also in other sectors of the economy.

Due to the complex nature of a port, analysing investments in ports has to be done at several levels by looking at: investments in port infrastructure, investments in the superstructure, investments in hinterland connections, investments by logistics companies and investments by companies from the industrial and service sectors. Analysing the factors that affect port investment is a difficult task because investment operates at different levels and involves a large number of decision takers. The analysis is further complicated by the interconnections between the different investment levels. For this reason, this chapter is restricted to some specific aspects of port investment.

The first part treats the problem of private and/or public involvement and the impact on the competitiveness of a port. It is clear that for some types of port investment private capital can easily be attracted. But given the large amounts of capital needed for some other types of port investments and the long payback time of the investment projects, public money is often the only option. However, one needs a good and reliable social cost–benefit analysis to find out whether public investment is worthwhile from a social point of view. One of the dangers of public involvement in economic activity is that it can lead to distortions of competition and efficiency losses, which should be avoided.

The second part examines the consequences of uncertainty for the rules, which guide the decision to invest. Investment in port infrastructure often involves large sunk costs. In combination with uncertainty this requires adjustment of the traditional net present value rule, whether applied to private or public investments. In the presence of uncertainty and irreversibility the decision will not solely be whether to invest, but when to invest.

The last part considers the problem of forecasting port traffic and its volatility. Given the long time horizon of port investments, it is crucial to have good tools to forecast the costs, and especially the future returns of the investment project. Too often forecasts of the returns are based upon some form of trend extrapolation or some simplified scenario. However, one should at least pay attention to two important elements that have an impact on the returns of the port investment, the future economic situation, and the competitive position of the port. These factors will not only affect the investment in port infrastructure, but will also have an impact on the investment decisions about the superstructure and the location of service providers and industrial companies.

2. FINANCING PORT INVESTMENTS: PUBLIC AND/OR PRIVATE?

A port is a complex entity bringing together a variety of activities and many kinds of infrastructure (Fig. 1). Its accessibility by sea is straightforward, but it also needs good, reliable links with the land-side. As a consequence, port investments cover not just the internal infrastructure (berths, docks, storage areas, etc.) and superstructure (cranes, terminals, etc.), but also the infrastructure for maritime access (breakwaters, locks, buoys, etc.) and for hinterland connections (roads, railways, etc.).

The port industry is clearly an industry in transition. In the past, ports were considered as suppliers of services, which were of general (economic)

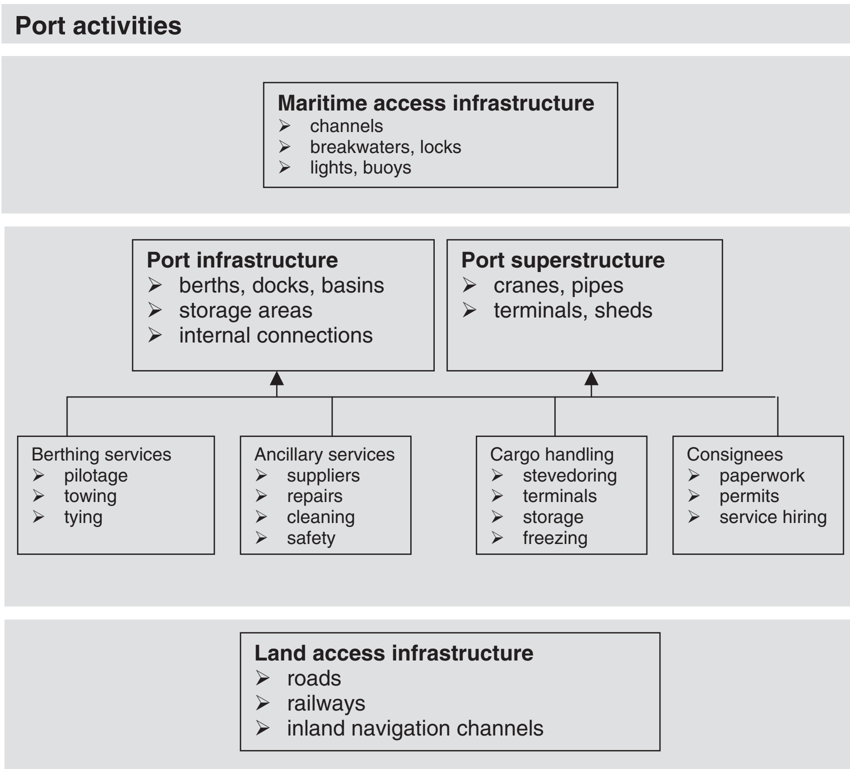

Fig. 1. Port Activities and Infrastructure. *Source:* Estache & de Rus (2000).

interest. For that reason they were in the hands of the public sector and financed by the taxpayer. There was no immediate concern for efficiency and cost minimisation. Modern developments, such as containerisation and the introduction of IT, have put pressures on ports to become competitive and efficient.

Ports are becoming commercial entities providing optimal services at profitable prices in such a way that they recover their costs from port users. As a consequence, since 1990 the private sector has become more and more involved in port activities. Fig. 2 is based on the World Bank's Private Participation in Infrastructure (PPI) Project Database that records details of all projects owned or managed by private companies in developing countries. It gives the evolution of the annual investment in seaport projects with private participation in developing countries in billions of US dollars.

As shown in Table 1, private participation in port projects is not evenly distributed. In regions where risk and uncertainty are experienced as too high, private capital can be difficult if not impossible to attract. This is illustrated in Fig. 3, which contains three indicators for country risk and creditworthiness. Developing countries in sub-Saharan Africa, South Asia, Europe and Central Asia have the highest degree of risk and are therefore not attractive for private capital investment. As a consequence, they have to rely on public money, resulting in ports which are partially financed by the public sector and partially by private capital.

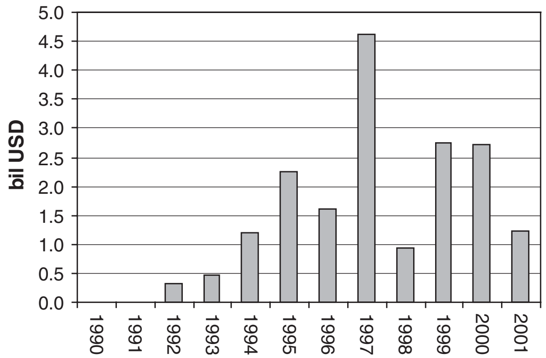

Fig. 2. Investment in Seaport Projects with Private Participation in Developing Countries. *Source*: Based on the World Bank's Private Participation in Infrastructure (PPI) Project Database.

Table 1. Port Projects with Private Participation in Developing Countries by Region (1990–1998).

Region	No. of projects	Total Investment (1998 US$ millions)
East Asia and the Pacific	38	5,410.5
Europe and Central Asia	8	23.4
Latin America and the Caribbean	48	2,497.7
Middle East and North Africa	5	376.5
South Asia	9	942.6
Sub-Saharan Africa	4	32.0
Total	112	9,282.7

Source: Sommer (1999).

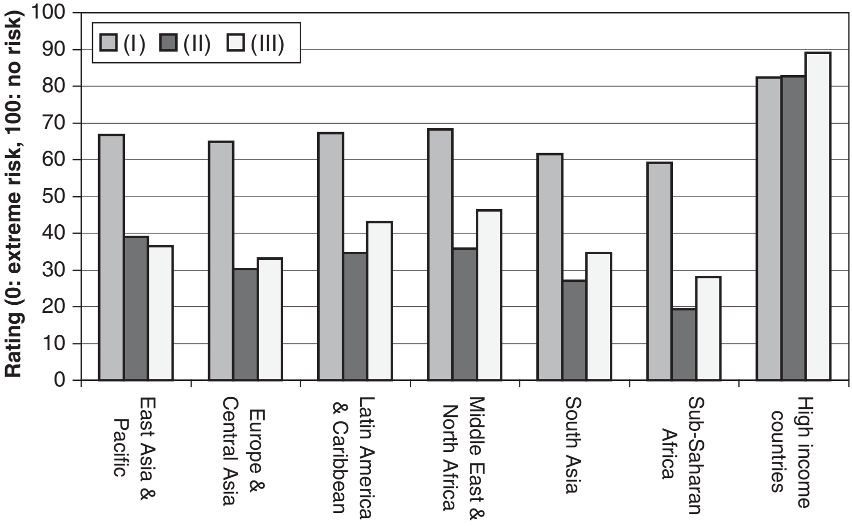

Fig. 3. Country Risk and Creditworthiness Indicators: (I) Composite ICRG risk rating; (II) Institutional Investor credit rating; (III) Euromoney country creditworthiness rating. *Source*: World Bank, World Development Indicators 2000, Washington DC (Table 5.3).

Even in developed countries with less risk, ports are not fully privatised and there is often still an important role for the public sector. According to Gwilliam (1997) the reasons for this are twofold:

- on the one hand, governments may resist full privatisation because it is believed that
  - strategic issues are at stake,
  - public ownership is necessary to control social impacts,
  - and/or a private monopoly would exploit users; and
- on the other, private companies do not want to enter the sector because
  - there is no apparent revenue flow,
  - they think that there is a high probability of damaging government interventions,
  - and/or sunk capital will not be recoverable.

As a consequence, there are different types of ports varying from fully publicly owned to fully privately financed. Table 2 gives an overview of four types of port organisation in the European Community resulting from an investigation of the European Commission (Commission of the European Communities (2001)). According to this investigation, 90% of European maritime traffic is estimated to be handled in ports where decisions on funding for infrastructure and charging of expenditure are, to varying degrees, influenced by public authorities (Types I–III).

Table 3 gives an overview of public financing per investment category in ports of the European Community. Investment is mainly in port infrastructure (32%) and may reflect construction in existing port areas by spending on such infrastructure as docks, quay walls, or internal docks. Although Juhel (1998) states that all superstructure and equipment tends to be privately owned, there was still in the EC a considerable amount of public money going into port superstructure and port services (663.6 million Euro or 41% of the total amount of public investments in EC ports).

Privatisation of port infrastructure and services can take different forms: full privatisation, joint ventures, concessions, leasing, licensing, management contracts, etc. The type chosen depends on a number of aspects such as types of traffic, traffic levels, port facilities, etc.

One of the big issues in the wave of privatisation, is the guaranteeing and safeguarding of competition. Developments on a worldwide scale indicate a tendency towards more private initiative and more transparency when concessions are given. Fair and efficient pricing, the problem of infrastructure charging, and the access to port services are issues which are at the heart of the European Commission's policy for ports and its competition policy. The major aim is to create transparency and fair competition to stimulate port investment in modern, innovative and cost-efficient infrastructure and

Table 2. Organisational Structure of European Ports.

	Public Type I	Public Type II	Type III	Private Type IV
Ownership	Public	Public	Mixed	Private
Autonomy of port management	Very restricted	Limited	High	Complete
Responsibility of port management	State operated/ 'Tool 'port'[a]/ 'Landlord port'[b]	'Landlord port'[b] (predominant) 'Tool port'[a]	'Full service port'[c]	'Full service port'[c]
External public funding	Extensive	Important	Very limited	No public aid
Cost recovery practices	Not principal objective	Partial recovery predominant	Full services, Some infrastructure investments	Full cost recovery
Access to provide services	Open tender/ direct agreement	Direct agreement predominant	Direct agreement	Normally closed
Relative importance in traffic terms[d]	Limited 8%	Very important 75%	Limited 7%	Limited 10%
EU states employing organisation types I–IV	Dk, Gr, F, P, D, I	B, Dk, Fin, F, D, Gr, NL, P, E, S, I	Dk, Ir, S, U.K.	Mostly U.K., but also in other member states

Source: Commission of the European Communities (2001).

[a]A port where the public authority is not only providing basic infrastructure but also (some) facilities to port operators.

[b]A port where the public authority is co-ordinating port development and manages only basic infrastructure.

[c]A port operating company runs the port entirely. This company is very often established in a mixed holding between public and private operators.

[d]Traffic estimates based on EU member states replies and best evidence available.

equipment. A lack of transparency in the structure of ports, their ownership, the involvement of central, regional and local governments, pricing rules, administrative practices, etc. will only increase uncertainty and hamper investments.

Table 3. Public Financing per Investment Category.

Investment Category	1997 Euro (million)	Split per Investment Category (1997) (%)	Evolution 1995–1997 (%)
1. Land purchase	69.4	4	139
2. Maritime access	77.1	5	−28
3. Port infrastructure	507.6	32	55
4. Port superstructure	358.4	22	6
5. Infrastructure links	24.1	2	−47
6. Port maintenance works	219.1	14	30
7. Port services	305.2	19	31
8. Other port activities	35.7	2	−7
Total public financing	1,596.6	100	24

Source: Commission of the European Communities (2001).

3. PORT INVESTMENTS, IRREVERSIBILITY AND UNCERTAINTY

A correct evaluation of the investment project, its costs and its returns, is always a necessity whether the project will be financed with public or with private capital. The major characteristics of investment projects in port infrastructure are that they often are of a large scale, are highly irreversible and, due to the long time horizon, the returns of the project have a high degree of uncertainty.

The presence of uncertainty in combination with the high degree of irreversibility of many of the investment projects in port infrastructure has consequences for the decision to invest. The traditional net present value (NPV) rule for evaluating investment projects is no longer valid and needs to be adjusted. Recent developments in investment theory borrow from real option theory to analyse this kind of investment decision. The result is that the timing of the investment becomes important and it can become important to design the project as a number of consecutive stages.

Discussing the importance of uncertainty of the economic environment on the decision to invest is not new. Traditionally, taking into account uncertainty in investment analysis was done by introducing expectations on a set of variables in the investment function, varying from simple adaptive expectations to more complex models with rational expectations.

During the past two decades, a new strand of theory has emerged, linking uncertainty and investments. This theory is based on the simultaneous existence of three phenomena: uncertainty, irreversibility of investment and some freedom of choice on the timing of investment. It starts from the fact that investment decisions are to a large extent irreversible, i.e. it cannot be reversed except at a high cost (the cost is largely 'sunk'). Combining irreversibility with the existence of uncertainty over the future behaviour of variables that affect the value of the investment (such as future output prices) leads to the following intuitive reasoning. Suppose there is some leeway in delaying investment until more information about the uncertain future becomes available, it may then be optimal to wait for some time before investing. It is clear that waiting to invest implies risks (e.g. entry of competitors) and foregone profits, but it may prevent one from being trapped in an irreversible investment project, which turns out to be very costly when an adverse future materialises.

The theory states that an investment project, which satisfies these three characteristics is best treated as analogous to holding a (American-type) financial call option. For some specific time period, an investor (a firm) has the right, but not the obligation to pay a certain price (the investment cost) in return for an asset (an investment project) that has some value. When the investment decision is made the option is exercised, which is an irreversible decision. Like a financial option, the option itself has some (non-negative) value a/o. because of uncertainty over the future value of the investment project. As a consequence, option-pricing theory can be used to 'price' investment decisions and decide on the optimal timing of the exercise. This theory has given rise to a large body of new literature and a new class of models usually referred to as 'real options' models.[1]

The basic model was originally developed by McDonald and Siegel (1986). For a project whose present value is V and for which a sunk cost I has to be made, the NPV rule will lead to investing actually in the project if $V \geqslant I$. Now, it is assumed that the value V varies over time and follows a geometric Brownian motion with drift

$$\mathrm{d}V = \alpha V\,\mathrm{d}t + \sigma V\,\mathrm{d}z \tag{1}$$

where α is the mean growth rate, σ^2 the variance of $\mathrm{d}V$, and $\mathrm{d}z$ the increment of a Wiener process such that

$$\mathrm{d}z = \varepsilon_t\sqrt{\mathrm{d}t} \quad \text{where } \varepsilon_t \sim \mathrm{N}(0,1); \qquad E(\varepsilon_i\varepsilon_j) = 0 \quad \forall i,j \;\; i \neq j$$

This implies that the future values of the project are log-normally distributed with a variance that grows exponentially with time (which is not always the case in reality).

One has to find the point in time T at which it is optimal to invest an amount I. This point will be reached if the expected present value of the option to invest, $F(V)$, is maximised:

$$F(V) = \max\ E[(V_T - I)\mathrm{e}^{-\rho T}] \tag{2}$$

where ρ is the discount rate. Holding the option and delaying the investment is similar as holding an asset, which yields no cash but which may appreciate over time. The optimality condition is given by the Bellman equation

$$\rho F\ \mathrm{d}t = E[\mathrm{d}F] \tag{3}$$

which shows that the total expected return of the investment opportunity is equal to its expected rate of appreciation.

Using Ito's lemma,

$$\mathrm{d}F = F'(V)\mathrm{d}V + \tfrac{1}{2}F''(V)(\mathrm{d}V)^2 \quad \text{with } F' = \mathrm{d}F/\mathrm{d}V \text{ and } F'' = \mathrm{d}^2F/\mathrm{d}V^2 \tag{4}$$

Substituting (1) for $\mathrm{d}V$ into (4) gives

$$E[\mathrm{d}F] = \alpha VF'(V)\ \mathrm{d}t + \tfrac{1}{2}\sigma^2 V^2 F''(V)\ \mathrm{d}t \tag{5}$$

Substituting this expression into (3) after dividing throughout by $\mathrm{d}t$, gives for the Bellman equation,

$$\rho F = \alpha VF'(V) + \tfrac{1}{2}\sigma^2 V^2 F''(V) \tag{6}$$

Apart from this condition, the optimal investment rule requires that the value of the option to wait must also satisfy three boundary conditions

$$F(0) = 0 \tag{7}$$

$$F(V^*) = V^* - I \tag{8}$$

$$F'(V^*) = 1 \tag{9}$$

The first condition states that the option to invest will be of no value when $V = 0$. The second condition determines the net payoff at the value V^* at which it is optimal to invest. When Eq. (11) is rewritten as $V^* = I + F(V^*)$, the value of the project is compared to the full cost of making the investment (direct cost I plus opportunity cost $F(V^*)$). The third condition is needed to guarantee that the function $F(\cdot)$ is continuous and smooth around the optimal investment timing point.

The solution to (6) subject to conditions (7)–(9) is

$$F(V) = AV^b \tag{10}$$

with $b > 1$.

Substituting (10) into (8) and (9) gives

$$V^* = \frac{b}{b-1} I \tag{11}$$

and

$$A = \frac{V^* - I}{(V^*)^b}$$

where

$$b = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} \tag{12}$$

Since $b > 1$, Eq. (11) states that the traditional NPV rule is incorrect because investment only becomes worthwhile for values which are bigger than the investment cost ($V^* > I$). Uncertainty and irreversibility drive a wedge between the critical value V^* and the investment cost. The exact magnitude of this wedge will depend upon the growth rate α of the value of the project, the variance σ^2 of the value of the project, and the expected rate of capital appreciation ρ. An important consequence is that the value of b will increase with higher values of σ^2, and hence with higher volatility of the value of the project. This is illustrated in Table 4. For an expected growth rate of 2%, an expected rate of capital appreciation of 4% and a variance of 0.0001, the present value of the investment project must be twice as high as the investment cost to make the investment worthwhile. The higher the rate of capital appreciation, the smaller will be the wedge. Due to the fact that the opportunity cost of waiting goes up when ρ increases, it becomes worthwhile to kill the option sooner. A higher expected growth rate of the value of the project increases the wedge, because it is worthwhile to postpone the killing of the option.

The most important consequence resulting from this model solution is that uncertainty (and irreversibility) introduces a difference between the minimum-acceptable value of the project in order to invest (V^*) and the cost of investment (I). More importantly, the greater the level of uncertainty, the more the value of the investment opportunity must exceed its cost before

Table 4. Critical Value V^* as a Function of α, ρ and σ.

α	ρ	σ	σ^2	I	b	Wedge	V^*
0.02	0.04	0.01	0.0001	100.00	2.00	2.00	200.50
0.02	0.04	0.02	0.0004	100.00	1.98	2.02	201.98
0.02	0.04	0.03	0.0009	100.00	1.96	2.04	204.41
0.02	0.04	0.04	0.0016	100.00	1.93	2.08	207.71
0.02	0.04	0.05	0.0025	100.00	1.89	2.12	211.84
0.02	0.04	0.10	0.0100	100.00	1.70	2.43	242.54
0.02	0.04	0.20	0.0400	100.00	1.41	3.41	341.42
0.02	0.04	0.30	0.0900	100.00	1.26	4.84	483.65
0.02	0.04	0.40	0.1600	100.00	1.18	6.70	670.16
0.02	0.04	0.50	0.2500	100.00	1.12	9.03	902.85
0.02	0.06	0.01	0.0001	100.00	2.99	1.50	150.37
0.02	0.06	0.02	0.0004	100.00	2.94	1.51	151.47
0.02	0.06	0.03	0.0009	100.00	2.88	1.53	153.24
0.02	0.06	0.04	0.0016	100.00	2.80	1.56	155.60
0.02	0.06	0.05	0.0025	100.00	2.71	1.58	158.47
0.02	0.06	0.10	0.0100	100.00	2.27	1.78	178.44
0.02	0.06	0.20	0.0400	100.00	1.73	2.37	236.60
0.02	0.06	0.30	0.0900	100.00	1.47	3.15	314.86
0.02	0.06	0.40	0.1600	100.00	1.32	4.14	413.75
0.02	0.06	0.50	0.2500	100.00	1.23	5.34	534.43
0.01	0.06	0.01	0.0001	100.00	5.86	1.21	120.59
0.01	0.06	0.02	0.0004	100.00	5.50	1.22	122.20
0.01	0.06	0.03	0.0009	100.00	5.07	1.25	124.56
0.01	0.06	0.04	0.0016	100.00	4.65	1.27	127.43
0.01	0.06	0.05	0.0025	100.00	4.26	1.31	130.66
0.01	0.06	0.10	0.0100	100.00	3.00	1.50	150.00
0.01	0.06	0.20	0.0400	100.00	2.00	2.00	200.00
0.01	0.06	0.30	0.0900	100.00	1.61	2.65	264.66
0.01	0.06	0.40	0.1600	100.00	1.41	3.45	345.24
0.01	0.06	0.50	0.2500	100.00	1.29	4.43	442.91

investment takes place. As such, the individual investment decision is, in theory, very dependent on the level of uncertainty.

Fig. 4 illustrates that for a project with a return value V between points 1 and 2, the NPV rule would lead to the decision to invest, whereas the Real Options rule suggests not to invest. Similar analyses can be used to determine the most profitable timing of investments in infrastructure that can be constructed in different, consecutive stages. The general conclusion is that the traditional NPV rule will not necessarily lead to the best decision for

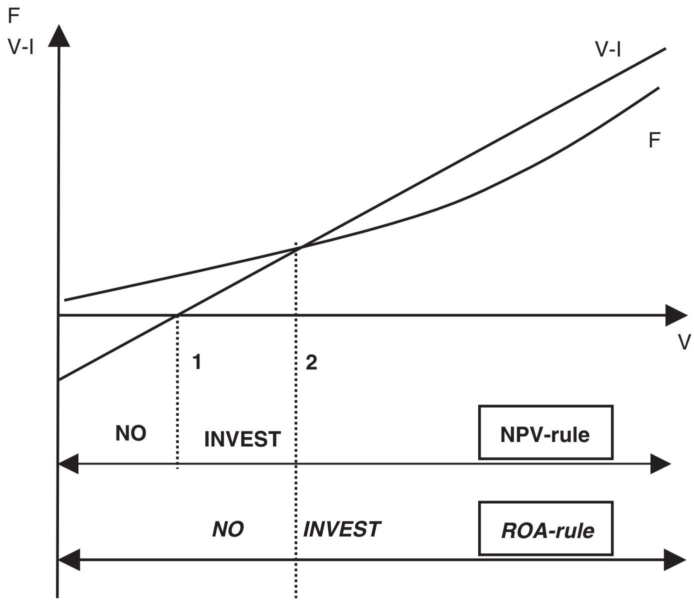

Fig. 4. Real Option Analysis (ROA) versus the NPV Rule. *Source*: Cassimon, Engelen, Meersman, and Van Wouwe (2003), p. 197.

infrastructure projects with high, irrecoverable sunk costs and which face a lot of uncertainty.

4. FORECASTING THE GROWTH AND VARIANCE OF THE EXPECTED VALUE OF PORT INVESTMENTS

From the previous discussion, it is clear that knowledge of the expected growth rate and the variance of the present value of an investment project will be of great help in the decision whether to invest or not. On the one hand, the success of port investments is closely related to the evolution of maritime traffic flows, and on the other, the competitive position of a port.

Maritime traffic is a very general concept that hides the complexity of what really goes on in the sector. It is clear that short sea shipping is quite different from deep-sea traffic and that container traffic and liner shipping are totally different industries to bulk traffic. Forecasting traffic flows to and

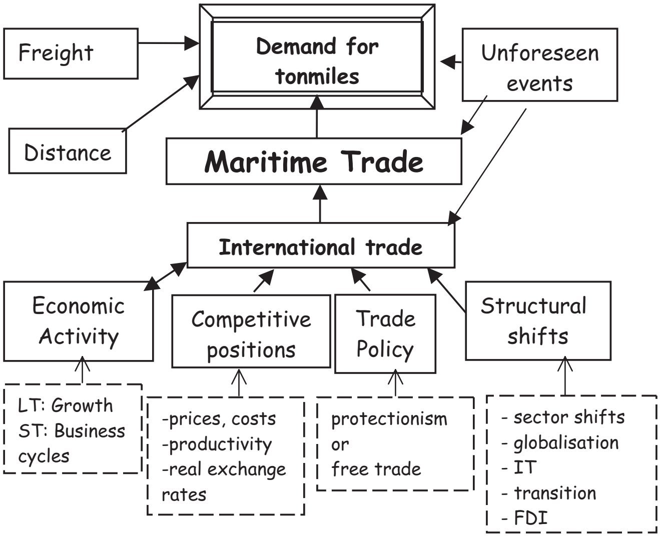

Fig. 5. Factors Influencing the Demand for Maritime Transport.

from a specific port is different from forecasting the overall trend in maritime traffic. The volume of maritime traffic (in general) is the result of a very complex process, which is summarised by the scheme in Fig. 5.

From this scheme it is clear that uncertainties can penetrate maritime trade, the demand for sea transport and, hence, the returns on port investments in a lot of different ways. A good example is the East-Asian crisis, which disturbed economic growth and trade patterns. It also had consequences on the financial markets, which affected investment decisions.

The problem is that long-term evolutions in maritime trade are not under the control of port authorities and port operators. They do not decide on trade policy, on business cycle evolutions, on exchange rates, on economic policies, etc. These are exogenous factors for which one can try to find, buy or produce good and reliable forecasts based on alternative scenarios.

The competitive position of a port will determine which part of maritime traffic it can attract at present as well as in the future. Huybrechts et al. (2002) give a good account of the complexity of determining the competitiveness of seaports. It is clear that it is impossible to give a static definition of a port and of port competitiveness. The role and significance of seaports have changed considerably and the modern seaport has to position itself as a critical node in the logistics chain. Whether investments in port infrastructure will be profitable depends to a large extent on the ability of the port to be one of the key players in the process to minimise the generalised costs of the entire chain.

Modelling and forecasting the competitive position of a port is a complex and not always transparent process. Until now, there has not existed a scientifically sound instrument to simulate the consequences of all kinds of policy measures and strategies on the continuous fight for commodity flows. To some extent this has to do with the lack of reliable information and data, but it is also due to the complexity of the behaviour on which shifts among ports are based. One needs strategic market share models and simulation tools, which can capture the game-theoretic behaviour of all the market

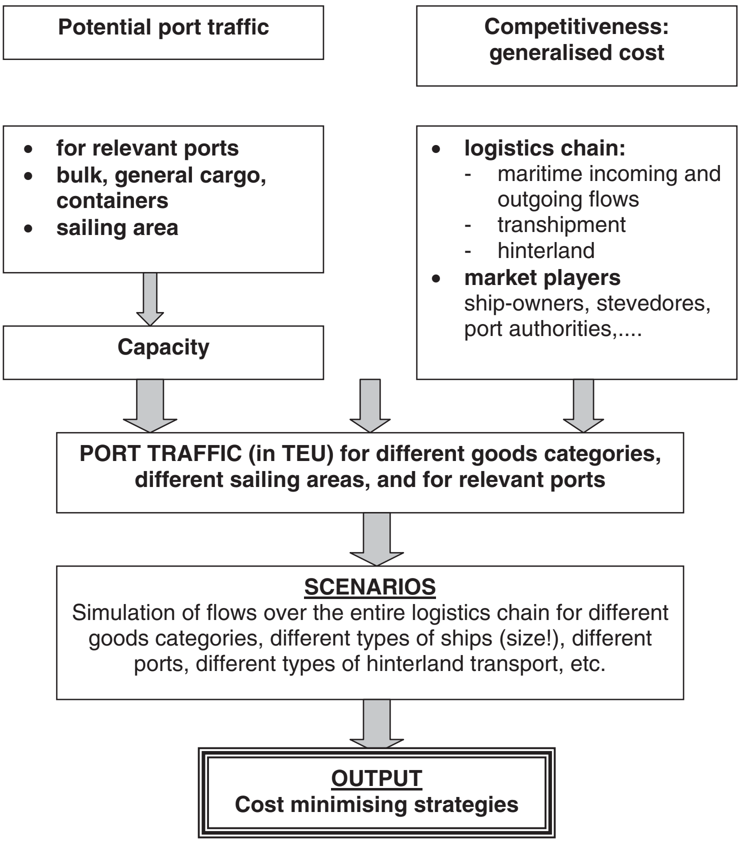

Fig. 6. General Structure of a Forecasting Model for Port Traffic Flows.

players involved in the port choice. It is self-evident that in the long run all parties involved want to maximise profits, but the complexity is mainly due to the different strategies the market players will adopt in the short term to realise their long-term objectives.

Fig. 6 gives an overview of the structure of a model for forecasting port traffic flows, which tries, as much as possible, to incorporate all the relevant decision variables and market players (Winkelmans, Van de Voorde, Huybrechts, Meersman, & Verbeke (1998)).

This model contains two major blocks, the first of which defines potential traffic flows for relevant ports (actual or potential competitors), for different goods categories and for different sailing areas. In this first stage, the potential flows can already be compared with the existing port capacity. The second block analyses in detail all the factors influencing the competitiveness of the port with special attention given to the generalised costs. It is in this part that modelling the strategic behaviour of market players is crucial. Bringing together both blocks results in forecasts of the market shares and realised traffic. Finally, scenarios can be designed to simulate freight flows over the entire logistics chain starting from the port of origin to the final destination of the commodities.

From the previous discussion, it is clear that it is still a very hard job to forecast port traffic. If one cannot model in a reliable way the factors

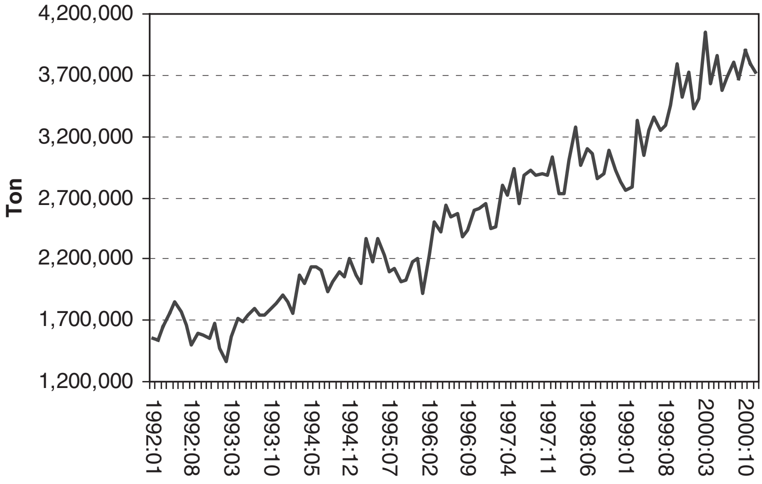

Fig. 7. Container Traffic in the Port of Antwerp (1992–2000). *Source*: Antwerp Port Authorities.

determining the competitive position of a port, it will be difficult to take full account of uncertainty in the decision to invest in port infrastructure.

One way to bypass the difficulties faced when trying to model in detail the competitive position of a port is to use forecasting methods based on time-series analysis. This is illustrated for the case of the port of Antwerp. Fig. 7 gives the evolution of container traffic in the port of Antwerp from 1992 to 2000 on a monthly basis. There is clearly some volatility present in the traffic over this time period.

The evolution of the container traffic can be modelled in logarithms by means of an ARIMA(12,1,24)–GARCH(1,1) specification:

$$\text{dln}\, y_t = \sum_{i=1}^{12} \alpha_i \text{dln}\, y_{t-i} + \sum_{j=1}^{24} \beta_j u_{t-j} + u_t$$

and

$$\sigma_t^2 = c + \gamma \sigma_{t-1}^2 + \rho u_{t-1}^2$$

where

dln y is the rate of change in container traffic in Antwerp (monthly changes), u a stochastic error term, σ^2 the variance of the error term and of dln y and α_i, β_j, c, γ, ρ are the coefficients to be estimated.

Table 5. ARIMA–GARCH Estimation of Container Traffic in the Port of Antwerp.

	Coefficient	S.E.	z-Statistic	Probability
AR(1)	−0.350411	0.096609	−3.627099	0.0003
AR(12)	0.336994	0.090640	3.717929	0.0002
MA(1)	−0.287928	0.056208	−5.122509	0.0000
MA(12)	0.055680	0.045186	1.232249	0.2179
MA(24)	0.557891	0.058584	9.522980	0.0000
	Variance Equation			
C	0.001251	0.000530	2.361890	0.0182
ARCH(1)	−0.107506	0.019511	−5.509923	0.0000
GARCH(1)	0.648493	0.193055	3.359112	0.0008
R^2	0.464332	Mean-dependent variable		0.009741
Adjusted R^2	0.421232	S.D.-dependent variable		0.069094
S.E. of regression	0.052564	Akaike info criterion		−2.959009
Sum-squared residue	0.240382	Schwarz criterion		−2.743945
Log likelihood	148.5529	Durbin–Watson statistics		1.949687

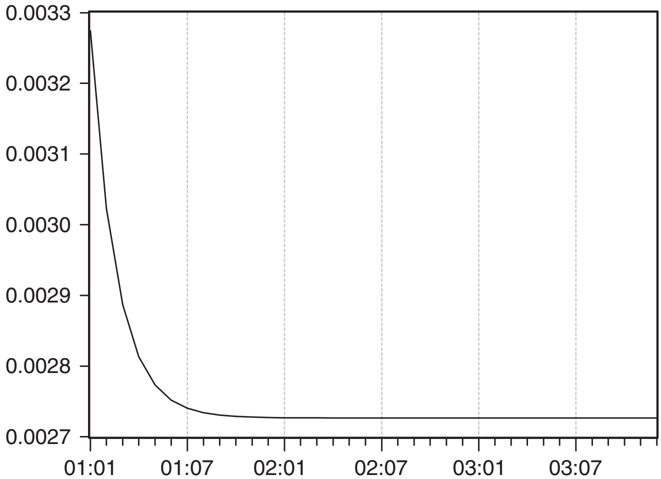

Fig. 8. Forecasts of the Variance of the Rate of Change of Container Traffic in Antwerp Based on an ARIMA(12,1,24)–GARCH(1,1) model.

Table 5 gives the results of the ARIMA–GARCH estimation.

The advantage of this method is that it allows one to forecast the growth rate of the traffic and also the variance (Fig. 8). This information can be very helpful in the evaluation of investment projects in ports.

This methodology has the advantage that it can be used with a limited number of variables, in contrast to a model that tries to capture all the factors influencing the competitive position of a port.

5. CONCLUSION

Uncertainty is a crucial aspect of the future. It is impossible to make waterborne transport more attractive without the necessary investments in infrastructure, in ports, in intermodal nodes, etc. It is quite obvious that those investment projects need to generate enough benefits above costs (private or social) to attract the necessary capital, whether private or public, and should be evaluated in the correct way.

For the traditional NPV rule one needs forecasts of all the future cash flows. Traditionally, the NPV is calculated with those forecasts and a sensitivity analysis gives an idea of the NPV for alternative scenarios. The uncertainty is not explicitly introduced in the decision.

Investments in port infrastructure are by their nature often irreversible and the amounts invested can be to a large extent sunk costs. The consequence is that, for this type of project, the presence of uncertainty will have a strong impact on the validity of the traditional NPV decision rule. Real option theory, applied to irreversible investments, shows that in the presence of uncertainty it can be better to wait to invest even when the project has a positive NPV. The higher the degree of uncertainty, the greater will be the probability of postponement.

One of the problems is the difficulty in obtaining reliable forecasts of future returns of the investment project and of their volatility. Good forecasts of port traffic can be of great help, but they are also hard to get. On the one hand, port and maritime traffic are derived from international trade. General economic conditions, trade policy, international competitive positions and structural changes will all have an impact on trade and make it difficult to forecast accurately future port traffic. On the other hand, the competitive position of a port will determine its attractiveness and its market share. Modelling port competitiveness is complex and difficult because of the need for good information and insight into the decision processes and strategies of all the relevant market players involved. In the meantime, one can rely on time-series methods using ARIMA–GARCH models (or extensions such as EGARCH and GARCH in M models) to generate forecasts not only of the growth rate of port traffic, but also of its volatility.

Potential investors should be well aware of the fact that increasing uncertainty, reflected in a higher volatility, requires a higher critical present value to make it worthwhile. This may be one of the reasons why it is difficult to attract private capital for large, irreversible port infrastructure projects. During the past few years, however, we have seen an evolution towards a larger involvement of the private sector, which has resulted in more efficiency, higher productivity and better service. However, there is still a long way to go. In order to continue this process of privatisation, governments on a national and international level should create and safeguard a climate of fair competition, which might increase returns on investment, but, even more importantly, could also reduce the volatility of future returns. It is especially this last element that is needed to make investments in large, irreversible infrastructure projects more attractive.

NOTES

1. See e.g. McDonald and Siegel (1986), Caballero and Pindyck (1992), Chirinko (1993), Pindyck and Solimano (1993), and Bertola and Caballero (1994).

A comprehensive theoretical treatment is given in Dixit and Pindyck (1994). A recent extensive review of theory and empirics is presented in Carruth et al. (2000).

REFERENCES

Bertola, G., & Caballero, R. J. (1994). Irreversibility and aggregate investment. *Review of Economic Studies*, *61*(2), 223–246.

Caballero, R. J., & Pindyck, R. (1992). Uncertainty, investment, and industry evolution. Paper presented at the *economic policy conference*, Gotheburg, Sweden, August.

Carruth, A., Dickerson, A., & Henlay, A. (2000). *What do we know about investment under uncertainty? Journal of Economic surveys*, *14*(2), 119–153.

Cassimon, D., Engelen, P. J., Meersman, H., & Van Wouwe, M. (2003). Investment, uncertainty and irreversibility: Evidence from Belgian accounting data. In: P. Butzen & C. Fuss (Eds), *Firms' investment and finance decisions* (pp. 194–219). Cheltanham: Edward Elgar.

Chirinko, R. S. (1993). Business fixed investment spending: Model strategies, empirical results, and policy implications. *Journal of Economic Literature*, *31*, 1875–1911.

Commission of the European Communities. (2001). *On public financing and charging practices in the Community sea port sector (on the basis of information provided by the member states)*. Commission staff working document, SEC 234, Brussels.

Dixit, A., & Pindyck, R. (1994). *Investment under uncertainty*. Princeton, NJ: Princeton University Press.

Estache, A., & de Rus, G. (Eds) (2000). *Privatisation and regulation of transport infrastructure: Guidelines for policymakers and regulators*. Washington, DC: World Bank Institute.

Gwilliam, K. (1997). *Contract design for concessions and franchising*. Washington, DC: World Bank Institute.

Huybrechts, M., Meersman, H., Van de Voorde, E., Van Hooydonk, E., Verbeke, A., & Winkelmans, W. (2002). *Port competitiveness. An economic and legal analysis of the factors determining the competitiveness of seaports*. Antwerp: Editions De Boeck Ltd.

Juhel, M. (1998). Globalisation, privatisation and restructuring of ports. Paper presented at the 10th Annual Australasian Summit on Ports, Shipping and Waterfront Reform.

McDonald, R., & Siegel, D. (1986). The value of waiting. *Quarterly Journal of Economics*, *101*, 707–728.

Sommer, D. (1999). Private participation in port facilities – recent trends. *Public policy for the private sector*. Note 193, Washington, DC: The World Bank Group.

Winkelmans, W., Van de Voorde, E., Huybrechts, M., Meersman, H., & Verbeke, A. (1998). *Aspecten van havencompetitiviteit*. Final research report of the concerted action on Port Competitiveness (1995–1998). University of Antwerp.