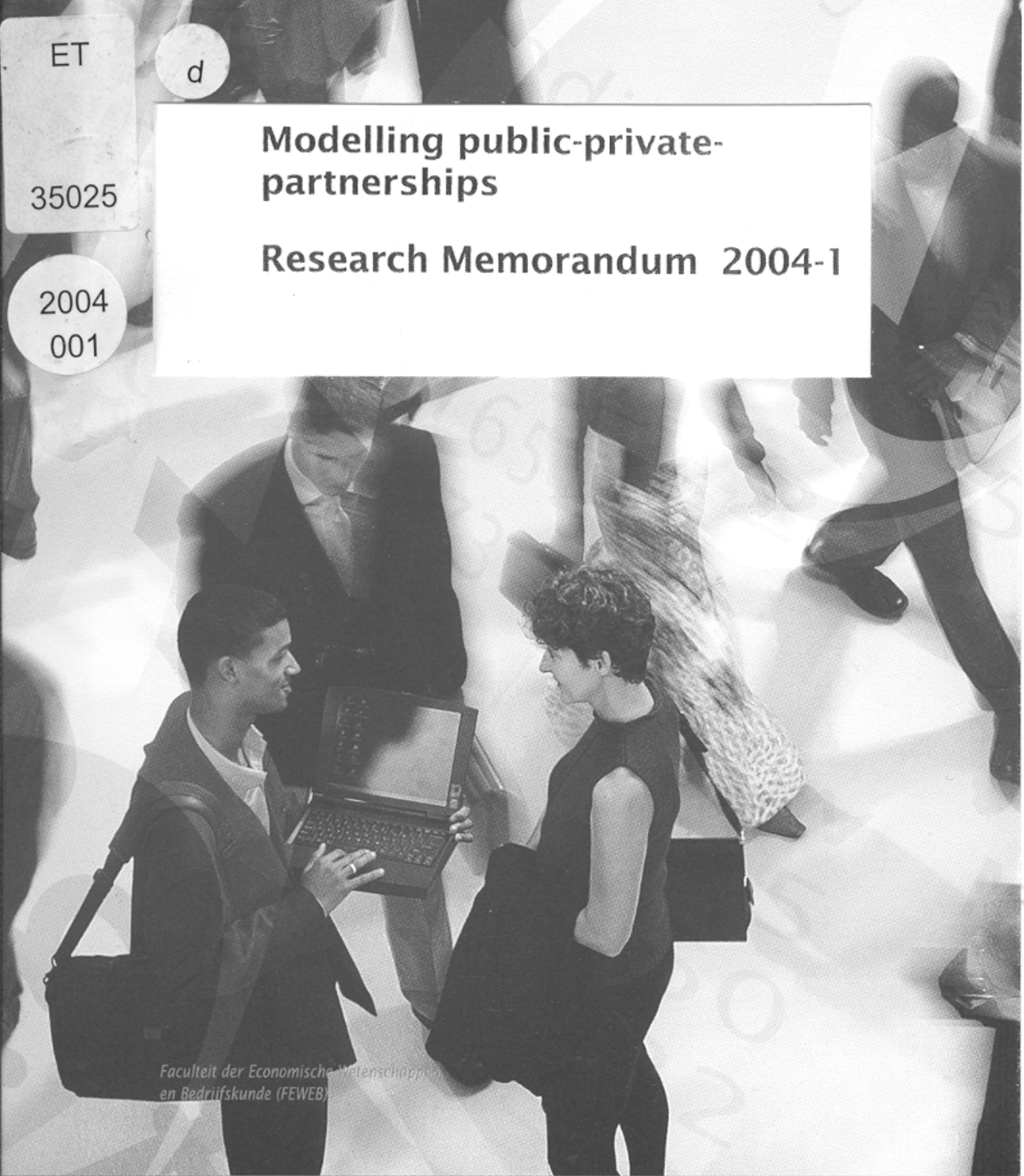
Modelling public-private-partnerships

Research Memorandum 2004-1



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1 Introduction

In recent years governments have deliberately redefined the conventional boundaries between the public and private sectors. The provision and management of public and semi-public goods, which has previously been the preserve of the public sector, is increasingly becoming an important element in the investment portfolio and operation of the private sector.

The involvement of the private sector in the delivery of public services such as railway operations, covers a wide spectrum of initiatives: ranging from the wholesale privatization of state-owned rail assets, to the contracting out of services (such as cleaning and catering) and the use of private finance and expertise. Our analysis will focus, in particular, on the alternative strategies that entail the intervention of the private sector in the provision of rail services.

The development of such private participation in railway operation can be attributed to two main factors. First, we note that budgetary constraints and the desire to maintain a lower tax burden on the public have compelled national governments to transfer part of their spending to finance the upgrade and expansion of the railway infrastructure and services to the private sector. The second factor which is, in our view, the major justification for private intervention is that the private sector is regarded as a means to deliver rail services more efficiently than the public sector. However, recent research (Flyvbjerg et al., 2002) shows that almost nine out of ten transportation projects financed by the public sector claimed underestimated costs. In the study, rail projects actual costs are on average 44.7% higher than estimated costs. The conclusion is that provision of rail services is being undertaken at excessive cost. Public sector provision of rail services has often been characterized by time and cost overruns, which are frequently due to the lack of coordination between expertise and incentives.

In the private sector it is possible to identify clear aims in relation to operation and investment, that is, the maximization of the profit, and to therefore align the interest of the shareholders and employees through appropriate incentive structures. On the other hand, such a task is not so simple to fulfil in the public sector. Often the provision of rail services is regulated and managed by different agencies with sometimes conflicting and confused objectives. In addition, within the public sector, i.e. public sector managers, civil servants, politicians and the public, may also often have conflicted objectives and complex relationships. As Arrow proves in the Impossibility Theorem: "it is not necessarily the case that a voting system with generally desirable properties maximizes net benefits to voters". This confusion and contrast of objectives that we recognize in the public sector is often the result of cost and productive inefficiency.

Another source of possible inefficiency in the public sector is the difficulty of monitoring the operation and managing the service provision to thereby create a system of incentives for efficient use the allocated resources. As Vickers and Yarrow (1988) state, "as a matter of general principle, it can safely be concluded that incentive structures for public enterprises will tend to exhibit significant imperfections at each level of the monitoring hierarchy". In contrast, in the private sector, since there is a clear relationship between managers and shareholders, monitoring is a far easier task than in the public sector.

However, the decision to allow the intervention of the private sector in the operation and provision of railway services must rely on the type of participation governments decide to pursue. In any form of private participation, the public sector must ensure achievement of value for money by comparing the costs of rail services provided in various alternatives. A private sector monopoly may often be the unlikely optimal decision over the quality and quantity of railways; the case of the Railtrack company in the UK, which has been re-nationalizing after the privatization attempt, is an illuminating example. A more flexible intervention of the private sector in public goods provision is, however, given by the public private partnership (PPP).

We define as public private partnership (PPP) all the different contractual arrangements relating the private and public sectors in the achievement of the same objectives through different means. In other words, the private sector will provide the services or goods by maximizing its profits, whereas the public sector will obtain the same objective by maximizing its welfare function. This definition allows many forms of relationship to be classified as PPPs, which, however, must have in common a level of flexibility in the relation between the private and public sector, and an appropriate transfer of risks from the public to the private sector.

The advantages of entering into a PPP contract for the provision of railway services can be manifold. We have seen the efficiency argument, but a strong argument – in particular for transportation services – is that to retain public sector involvement allows for policies to be coordinated across different modes of transport. This is particularly important in transportation, where the integration of the system is a paramount goal at both the national and the international level.

A further advantage in favor of PPPs is that, when the public interest is high in relation to quality and safety for the public sector to retain control over the provision of the transport services, there are relevant social benefits. Moreover, there is wider concern across the public sphere that certain services and goods should not be provided through a privatized system. By combining the qualities of both sectors, public-private partnerships may have a higher public acceptability than by mere privatization.

In the next section we examine how and when there is an economic advantage for the public sector to enter (as well as not entering) in partnership with the private sector. In this section a model is presented which accounts for the fact that public and private parties have distinctly different objectives. The public party therefore needs to provide the private party with the necessary incentives (or limitations) to reach a common objective.

2 A basic model to analyse PPP

This section presents an economic model that captures the different options of organizing the rail industry. We only consider passenger traffic. The model assumes that there is a network operator that is responsible for transporting passengers from an origin to a destination. Furthermore, there is an infrastructure operator that provides the necessary infrastructure to the network operator. Finally, there is a government (in this paper we do not distinguish between national and local governments). Rail and infrastructure services can be offered publicly or privately. When there is a public-private partnership, rail services are offered by a private network operator, while infrastructure services are offered by the infrastructure operator on behalf of the government.

To analyse the different outcomes, we begin with the specification of passenger demand (we neglect freight). After that, we set up the private and public objective functions. For expositional simplicity, we consider only one line between two stations in this paper.

Demand

Demand in market j (between an origin and destination station) is characterized by a linear inverse demand function:

$$D_j = \alpha_j - \beta_j Q_j$$

where α_j is the maximum reserve price in market j, β_j is demand sensitivity and Q_j is the number of passengers transported in market j. Each passenger faces a linear generalized cost function for travelling in market j:

$$GC_j = p_j$$

where p_j is the fare in market j. According to Wardrop's equilibrium conditions, marginal benefits as given by the inverse demand function are equal to the generalized costs in equilibrium:

$$p_j = \alpha_j - \beta_j Q_j$$

This expression gives the equilibrium fare, that is included in the revenue function for the network operator. Revenues in market j can thus be written as:

$$R_j = (\alpha_j - \beta_j Q_j) Q_j$$

Infrastructure operator

The infrastructure operator incurs a cost k for each train running across the line; we assume constant returns to scale so that marginal cost = average variable cost = k. Furthermore, there are fixed costs K_i. When the infrastructure is private, these costs are added to the objective function of the private network operator. Alternatively, one could assume two profit maximizing private operators. Because the network operator and infrastructure operator offer complementary services, this assumption leads, however, to efficiency losses because the infrastructure operator does not internalise the negative effect of a pricing decision on network operator demand.

An public infrastructure operator is assumed to be less efficient; marginal costs are a factor δ_k higher, where δ_k needs to be established empirically. When the public infrastructure operator charges marginal cost for the service delivered, fixed costs K_i are not recovered[1]. When the infrastructure operator operates under a cost recovery constraint, the user charge is $\delta_k k + K_i/Q$. An alternative strategy for the public infrastructure operator is welfare maximization. In that case, the infrastructure charge may be negative, depending on the strategy of the rail network operator. When the latter acts as a monopolist, a subsidy is necessary to maximize welfare (unless δ_k is relatively large). This translates to a negative infrastructure charge.

[1] We assume that there is no inefficiency in the fixed cost level; i.e. a public and private supplier of rail services have the same fixed cost level. The model is easily extended to the case where the public operator has relatively high fixed costs, as well as relatively variable costs. For expositional clarity, we will not consider this case in this paper.

With the demand function and infrastructure costs specified above, we can now determine the objective functions and pay-offs for the public and private party in the different organizational structures. We consider the following options:

- Public: The public authority operates both the transport network and the infrastructure. In this case, welfare (consumer profits minus operational costs) is maximized.
- PPP: A private party operates the network, and uses infrastructure offered by the operator on behalf of the authorities. The infrastructure operator may have one of the following three strategies: marginal cost pricing, average cost pricing or welfare maximization. As mentioned above, welfare maximization may lead to negative infrastructure charges when the infrastructure charge is used as a policy instrument to maximize welfare and the network operator (railway company) has significant market power. Van Vuuren (1992) found evidence that the Dutch railway company engages in monopoly pricing during off-peak hours. During peak-hours, prices reflect marginal cost. This pricing scheme is the result of the specific fare regulation which imposes a maximum difference between peak and off-peak prices. Fare regulation is seen as an interesting expansion of this paper, and is not considered in this paper.
- Private: A private company offers transport services to the public and also operates the infrastructure. As mentioned above, we do not consider two separate profit maximizing complementary private companies.

Public provision of rail services.

The public provider of transport services maximizes welfare ϖ_p:

$$\max_{Q_j} \varpi_P =$$

$$\int_0^{Q_j} (\alpha - \beta x)dx - Q_j(\delta_c c + \delta_k k) - F - K$$

δ_c is the relative inefficiency of the public operator (compared to the private sector); $\delta_c \geq 1$. The welfare function includes the consumer surplus and the costs of offering the infrastructure publicly. The first-order necessary condition for welfare maximization is:

$$\frac{\partial \varpi_P}{\partial Q_j} = \alpha - \beta Q_j - (\delta_c c + \delta_k k) = 0 \Leftrightarrow Q_j = \frac{\alpha - (\delta_c c + \delta_k k)}{\beta}$$

When fixed costs are considerable, this strategy may lead to operational losses. The public operator may therefore include a break-even condition:

$$Q_j(\alpha - \beta Q_j) \geq Q_j(\delta_c c + \delta_k k) + F + K$$

When this constraint is binding, optimal outputs are:

$$Q_j = \frac{1}{2}\frac{\alpha - \delta_c c - \delta_k k + \sqrt{(\delta_c c + \delta_k k - \alpha)^2 - 4\beta(F + K)}}{\beta}$$

PPP: Private rail network operator, public infrastructure operator

The private rail network operator incurs a cost c_k for each passenger movement (e.g. personnel costs, station cost, ticketing etc.). Furthermore, the railway company pays t to the infrastructure operator for each train running along the line. Finally, there is a fixed cost F. Total costs are:

$$TC = (c + t)Q_j + F$$

For single link 2-node network profits then are:

$$\pi = R_j - TC =$$
$$(\alpha - \beta Q_j)Q_j - Q_j(c + t) - F$$

π is maximized over Q_j. The first-order necessary conditions are:

$$\frac{\partial \pi}{\partial Q_j} = \alpha - 2\beta Q_j - c - t = 0 \Leftrightarrow$$

$$Q_j = \frac{\alpha - c - t}{2\beta}$$

When the infrastructure charge is set at marginal cost level, the optimal Q is obtained by simply substituting $\delta_k k$ for t. When the infrastructure charge is fixed at the average cost level, we substitute $\delta_k k + K_i/Q$ for t. This implies that the private network operator reacts to the infrastructure charge set by the infrastructure operator in a Stackelberg-fashion. The public infrastructure operator thus operates as the leader in the game between the public and private party. Substituting for t in the rail operator's optimal output yields the equilibrium output level (including the response to the infrastructure charge). Substituting this output level in the expression for t yields the optimal infrastructure charge level.

When a public infrastructure operator sets its infrastructure charge so as to maximize welfare, it may end up subsidizing the network operator. Comparing the network operator's first order condition for profit maximization and the first order condition for welfare maximization yields

$$\frac{\partial \pi}{\partial Q_j} - \frac{\partial \omega}{\partial Q_j} = \alpha - 2\beta Q_{AB} - c - t - \left(\alpha - \beta Q_{AB} - c - \delta_k k\right) = 0 \Rightarrow$$
$$t = -\beta Q_{AB} + k$$

Substituting this expression for t in the rail network operator's optimal output yields the equilibrium output; this again is a Stackelberg solution.

Private rail network and infrastructure operator

This simply is an extension o the case of the private network operator, the only extension being the cost of offering the infrastructure:

$$\pi = R_j - TC =$$
$$\left(\alpha - \beta Q_j\right)Q_j - Q_j\left(c + k\right) - F - K$$

The first-order condition is:

$$\frac{\partial \pi}{\partial Q_i} = \alpha - 2\beta Q_j - c - k = 0 \Leftrightarrow$$
$$Q_j = \frac{\alpha - c - k}{2\beta}$$

3 Comparison of pay-offs

The optimization problems specified in Section 2 yields the pay-off matrix in Table 1. As mentioned above, the public party takes the lead in the game. By comparing pay-offs (welfare levels) in the different policy options, it chooses its strategy. We do not report solutions for the cost-recovery strategy of a private operator; we assume that a private operator will not enter (or will leave) the market when fixed costs cannot be recovered.

We define an indifference curve between strategies x and y as the curve given by $\omega_y/\omega_x = 1$. Solving this expressions for the different policy options, with x=public, we get the following decision rules:

- PPP (with marginal cost pricing for infrastructure) is preferred over public operations of the network and infrastructure when

$$\delta_c \in \left[\frac{\alpha - \delta_k k + \frac{\sqrt{2}}{3}(c + k - \alpha)}{c}, \frac{\alpha - \delta_k k - \frac{\sqrt{2}}{3}(c + k - \alpha)}{c}\right]$$

- PPP (with welfare maximizing charges for infrastructure) is preferred over public operations of the network and infrastructure when

$$\delta_c \in \left[1, \frac{2(\alpha - \delta_k k)}{c} - 1\right]$$

- private operations are preferred over public operations of the network and infrastructure when

$$\delta_c \in \left[\frac{\alpha - \delta_k k + \frac{\sqrt{2}}{3}(c + \delta_k k - \alpha)}{c}, \frac{\alpha - \delta_k k - \frac{\sqrt{2}}{3}(c + \delta_k k - \alpha)}{c}\right]$$

Because the public and PPP options with average cost pricing for infrastructure yield decision rules that are difficult to interpret, these will be analyzed in a numerical exercise.

	Infrastructure offered at marginal cost	Infrastructure offered at average cost $A = -\alpha + c + \delta_k k$	Infrastructure offered at welfare maximizing price
Public rail and infrastructure operator	$\omega_{PUBM} = \frac{1}{2}\frac{\left(-\alpha + \delta_c c + \delta_k k\right)^2}{\beta} - F - K$	$\omega_{PUBA} = \frac{1}{4}\frac{A\left(A - \sqrt{A^2 - 4\beta K}\right) - 2\beta(F - K)}{\beta}$	ω_{PUBM}
Private network operator Public infrastructure operator	$\pi_{PPPM} = \frac{1}{4}\frac{\left(-\alpha + c + \delta_k k\right)^2}{\beta} - F$ $\omega_{PPPM} = \frac{3}{8}\frac{\left(-\alpha + c + \delta_k k\right)^2}{\beta} - F - K$	$\pi_{PPPA} = \frac{1}{16}\frac{3A\left(A - \sqrt{A^2 - 8\beta K}\right) - 4\beta(4F - 3K)}{\beta}$ $\omega_{PPPA} = \frac{1}{8}\frac{3A\left(A - \sqrt{A^2 - 8\beta K}\right) - 4\beta(2F - K)}{\beta}$	$\pi_{PPPW} = \frac{\left(-\alpha + c + \delta_k k\right)^2}{\beta} - F$ $\omega_{PPPW} = \frac{1}{2}\frac{\left(-\alpha + c + \delta_k k\right)^2}{\beta} - F - K$
Private rail and infrastructure operator	$\pi_{priv} = \frac{1}{4}\frac{\left(-\alpha + c + k\right)^2}{\beta} - F - K$	-	-

Table 1 *Pay-off matrix*

The decision rules given above are intuitively appealing. The second decision rule (PPP with welfare optimizing infrastructure charges) yields the welfare optimum. An efficient private network operator uses infrastructure provided at welfare maximizing charges (i.e. subsidies). From a welfare economic perspective, the public authority cannot do any better, although it may politically be somewhat tedious to subsidize a private monopolist. The upper boundary indicates that at very high inefficiency levels, optimal outputs in the base case (public operations) will be negative. This can still yield a positive welfare level, although it is of course irrelevant. We may therefore ignore the upper limits to δ_c.

When infrastructure is not offered at a welfare maximizing charge, there is a welfare economic in a PPP loss due to the market power effect. As a result, a relatively inefficient public operator may still operate the network and infrastructure at a higher pay-off (welfare level) than can be obtained in a PPP. This is reflected in the first decision rule, where the lower limit to δ_c is larger than 1.

Finally, when δ_k=1, the PPP and private options yield the same pay-off. Only when δ_k>1 there is a difference. When δ_c is not too large compared to δ_k, a PPP is preferred over the private option, because then the infrastructure is still offered at marginal cost (unlike in the private case).

4 Conclusion

This paper formulates a model to analyze the optimality of PPP from a welfare-economic point-of-view. The analysis rests on the assumption that private agents operate more efficiently than public agents; i.e. marginal costs are lower for private operators. An efficiency level at which a PPP yields a higher welfare level than public operations only is derived. This efficiency level is not necessarily equal to one; it would only be so if the private operators do not have any market power. In the applications shown in this paper, the rail network operator does have market power (cf. Van Vuuren, 2002). As a result, the rail network operator does not set its output at the welfare maximizing level. This means that a relatively inefficient public party may still be able to offer services that yield a higher welfare level; in this case, the inefficiency effect (i.e. higher marginal costs) is swamped by the market-power effect in a PPP. In practice, there have been experiments with the introduction of competitors in rail networks; for instance, the Dutch national railway company faced competition form a small company (Lovers) in a single market for a few years. Competition would reduce the market power effect, but there may be other types of market failure that would allow a relatively inefficient public supplier of rail services to yield higher welfare levels, such as congestion, significant density economies etc.

Although a relatively inefficient public rail network operator may seem to be the optimal choice, there are of course other strategies that are not considered in this paper. Fare regulation may be used to encounter the market power effect, but regulation in a network setting may be quite tedious as it is difficult to assign network costs to specific markets. An alternative strategy may be to auction the right top operate or manage a rail network for a number of years, but it is quite difficult to determine the value of such a bid.

Possible (and necessary) extensions of this paper are the following. Firstly, we need an empirical illustration of the inefficiency of a public rail network operator. Secondly, it may be necessary to include density economies in rail network operations. A common conclusion is that rail networks are operated under increasing density economies, although there exists some information that constant or even decreasing economies are present; Preston (1994) finds negative returns to density for the Dutch national railway company, while Pels et al. (2003) find constant returns to scale for the same company. Pels et al. report returns to density coefficients that indicate increasing returns, but the associated standard errors are such that the null of constant returns cannot be rejected.