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Operating costs in Norwegian toll companies: A panel data analysis

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Abstract

The objective of this paper is to ease the planning of new toll projects by providing estimates of operating costs, and to help us make better informed decisions about the design of the toll collection system. To do so we use panel data for Norwegian toll companies to estimate average cost functions. The main results can be summarised as follows. We provide evidence of very important unexploited economies of scale. The estimates cost curves are very steep for traffic levels below the sample mean, and becomes almost entirely flat over a wide range above the sample mean. A higher share of vehicles using on board units will significantly reduce average costs. Competitive tendering will significantly reduce average operating costs by as much as 25 %. Our results also suggest that increased number of lanes, higher debt and passenger charging will increase average operating costs whereas average operating costs are lower for toll cordons compared with other projects.

1. Introduction

Toll financing in Norway has been used to finance new roads as a supplement to public funds for more than 70 years. While bridges often where subjected to tolls hundreds of years ago, toll financing as we know it today started in the early 1930s, when the Vrengen bridge situated near the town of Tønsberg were financed using tolls. Since 1980s the number and the type of projects financed by tolls have increased considerably. Today there are 48 toll projects scattered throughout the country. The seven toll cordons make up the bulk of the annual revenues while fjord crossings through tunnels and bridges still represent the majority of the projects.

The net revenues from toll financing constitute some 35 percent of the total annual budget for road construction. On average, Norwegian motorists spend 1400 NKr[1] a year on tolls per vehicle. Naturally, this raises some controversy among the motorists, and the cost of toll financing remains an important issue both politically and economically. As the number of projects is increasing the need to establish better estimates of the costs and net revenues is crucial.

The objective of this paper is to ease the planning of new projects by providing more precise estimates of the operating costs, and to help us make better informed decisions about the design of the toll collection systems. Moreover, from an economic point of view it is essential to be able to choose the right projects for toll financing. Some projects are clearly better suited for this method of finance than others, where traditional finance through government funds is more appropriate.

In spite of the extensive experience in toll financing, little research has been done to examine solutions for minimising the operating costs and hence maximising the social surplus of each project. We have therefore carried out a study to establish a cost function that can identify the main cost drivers in toll projects.[2] The empirical analysis is based on panel data for 26 Norwegian toll companies. A key issue will be to test whether or not toll collection is characterized by economics of scale, and to identify economic, technological and institutional variables that affect operating costs.

The literature on operating costs in the toll industry is scarce and close to non-existing. The emphasis has traditionally been on the financial viability and -rewards of the projects rather than if toll financing in itself provides an attractive option from a social point of view (see for example Moles and Williams (1995) and Wentworth and Beresford (1998)). However, as congestion charging is more debated and attracts

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[1] 1 NKr ≈ 0,13 €

[2] The present paper extends the analysis in Welde (2005).

more interest than ever, the need to curb the operating costs of such schemes becomes ever more crucial. Controversial issues such as congestion charging rely heavily on public acceptance. This is demanding but, in our opinion, any road user charging scheme should at least pass a social cost-benefit analysis, it should generate substantial net revenues and it should be acceptable to a major proportion of the public. Minimising the operating costs is critical for meeting all these three basic criteria.

The importance of the operating costs in road user charging schemes has been the focus of a recent debate in Transport Policy (Prud'homme and Bocajero (2005), Mackie (2005) and Raux (2005)). Without proper focus on the cost of collecting tolls, an often celebrated scheme such as the London congestion charge might very well be an economic failure. This illustrates the need to examine operating costs further through a larger sample of toll projects.

This paper proceeds as follows. Section 2 describes the organisational and decision making framework of Norwegian tolling. Section 3 examines the costs of toll financing. Section 4 discusses properties of the panel data set used in this study and specifies the empirical model to be estimated. In Section 5 we present results from the empirical analysis. Section 6 shows how the empirical results can be used to predict operating costs while Section 7 offers some conclusions.

2. Organisational framework of Norwegian tolling

Norway provides a striking example of a country with extensive experience from toll financing. Over 100 projects have been financed using tolls and only one has ever gone bankrupt. Parts of this success rate can probably be explained by the stable organisational and legal framework surrounding the toll projects which has eased the planning process for new projects and lead to a faster implementation of the projects than otherwise possible.

Each toll project is based on an initiative from the local municipality, local authorities or other members of the local community. This initiative is based on a real or perceived need for new roads in the area and will usually result in the founding of a toll company, organised as a limited liability company, non-recourse to the NPRA. The majority of the stocks are owned by public shareholders although private involvement is also common. The toll company acts as an enthusiast and will, often along with local politicians, work to establish political acceptance for the project. This process may take years and often includes lobbyism both locally and nationally until the project is approved by the Norwegian Parliament. Once the road project is realised, the role of the toll company is to operate the toll system and to administer the toll revenues. The toll company is organised as a non profit enterprise and the share owners receive no dividends. Each toll project is managed by a toll company, responsible for one project only. The toll collection is increasingly being contracted out from the toll companies to commercial toll road operators.

The local initiative is regarded as crucial to both political and public acceptance for the toll projects and local authorities typically act as guarantors through a system of conditional reimbursement for the loans taken up. Very few projects are exclusively financed by tolls and there is usually a mix between public and private funds for most projects. The local willingness to pay tolls will hence often be followed by additional government funds that would otherwise not be available.

The toll company bases its activities on a standard legal arrangement with the NPRA and is subjected to extensive operating regulations. The collection of tolls is restricted to a period of up to 15 years and the tolls have traditionally been used for road construction only. For the toll cordons the revenues have also been used for investment in public transport infrastructure (not operations and rolling stock) and today there is a development towards a more intermodal use of the toll revenues in urban areas.

In spite of the success rate of the toll projects, the organisational framework of Norwegian toll financing has come under growing criticism. The local initiative will often put the local roads administration under local political pressure and have often lead to the implementation of projects with a negative cost benefit ratio. Furthermore, it is increasingly being recognised that the relationship between the NPRA and the toll companies gives rise to a number of principal agent problems. The ever increasing number of toll companies implies that the asymmetry of information often observed in principal agent relationships becomes more visible and that the objectives of the NPRA and those of the toll companies often differ. Since the costs of monitoring the toll companies are high, the toll companies have sometimes pursued policies which do not reflect those of the NPRA. The toll companies have been criticised for not doing enough to minimise their costs and the NPRA has thus recently put more emphasis on operating costs and how these are influenced by the organisational framework as well as other variables.

3. The costs of toll financing

Toll financing is an important and integrated part of the total annual road investments. This implies that toll projects should be subjected to the same social cost benefit test, i.e. to be required to have a positive net social benefit, as other road projects.

As mentioned in section 2, the organisational framework of Norwegian toll financing may give rise to certain principal agent problems such as asymmetry of information and insufficient incentives for cost efficiency. We do, for example, observe that the marginal operating cost of the toll companies vary considerably with variations between 5-10 % and 35-40 %. This might be due to differences in tolls and traffic levels but it nevertheless illustrates the need to choose the right projects for toll financing and the importance of better knowledge of costs and how the performance of the toll companies can be compared. Figure 1 illustrates the development in the marginal operating costs over the last decade.

Figure 1 about here

A common critique against toll financing is that financing road investment through tolls is costly to society as the sum of the total finance and operating costs over the tolling period will be huge. However, if we assume that the average interest rate is equal to or close to the discount rate used in cost benefit analyses, the net present value of finance costs paid over the project period will be close to zero. The cost which remains is the additional risk premium private finance requires compared to public finance. For non-profit organizations such as the Norwegian toll companies this premium will presumably be low or close to non-existing but it is generally acknowledged that private finance is more expensive than public. The difference in finance costs between the public and private sector is likely to vary between countries and contractual structures. However, given the long tradition and the low risk of Norwegian toll financing it is likely that this difference is comparatively small.

On the other hand, no money is free, even to governments who normally raise their funds through some form of taxation. The estimates of the deadweight loss of taxation varies but if we assume a shadow price of public funds of 1.2, toll financing might actually be welfare improving compared to public finance if the total costs of toll financing can be kept below 20 percent of the revenues. [3] This should therefore be the benchmark when we assess the performance of toll financing compared to public finance.

Introducing tolls on a road will generate a deadweight loss.[4] By tolling the road, generalized costs will not be reduced according to the potential time savings by the new road and a deadweight loss will occur. The deadweight loss due to traffic deterrence will depend on the slope of the demand curve and the deviation from the marginal cost. Inelastic demand (a steep demand curve) will be largely unaffected by tolls whereas elastic demand will be more sensitive to tolls.

How motorists react to tolls are context specific but previous studies have mainly found demand elasticities to be relatively inelastic. Norwegian studies indicate elasticities between 0,3 and 0,8 (Odeck and Bråthen, 2004) while Hirschman et al (1995) found elasticities on bridges and tunnels into New York to average 0,1. Other studies from Singapore (Luk, 1999) and Spain (Matas and Raymond, 2003) reveal elasticities from 0,2 to 0,6 and 0,2 to 0,8. All studies show that the elasticities, and hence the dead weight loss, are larger in projects with high tolls and where an untolled alternative exists. Traffic levels and trip lengths can be extremely sensitive to tolls when motorists have an alternative to the tolled road and when tolls increase beyond a critical level. Under conditions as these, such as on Toronto's Highway 407, Mekky (1999) have found toll elasticities as high as 4,0.

On the other hand, under congested conditions traffic reduction and -rerouting is normally desirable. If tolls can reduce congestion and hence distort the motorists'

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[3] In Norwegian cost- benefit analyses a standard shadow price of public funds of 1,2 is used.

[4] Shadow tolls have not been used to finance road investment in Norway. All tolls are real tolls.

behaviour in a desired direction, the operating costs will be the only costs of toll financing.

The marginal social costs of toll financing can hence be defined as follows[5]:

$$\mu = \frac{\alpha + T}{R - \alpha} \tag{1}$$

where μ is marginal social cost of toll financing, α operating costs, T value of traffic deterrence and R is gross toll revenues.

If μ in equation (1) can be kept below 0,2, the project should be financed using tolls rather than traditional public finance. This is a fact that is often ignored in the public debate.

The relevance of this is illustrated by a study currently being carried out by the NPRA (forthcoming). Quantifying the total marginal costs of toll financing (operating costs and traffic deterrence) in 4 toll projects showed that the marginal costs of toll financing were below 0,2 in three of the four projects examined. This shows that toll financing can be a good deal to society in some cases but also that the total marginal cost can exceed the shadow price of public funds in other cases, especially when the operating costs are high.

Focusing on operating costs is therefore important for both the decision maker and for the planner. The objective is evident – to save money! In order to do that, we will estimate a cost function that gives us better knowledge of toll financing and how this method of finance can be used to the benefit of society.

4. Data and empirical specification

In this study we utilise a panel data set for 26 toll companies. The panel data set is unbalanced; the longest time series is seven years (1998 – 2004) whereas the shortest

[5] Larsen (1995) uses a similar expression.

series is 2 years. In addition to the 26 toll companies used in the empirical analysis, we have information for 4 companies in 2004, only. Information about these companies is used to investigate the out of sample predictions of the estimated model.

A key issue in the empirical analysis will be to test whether or not toll companies are characterized by economies of scale. To do so, we investigate the relation between average operating costs per paying vehicle, AVC_{it}, and the total number of paying vehicles per year, $Traffic_{it}$. The descriptive statistics reported in Table 1 reveal that both average operating costs and the traffic volume are very much dispersed. Average operating costs vary from 0.7 NKr to approximately 40 NKr per paying vehicle with a mean of approximately 6.6 NKr .Traffic varies from a minimum of 93 thousands to more than 90 millions paying vehicles per year with a mean of approximately 9 millions. Figure 2 reports a cross plot of average operating costs against Traffic. It is rather evident from the raw data that average operating costs are decreasing in traffic volume. The average cost curve is very steep for low levels of traffic, but seems to become rather flat for traffic volumes somewhat above the sample mean. From Figure 2 we also note that most observations cluster around a traffic volume below the sample mean whereas there are a few observations with a traffic volume close to the sample maximum.

Table 1 about here.

Figure 2 about here

In order to investigate scale economics more formally, we formulate a modified Cobb-Douglas function given by

$$\ln AVC = \alpha + \beta_1 \ln Traffic + \beta_2 \left(\ln Traffic\right)^2 + controls. \qquad (2)$$

This specification entails flexibility regarding scale economies. Our hypothesis is that average operating costs are decreasing in traffic $(\beta_1 < 0)$, but might start to increase after a certain level. In the case of $\beta_1 < 0$ and $\beta_2 > 0$, the operating costs as a function of traffic will be U-shaped, and the minimum of average costs is reached at a traffic volume given by

$$Traffic_{MIN} = e^{-\beta_1/2\beta_2} \qquad (3)$$

Equation (2) is expanded with a set of economic, technological and institutional variables that might affect average operating costs. We include the number of lanes in the toll station(s) because the number of lanes may increase the need for staff and equipment and therefore average costs. We also include financial debt as the toll companies report that a large share of the operating costs are related to financial management which might imply that average costs increases with higher debt.

As the number of cars equipped with on board units (OBUs) increase, the need for employees to man toll stations will decrease. As labour costs are the dominating cost components, we expect that projects with a high OBU share will have lower average costs that those with low (or zero) OBU share.

Toll cordons are in general larger than other projects and utilize modern technology. To investigate whether or not average costs are lower for toll cordons than for other projects, we include a dummy variable equal to 1 if the project is a toll cordon. Charging for passengers is only done in fixed link projects that have superseded ferry crossing where passengers traditionally have been charged. Since it is difficult to combine electronic fee collection and passenger charging, these projects might be more labour intensive, experiencing higher average operating costs.

Finally, we investigate whether or not competitive tendering reduces average operating costs. In a survey article, Domberger and Jensen (1997, p. 68) state that

"Substantial evidence that has emerged since the mid-1980s suggests that governments can save in order of 20 per cent of expenditures on services by putting them through a competitive tendering process". Based on this evidence, we include a dummy variable equal to 1 if the project has been exposed for competitive tendering.

The upshot of the discussion above is the following specification of the average cost function

$$\begin{aligned} \ln AVC_{it} = \alpha + \beta_1 \ln Traffic_{it} + \beta_2 \left(\ln Traffic_{it}\right)^2 + \beta_3 \ln Lanes_{it} + \beta_4 Debt_{it} \\ + \beta_5 OBU_{it} + \beta_6 TC_{it} + \beta_7 PC_{it} + \beta_8 COMP_{it} + \alpha_t + \eta_i + u_{it} \end{aligned} \quad (4)$$

where $Lanes_{it}$ is the number of lanes in the toll station(s), $Debt_{it}$ is total debt by the end of each year, OBU_{it} is the shares of vehicles using on board units, TC_{it} is a dummy variable for toll cordon, PC_{it} a dummy variable for passenger charging and $COMP_{it}$ a dummy variable for competitive tendering. Finally, α_t is a full set of time dummies included to control for any effects of aggregate factors common to all companies, η_i represents company specific random effects, and u_{it} is the remaining error term assumed to be identically and independently distributed.[6]

Table 1 also reports also reveals that the other explanatory variables are highly dispersed: The number of lanes varies from 2 to 66 with a mean of 11.9, *Debt* varies from zero to 2.0 with a mean of 0.4, and the share of vehicles using on board unit, *OBU,* varies from 0 to 94 % with a mean of approximately 30%. From the decomposition of the standard errors, we also note that the dispersion is mainly due to variation between companies whereas the variation over time (within companies) is much less. For average operating costs the ratio of the between groups to the within

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[6] As one could argue that average costs decreases as toll companies gather experience and introduce more efficient organizational solutions, we also included variables measuring the number of years since the opening of the project. However, the estimated effects were both hard to interpret and statistically insignificant.

groups standard error is 6.5 whereas the corresponding ratio for *Traffic* is 17.5 and approximately 11 for *Lanes*.

Further inspection of the data shows that toll cordons are on average much larger than other projects, and they have significantly lower average operating costs – possibly resulting from economics of scale and the utilisation of the latest tolling technology. For toll cordons, the mean value of AVC is 1.3 NKr and mean value of Traffic is 32.9 millions paying vehicles. For other projects the corresponding numbers are 8.2 NKr and 1.66 millions paying vehicles. Projects with passenger charging are very small (mean of Traffic = 0.87 mill) and have higher average operating costs (mean value =11.1 NKr) than other projects.

5. Empirical results

The random effects model is estimated using Generalized Least Squares. Table 2 reports empirical results for different specifications of the average cost function. Results for the most general specification given by equation (4) are reported in column I. We first note that the estimated parameters of the log of paying vehicles, $\ln Traffic_{it}$ and its square, $(\ln Traffic_{it})^2$ are both highly significant from zero. So are also the estimated effects of the share of vehicles using on board units, OBU_{it}, and the dummy for competitive tendering, $COMP_{it}$. The estimated effects of the log of lanes, $\ln Lanes_{it}$, total debt, $Debt_{it}$, and the dummy variables for toll cordon, TC_{it}, are all statistically significant at a level of significance below 10 per cent whereas the dummy for passenger charging, PC_{it}, is more borderline significant (p-value = 0.12).[7]

Table 2 about here

As expected, average operating costs are decreasing in traffic volume. For low levels, increased traffic by 1 % will reduce average operating costs by approximately 2.3 %. The second order term is positive and statistically significant which means that the average cost curve becomes more flat for very high traffic volumes. The estimate of the second order term is small, and given the estimates reported in Table 2, column I, a hypothetical minimum of average costs is reached at a traffic volume of approximately 190 millions paying vehicles per year. Since this is well above the sample maximum of approximately 90 millions paying vehicles, this result indicates very important unexploited economies of scale. Figure 3 graphs average cost curves using the estimates in column I and mean values of all explanatory variables other than *Traffic* and *COMP*. The estimated cost curves are very steep for low traffic levels, but are almost entirely flat over a very wide range of traffic.

Figure 3 about here

For given traffic volume, increased number of lanes will increase average operating costs. The estimated elasticity in column I approximates 0.15. Although the estimated elasticity is rather small, the economic implications are important as the number of lanes is very dispersed across projects. The estimated elasticity implies that increasing the number of lanes from the sample minimum to maximum will increase average operating costs by 53 % whereas an increase by one standard deviation around the sample mean will increase average costs by 30 %.

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[7] These conclusions are based on tests with a two-sided alternative. With a one-sided alternative, all estimates except the effect of passenger charging have p-values below 0.05 whereas the p-value of *PC* is 0.061.

The estimated effect of total debt is 0.153 which implies that an increase from sample minimum to maximum will increase average costs by approximately 30 % while an increase by one standard deviation will increase average operating costs by 6.6 %.

A higher share of paying vehicles using on board units will reduce average costs significantly. The estimated effect is substantial as an increase in the *OBU* share from the sample minimum to the maximum value will reduce average costs by 34.6 % while an increase by one standard deviation (an increase by approximately 35 %) will reduce average costs by 13.4 %.

The dummy variable for toll cordons is negative and statistically significant. This means that a significant cost difference remains after controlling for scale (and other variables). Given the estimate in column I, toll cordons have approximately 20 % lower average operating costs than other toll projects.

The results in column I means that passenger charging has a cost driving effect of approximately 25 %, but the estimate of the dummy variable *PC* is not statistically significant at conventional levels.

Finally, the dummy variable for competitive tendering is negative and statistically significant. The estimate based on the most general specification means that the benefits by competitive tendering is substantial as the average operating costs in such projects are approximately 24 % lower than in other projects. Figure 3 illustrates the difference in average operating cost for projects without (thin line) and with competitive tendering (thick line). Our result fits very well with the survey evidence reported in Domberger and Jensen (1997).

Turning to a sensitivity analysis we first exclude observations with extremely high traffic, cf. the outliers in Figure 2, and re-estimate the basic model. The results based on the reduced sample reported in column II are all close to their corresponding counterparts based on the full sample. Hence, the results (especially concerning economics of scale) are not driven by a few, extremely high observations.

Since some of the estimated effects reported in column I are somewhat imprecisely determined, we carried out a simplification search by sequentially excluding variables with lowest t-statistics. The results based on the simplified models (using the full data set) reported in column III to V in Table 2 show that the partial estimates of the remaining variables are barely affected by excluding variables with statistically insignificant effects.

The time dummies included in the specifications reported in columns I to V were jointly significant, but the results revealed a significant jump from 2001 to 2002, possibly due to the introduction of indirect taxes on services. In column IV we replace the full set of time dummies with a single step dummy, TAX, which is equal to zero until 2001, and one thereafter. This simplification is accepted by data as a test of the simplification returned a p-value of 0.09. Again, the re-specification of the model has only minor impact of the estimated partial effects.

To summarise our findings, a comparison of the estimates for the different specifications reveals that the estimates of $\ln Traffic$ and its square, the share of paying vehicles using on board unit, and the dummy variable for competitive tendering are always statistically significant and very robust with respect to specification. Also, the dummies for toll cordon and passenger charging are robust as long as they are included. While the former becomes statistically insignificant as the model is simplified, the latter is never significant from zero. The estimated effect of debt is also rather robust, but drops in magnitude and becomes statistically insignificant when the full set of time dummies are replaced with the single tax dummy.

The estimated cost driving effect of increasing the number of lanes seems to be rather sensitive with respect to model specification. The estimated effect drops and becomes statistically insignificant when the cost function is simplified. It might be somewhat surprising that the estimated effect of lanes becomes insignificant. However, the number of lanes is highly correlated with traffic (correlation = 0.75). Furthermore, one may argue that the number of lanes is an endogenous variable, and if the number of lanes is set optimally we should possibly expect a small effect of this variable.

Although most partial estimates are robust with respect to model specification, the estimated traffic level that minimises average operating costs is rather sensitive. The estimated costs curves are almost entirely flat over a wide rage of traffic which makes it hard to determine "optimal" traffic volume precisely. Nevertheless, all estimates except those reported in column IV implies an optimal traffic volume well above the sample maximum of 90 millions paying vehicles.

6. Predictions

As noted above, we have information about 4 companies for 2004 only. This information is used to investigate the out of sample predictive ability of the estimated model. Table 3 report actual values for average costs and predicted values using the estimates for Model I and Model VI. As is evident, the predicted values based on both models are close to the actual values for most companies. Using Model I, the average of absolute prediction errors is about 10.4 % of the actual values whereas the average prediction error is 11.2 % using model V.

Table 3 about here

This is encouraging. The model is largely based on historical data with observations going back to 1998. This does, however, not seem to affect its ability to predict the operating costs in new projects, often using different technological arrangements to those of previous years. If the estimation is repeated annually, as more observations are collected, it can thus be a powerful tool for planners who wish to predict the operating costs (and net revenues) in toll projects with a higher degree of accuracy than today.

7. Concluding comments

The objective of this paper has been to ease the planning of new toll projects by providing estimates of operating costs, and to help us make better informed decisions about the design of the toll collection system. To do so we have used panel data for Norwegian toll companies to estimate average cost functions.

The main results from the empirical analysis can be summarised as follows. First, we provide evidence of very important unexploited economies of scale. The estimates cost curves are very steep for traffic levels below the sample mean, and becomes almost entirely flat over a wide range somewhat above the sample mean. Second, a higher share of vehicles using on board units will significantly reduce average costs. Third, our results suggest that competitive tendering will reduce average operating costs by as much as 25 %. Our results also suggest that increased number of lanes, higher debt and passenger charging will increase average operating costs whereas average operating costs are lower for toll cordons compared with other projects.

Given the huge differences in the toll companies' average costs, we suggest a rethink in the planning of toll projects. Instead of focusing on financial viability, more emphasis should be put on maximising social surplus. This implies cost efficient solutions for collecting the tolls but perhaps more importantly, choosing the right projects for toll financing. Some projects are clearly unsuited for this method of finance and should instead be financed using other sources of finance.

Evidence from Norwegian toll projects clearly show that minimising the operating costs is important for achieving a positive benefit-cost ratio but also that toll financing in some cases can outperform traditional public finance. Quantifying the costs of traffic deterrence and the operating costs in selected projects reveals that the total (marginal) costs of toll finance can be kept below the shadow price of public funds. This means that successful toll financing in some cases can represent the difference between a negative and a positive cost benefit ratio. This is probably new knowledge to decision makers who often resort to toll financing due to financial constraints. Using the results presented in this paper, toll financing can thus not only finance much needed new road infrastructure but also improve the efficiency of the economy: A better deal for the motorists and for society.

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References

Domberger, S. and P. Jensen (1997): Contracting out by the public sector: Theory, evidence, prospects. Oxford Review of Economic Policy, 13, 67-78.

Hirschman, I. (1995): Bridge and Tunnel Toll Elasticities in New York; Some Recent Evidence. Transportation 22, pp. 97-113.

Larsen, O.I. (1995): The toll cordons in Norway: an overview. Journal of Transport Geography 3, pp. 187-197.

Luk, J.Y.K. (1999): Electronic road pricing in Singapore. Road & Transport Research 8, pp 28-30.

Mackie, P. (2005): The London congestion charge: A tentative economic appraisal. A comment on the paper by Prud'homme and Bocajero. Transport Policy 12, pp. 288-290.

Matas, A. and J-L Raymond (2003): Demand elasticity on tolled motorways. Journal of Transportation and Statistics 6, pp 91-108.

Mekky, A. (1999): Toll Revenues for Fully Electronic Highways Operating Under Transponder and Video-Imaging Systems. Transportation Research Record 1659, pp. 11-22.

Moles, P. and Williams, G. (1995): Privately funded infrastructure in the UK: Participants' risk in the Skye Bridge project. Transport Policy 2, pp. 129-134.

Odeck , J. and Bråthen, S. (2004): Travel demand Elastcities and user attitudes. Møreforsking, Molde.

Prud'homme, R. and Bocajero, J.P. (2005): The London congestion charge: a tentative economic appraisal. Transport Policy 12, pp. 279-287.

Raux, C. (2005): Comments on 'The London congestion charge: a tentative economic appraisal'. Transport Policy 12, pp. 368-371.

Welde, M. (2005): Bompengefinansiering – innkrevingskostnadene avhenger av mange forhold. Økonomisk Forum, No 1, 2005, pp 14 – 19.

Wentworth, M.A. and Beresford, A.K.C. (1998): Major U.K. tolled crossings reviewed. Transport Policy 5, pp. 51-59.

Table 1. Descriptive statistics

Variable	Minimum	Mean	Maximum	Standard deviation		
				Overall	Within groups	Between groups
AVC	0.705668	6.599020	39.95037	7.378292	1.151346	7.49281
Traffic	93338	9098203	90849406	19870054	1018446.64	17847561.21
Lanes	2	11.89781	66	17.67571	1.548356	16.70721
Debt	0	0.381061	2.014335	0.433584	0.125425	0.4065797
OBU	0	0.294347	0.94	0.364718	0.122277	0.360145

Table 2 Estimated cost functions. Left hand side variable is $\ln AVC_{it}$

Variable	I	II Ex outliers	III	IV	V	VI
$\ln Traffic_{it}$	-2.298 (4.65)	-2.356 (3.60)	-2.439 (4.96)	-2.472 (4.72)	-2.376 (4.64)	-2.292 (4.35)
$(\ln Traffic_{it})^2$	0.060 (3.55)	0.062 (2.74)	0.065 (3.86)	0.068 (3.85)	0.064 (3.71)	0.062 (3.47)
Traffic at minimum AVC (millions)	189.3	171.5	131.7	73.6	114.6	114.7
$\ln Lanes_{it}$	0.152 (1.71)	0.156 (1.71)	0.104 (1.23)	-	-	-
$Debt_{it}$	0.153 (1.85)	0.208 (1.82)	0.161 (1.94)	0.135 (1.64)	0.151 (1.83)	0.097 (1.21)
OBU_{it}	-0.368 (3.91)	-0.369 (3.83)	-0.376 (3.98)	-0.359 (3.88)	-0.348 (3.53)	-0.287 (3.18)
TC_{it}	-0.203 (1.81)	-0.195 (1.69)	-0.195 (1.73)	-0.172 (1.53)	-	-
PC_{it}	0.243 (1.56)	0.234 (1.47)	-	-	-	-
$COMP_{it}$	-0.240 (2.92)	-0.240 (2.84)	-0.246 (2.99)	-0.240 (2.95)	-0.253 (3.08)	-0.232 (2.83)
TAX_{it}	-	-	-	-	-	0.202 (7.53)
Const	21.450 (5.92)	21.873 (4.65)	22.565 (6.30)	22.607 (5.89)	22.059 (5.86)	21.408 (5.53)
Time dummies	Yes	Yes	Yes	Yes	Yes	No
σ	0.12709	0.13026	0.12751	0.12474	0.12616	0.12773

Notes: Estimated parameters with robust t-statistics in parentheses. Estimation method is GLS applied to RE-specification of the panel data model. The number of companies is 26 except for the regression in column II. The longest time series is 7 (1998 – 2004), shortest time series is 2.

Table 3. Actual values and out of sample predictions. Average operation costs.

		Model I		Model V		
Company	Actual	Predicted	Error	Predicted	Error	Traffic (1000)
28	4.570	5.862	1.291	5.820	1.250	559.7
29	0.920	0.843	-0.077	1.058	0.138	14 834.0
30	6.690	6.645	-0.045	6.581	-0.109	430.3
31	2.780	2.916	0.136	2.605	-0.175	1 858.8

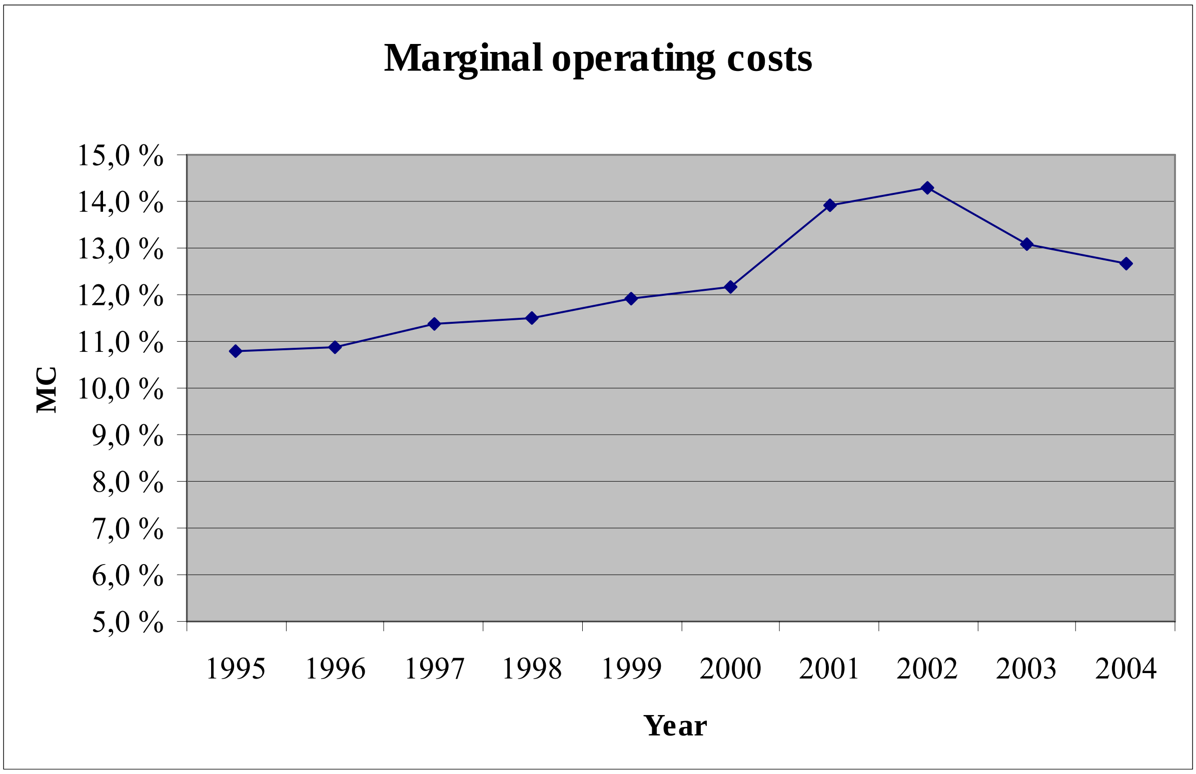

Figure 1: Marginal operating costs

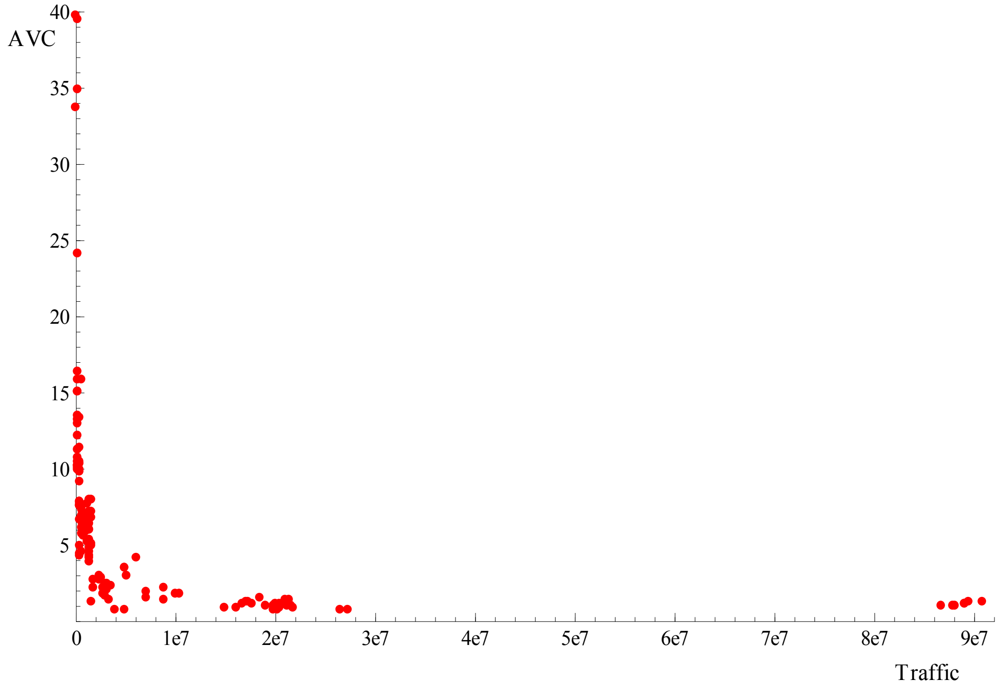

Figure 2. Cross plot of average operating cost and traffic volume

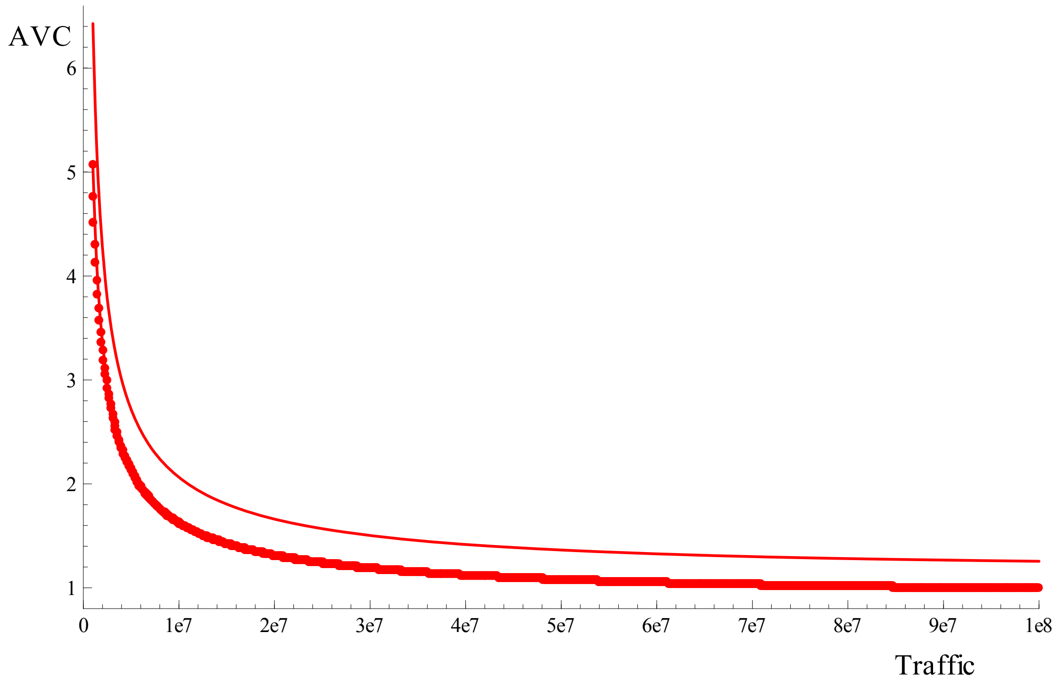

Figure 3. Average cost curves based on estimates in column I, Table 3.