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Private financing of roads and optimal pricing: Is it possible to get both?

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Abstract. Road pricing has been defended by economists as a useful instrument to internalize the costs that road users impose upon other users and the rest of society, with the aim of allocating scarce space and to reduce congestion to an efficient level. More recently, private participation in the construction, maintenance and operation of road infrastructure has been growing all over the world to face the challenge of tight budget constraints and increasing demand for additional road capacity. Fixed term concessions have been the standard contract between the public sector and private operators. Demand uncertainty and fixed term contracts have made impossible to fulfill the concession agreement in many cases, and contract renegotiation has been used to restore financial equilibrium. This has some undesirable economic consequences: selecting the most efficient concessionaire is not longer guaranteed and prices lose their role as signals for allocative efficiency. This paper addresses the problem of giving that role back to pricing, analyzing the possibility of achieving efficient pricing and cost recovery without contract renegotiation.

JEL classification: D4, H4, L9, R4

1. Introduction

Congestion is a common feature of road networks in both developed and developing countries, and can be defined as the delay imposed on all vehicles sharing a road by the presence of other vehicles. The difference between social travel costs and consumerś willingness to pay, between actual and optimal flow, is the social cost of congestion (Thomson 1998).

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Economists have repeatedly argued that road users should pay those additional costs imposed on other users sharing the road and on the rest of society. Optimal pricing means charging maintenance and operation costs according to the damage caused by the vehicle, the delays imposed on users, and the external costs[1] (Pigou 1920; Knight 1924; Vickrey 1969; Newbery 1988). Nevertheless, new road construction has been the common answer to demand growth in the last decades (Winston 1991). Private participation in the construction and operation of new roads has led to the introduction of toll roads, which coexist with free roads in many countries.

A standard road network is composed of free and toll roads. The financing of the network has different sources: public funds, fuel and vehicle taxes and, in some cases, road tolls. Those taxes and tolls do not reflect the economic principle behind the efficient provision and use of the road system. Vehicle taxes are fixed and fuel taxes cannot discriminate congested from uncongested roads. Moreover, tolls are mainly conceived as adjustment variables to fully cover the capital and operating costs. As pointed out in Newbery (2000) though the critical question is whether the net social benefit of introducing tolls is positive, in practice the usual question is whether the revenue is enough to guarantee a profit to the private operator.

Theoretically, it would be possible to recover total costs through optimal pricing, under the assumption of perfect divisibility and constant return to scale (Mohring and Harwitz 1962; Mohring 1965; Strotz 1965; Newbery 1989). Nevertheless, indivisibilities in the provision of road infrastructure and the rigidity of supply to adapt to changes in demand have led to contemplate pricing from an accounting perspective leaving aside its role as a device for economic efficiency in infrastructure provision. It is important to emphasize that without efficient pricing it is not possible to make efficient investment decisions concerning the expansion of capacity.

Private participation in roads has been increasing in recent years. Having private operators involved in road construction and operation has some advantages: efficiency gains, private financing, and better identification of attractive investment projects (Nijkamp and Rienstra 1995). In Europe 33% of the 51,242 kms of highways in 1998 were provided through concession agreements by private operators. Countries such as Austria, Denmark, France, Greece, Italy, Norway, Portugal and Spain have introduced tolls in these private operated roads. These tolls are directly paid by users, in contrast with "shadow tolls" also used in United Kingdom, Finland and Holland, which consists in government payments to the operator according to the number of users. Direct tolls are charged in 96% of the concessioned road length (Bousquet 1999).

Private participation in building and operating road infrastructure has been implemented through different versions of fixed-term concession contracts, usually awarding the concession to the bidder offering the lowest toll (Fishbein and Babbar 1996). Concession contracts have been associated to different problems of enforcement and commercial viability, requiring government intervention to rescue operators in financial difficulties. Some

[1] In this paper we ignore accidents and environmental impacts. For a comprehensive analysis of road pricing see Newbery (2002).

concessions have gone bankrupt, as it happened in Spain and France in the eighties (Gómez-Ibáñez and Meyer 1993), but the common solution has been to renegotiate contracts.

Sometimes, the breach of contract is due to disagreements between the private firm and the public agency that has to enforce the contract (Gómez-Ibáñez et al.1992), but the main reason behind contract renegotiation is the uncertain nature of demand. Fixed term concessions are based on forecasted revenues for 30 years or more, and therefore it is possible that benefits or losses occur as a consequence of actual demand deviating from expected values. When this happens, prices are usually adjusted in the opposite direction of what should be desirable according to economic efficiency: when demand is low the concessionaire asks for price increases, when demand is high public opinion claims for price reductions.

Variable term concessions (Engel et al. 1997, 2001; de Rus and Nombela 1999; Nombela and de Rus 2003) can help to deal with the uncertainty of demand, disentangling road pricing from financial equilibrium. Changing the length of the concession period according to demand conditions, allows prices to recover their role in the allocation of scarce road space.

In the second section of this paper optimal road pricing is analyzed, discussing its financial consequences. A brief description of fixed and variable term concessions is presented in Sect. 3. The analysis of optimal pricing, contract design and financial equilibrium is contained in Sect.4. Finally, the main conclusions are drawn in Sect. 5.

2. Optimal road pricing

We assume a simplified model consisting of a road with q users. Each driver travels the same distance in a identical vehicle, but has different willingness to pay for the trip. The total social cost of the road has two components: producer costs and user costs. Producer costs consist of constructing, maintaining and operating the road. User costs here consist only of vehicle expenses and time.

A key variable in road design is capacity. Infrastructure capacity determines the maximum number of users that can use a road in a period of time. The election of road capacity is determined by expected demand in a context of investment indivisibilities (Kraus 1981a). Indivisibilities are quite remarkable in the case of roads: in a highway, for example, each lane increases the capacity in two thousands vehicles per hour (Transportation Research Board 1985).

Toll road maintenance and operating costs include labor, equipment and materials needed to keep the road open and in good service, and to collect revenue. Maintenance and operating costs per year have two components: one is fixed and the other depends on the traffic volume and composition. The type of traffic is important because pavement damage is a function of “vehicle weight per axle” and the damage caused by an axle is defined by the number of “equivalent standard axle loads”[2] causing the same damage (Small et al.

[2] The concept “equivalent standard axle loads” defines the number of 10 tons axles producing the same road damage of a chosen vehicle. For example, a truck with two axles, loading 15 tons produces three times more road damage than another truck with the same load but one more axle. If the comparison is made with a car the damage is 1,000 times higher.

1989). The importance of maintenance and operation costs in a toll road in Europe is remarkable: 75% of building costs (French Highway Directorate 1999).[3]

Operator costs are assumed to be a function of two variables: the level of traffic borne by the road (q) and the investment and other fixed costs required to provide capacity. Equation (1) shows the annual cost of the road:

$$C_{(q,K)} = KCFI(K) + \alpha q. \tag{1}$$

Total costs in expression (1) are equal to all the infrastructure fixed cost per year $CFI(K)$ times the units of capacity (K) where construction costs, fixed maintenance and operating costs are included. The other component is variable with traffic and it is the result of multiplying the number of vehicles by the operating cost per vehicle (α), assumed constant for simplicity.

Road users pay for the vehicle costs, time spent in making their trips and impose time costs upon others when additional traffic reduces the speed of other vehicles increasing travel time. Total users cost can be expressed as the product of the average user cost, c_u(q,K), and the number of users, q:

$$C_u(q,K) = c_u(q,K)q. \tag{2}$$

The number of road users (q) is a function of the generalized cost of travel. The inverse demand function $g(q)$ shows the users' willingness to pay for making trips, and hence includes the user cost and the toll (p). In equilibrium, the willingness to pay of the marginal road user is equal to the generalized cost of travel at q:

$$g(q) = c_u(q,K) + p. \tag{3}$$

2.1. Optimal toll and capacity

Under the assumptions of perfect divisibility and perfect information on future level of traffic, the optimal price and level of investment can be derived by maximizing the social surplus generated from the operation of the road, i.e.

$$\max Z = \int_0^q g(z)dz - c_u(q,K)q - K.CFI(K) - \alpha q. \tag{4}$$

First order conditions yield:

$$\frac{\partial Z}{\partial q} = g(q^*) - \left[\frac{\partial c_u(q^*,K^*)}{\partial q} q^* + c_u(q^*,K^*)\right] - \alpha = 0 \tag{5}$$

$$\frac{\partial Z}{\partial K} = \frac{\partial c_u(q^*,K^*)}{\partial K} \cdot q^* - \left[CFI(K^*) + \frac{\partial CFI(K^*)}{\partial K} K^*\right] = 0. \tag{6}$$

Rearranging in Eq. (5) and using (3), the optimal price is obtained:

$$p = \alpha + \frac{\partial c_u(q^*,K^*)}{\partial q} q^*. \tag{7}$$

[3] For a concession period of 35 years and a traffic volume of 10,000 vehicles per day.

Pricing according to expression (7) allows an efficient use of the existing infrastructure. The first component (α) reflects the road damage borne by the responsible agent in maintenance and operation. The second component is the additional delay costs borne by other road users (Walters 1961; Vickrey 1969; Winston 1985; Newbery 1989).

The previous analysis assumed homogeneous traffic. The implementation of (7) requires distinguishing between different vehicle types according to their pavement damage and number of travelers. A classification of vehicles by the number of standard load axles and passenger car units (pcu) is required (see Fowkes et al. 1992).

From Eq. (6) the optimal investment decision rule can be obtained: invest in capacity until the saving in user costs equals the additional operator cost of expanding that capacity:

$$-\frac{\partial c_u(q^*, K^*)}{\partial K}q^* = CFI(K^*) + \frac{\partial CFI(K^*)}{\partial K}K^*. \tag{8}$$

2.2. *Private financing and optimal pricing*

To guarantee private participation in building and operating road infrastructure, road pricing must be compatible with cost coverage. According to expression (7) revenue is enough to cover maintenance and operating costs, but it is important to know whether revenue will also cover investment costs.

Pricing according to (7) and following the optimal investment rule in (8) allows the operator breaking even if there are constant returns to scale (Mohring and Harwitz 1962; Mohring 1965; Strotz 1965); therefore, it is unnecessary to add extra charges to cover infrastructure costs when optimal congestion pricing is being applied.

The former analysis is fraught with difficulties in its translation into practical rules. Increasing return to scale and indivisibilities make impossible to cover costs when optimal pricing rules are followed (Newbery 1989).

Empirical evidence on roads is not conclusive. Constant returns to scale are obtained in Keeler et al. (1977) for urban areas, and in Small et al. (1989) for a group of roads. Others, like Jansson (1984), or Kraus (1981b) report economies of scale of 1.2 for highways.

Optimal rules for pricing and investment as expressed in (7) and (8) have been obtained under the assumption of perfect divisibility in capacity provision. In practice, the number of lanes is a discrete variable, with jumps in capacity and costs. The economic consequences of these indivisibilities are important:

(i) Capacity adjustments according to expression (8) are not so immediate. It may well be that a wide range of user cost savings exists, derived from capacity expansion, does not justify the required investment cost.

(ii) Road investments are made to meet expected traffic growth, taking into account the additional costs (traffic diversion, congestion) during the construction period. Investment in capacity is planned to meet demand for a long period of time, therefore, it is possible that financial difficulties arise in the first years.

(iii) There are economic implications of (i) and (ii) in terms of pricing. Demand forecasting is crucial as well as trading off additional costs of investment at the beginning and the social costs of further expansion in the future. It is advisable to avoid high prices in the first years when demand is below available capacity.
(iv) There are two cases where discounted revenues fall short of discounted costs: when the road exhibits increasing returns to scale and when demand is permanently low. With low demand and indivisibilities, the capacity might be high enough that congestion never occurs during the whole lifetime of the investment; hence, the optimal price would simply cover the maintenance costs, but no the investment costs. Nevertheless, if the road is socially justified, prices should be modified following second best rules. Another option is cross-subsidization, as in the French highway network (Gómez-Ibáñez and Meyer 1993).

3. Fixed term *versus* variable term concessions

Conventional road concessions share a common key feature: their lifetimes are fixed *ex ante* based on the value of expected costs and demand. Under the assumptions of perfect information on cost and demand, a fixed term concession is compatible with the operator breaking even, when the following condition is satisfied (assuming $q > 0$ when $p_t > \alpha$):[4]

$$I = \sum_{t=1}^{T} \frac{(p_t - \alpha)q_t}{(1+i)^t}, \tag{9}$$

where the toll p enables covering investment costs (I), equal to $KCFI(K)$ in (1), and variable costs (αq), during the predetermined concession period (T), at a discount rate (i). With perfect information, the concession is awarded to the most efficient firm. This result does not change when the firms bid for payments to be made by the government. For a comparison of both types of auctions with revenue uncertainties see Nombela and de Rus (2003).

In practice, there are information asymmetries (on costs) and demand uncertainty. Expression (9) suggests why renegotiation is so frequent in concessioned toll roads. Even assuming that costs do not deviate from the budgeted figures, the level of demand has to be predicted for T years (usually more than thirty). Demand uncertainty is the key point behind the breach of concession contracts, and governments have often responded with tax exemptions or revenue guarantees (Fishbein and Babbar 1996; Gómez-Lobo and Hinojosa 1999). Contract renegotiation in Argentina led to changing the canon to be paid to the government for a subsidy paid to the concessionaires, and to increasing the road tolls (Estache and Carbajo 1996). In other cases like France, Spain or Mexico, government intervention has been necessary to rescue the private companies going bankruptcy (Gómez-Ibáñez and Meyer 1993).

[4] Even with $q > 0$, if q and $(p - \alpha)$ are not large enough, T could be too long to make the investment attractive.

It is important to underline that contract renegotiation has damaging effects in the selection of the concessionaire as well. The goal of a bidding process is to award the concession to the most efficient operator but with demand uncertainty and contract renegotiation there is a high possibility of selecting the operator with more "optimistic" beliefs about future level of traffic.

The financial equilibrium of a fixed term concession, assuming for simplicity a discount factor equal to one, can be expressed as:

$$pq_E T_F = I + \alpha q_E T_F, \tag{10}$$

where T_F is a predetermined concession period.

Assume that demand can actually be high (q_A) or low (q_B) and a representative bidder calculates his offer based on expected demand, which not necessarily coincides with the estimated traffic level by the public agency (q_E). Moreover, costs vary between bidders submitting offers to be selected as concessionaries.

In a bidding process with a sufficiently large number of bidders[5] in which a road concession is awarded to the bid containing the lowest toll, every participant has to offer the lowest toll compatible with breaking even. The most efficient firm (i) will make the following offer:

$$p_i = \frac{I_i}{q_i T_F} + \alpha_i, \tag{11}$$

where q_i is the expected demand of firm i with costs I_i,α_i.

Equation (11) shows how the offer of the efficient bidder is not only determined by his costs but also by his demand expectations. If the contract is awarded to the lowest bid and firms have different expectations on future level of traffic, it may well be that the winning offer is not necessarily the most efficient.

Suppose the second more efficient firm (j) has costs $I_j > I_i$ and $\alpha_j \geq \alpha_i$, but expected demand $q_j > q_i$. The less efficient bid can win the contract if the efficient firm bids a higher price:

$$p_i = \frac{I_i}{q_i T_F} + \alpha_i > \frac{I_j}{q_j T_F} + \alpha_j. \tag{12}$$

Condition (12) is satisfied if:

$$\frac{q_j}{q_i} > \frac{I_j}{I_i} + \frac{(\alpha_j - \alpha_i) q_j T_F}{I_i}, \tag{13}$$

which only requires that the inefficient bidder is optimistic enough to compensate his cost disadvantage.

Although this is a simple approach to model the complex world of road concessions, it clearly shows how an inefficient bidder with optimistic beliefs (left hand side term of expression (13) higher than one) can reduce the proposed toll and win. It can be also noticed that as long as his beliefs are upward biased, it may well be that his offer cannot be fulfilled (the winner's curse); nevertheless, in a context of contract renegotiation, overoptimistic bidders

[5] It is assumed here that the number of bidders tends to infinite and they bid their reservation prices.

know that *ex post* changes in contract conditions reduce considerably the risk of losses, and this inevitably reduces incentives to minimize costs.

An alternative option appears feasible in the design of concessions: to allow the concession term to vary with exogenous demand shocks. Its rationale is to reduce the uncertainty of demand with the aim of selecting the most efficient operator. Once the concession has been awarded it is important that appropriate incentives are built into the contract to achieve cost minimization in the benefit of users and taxpayers.

In this system, price is not longer an endogenous variable. Instead of bidders offering a toll p to be charged for the use of the road, the government set the price and they bid fixed payments to be made by the government.

The *least present value of revenues* mechanism to award road concessions (Engel et al. 1997, 2001) or the *least present value of net revenue* (de Rus and Nombela 1999; de Rus et al. 2000; Nombela and de Rus 2003) are based on bidding to recover the investment and profits, without a predetermined concession term in exchange of constructing, maintaining and operating the road. In both, the government fixes the price (or a range of prices depending on traffic conditions). In the first type, the bidder asks for the total amount he wants to recover (least present value of revenue). In the second type, the bidder submits two figures: one for the main investment to be recovered and another (annual maintenance and operation costs) to be subtracted from the annual revenue.

When the concession period is variable and assuming that all maintenance and operating costs depend on traffic, firm i faces the following break even condition:

$$pqT = I_i + \alpha_i qT, \tag{14}$$

where p is predetermined by the public agency.

The life span of the concession is, for firm i:

$$T = \frac{I_i}{q(p - \alpha_i)}, \tag{15}$$

where T is not predetermined and changes with the actual level of demand. In this case, the efficient firm submits a bid (B_i) to cover total costs ($I_i + \alpha_i qT$). Inserting T, according to (15), in ($I_i + \alpha_i qT$), Eq. (16) is obtained:

$$B_i = \frac{p}{p - \alpha_i} I_i, \tag{16}$$

where the bid is independent of demand, and so the efficient firm always wins ($B_i < B_j$). In (16) demand uncertainty is eliminated and the bid depends exclusively on the *ex ante* investment to be recovered, and the externally fixed price. When α_i is equal to cero, the winning bid is equal to I_i. When α_i is positive the bid increases with α_i.

When the assumption of maintenance and operating costs depending on traffic, is relaxed, and some of these costs (M) are fixed per year (for example, lighting and labor costs for tolls collection) Eq. (16) becomes:

$$B_i = \frac{p}{p - \alpha_i - \frac{M_i}{q}} I_i. \tag{17}$$

Equation (17) shows why bidding with one variable (least present value of revenue) does not eliminate demand uncertainty. The bid depends on the expected number of years, which depends itself on the expected demand. A flexible-term concession based on the *least present value of net revenue* substantially reduces this problem, because any bidder submits an offer with a value for I and a value for M, this one being discounted from revenue every year during the life of the concession, until I is fully recovered (de Rus and Nombela 1999).

Once demand uncertainty has been eliminated it is practically unnecessary to renegotiate the contract, because the concessionaire is operating the infrastructure until the *ex ante* investment costs are covered. In exceptional circumstances, when there is a cause that justify to break the contract or to alter its condition (unforeseen expansion in road capacity, for instance) the amount to be paid is easily worked out as the difference between I_i and the discounted net revenue collected.

4. Pricing and type of concession

In a fixed term concession, prices lose their allocative role because once the life of the concession has been exogenously determined; price is the variable to be adjusted in order to let the operator breaking even. It is worth noticing that when demand is relatively inelastic, tolls will be adjusted in the opposite direction of what it should be desirable for an efficient use of the road.

Empirical evidence supports price elasticities lower than one,[6] and therefore when demand is low, and it is not possible to cover costs, prices will increase, though economic efficiency would require price cuts given the existing unused capacity. The problem can be even worse if the reason behind the low level of demand is the existence of alternative untolled roads. Increasing the road toll has the additional undesirable effect of increasing traffic in the congested substitutive free road (as it was the case in Mexico: Ruster 1997). Alternatively, when demand is high and congestion appears, price should be increased, but political pressure will go in the opposite direction.

4.1. Constant demand during the concession term

Following the analysis of Sect. 3, Fig. 1 shows that for a predetermined concession term, when actual demand is equal to expected demand (q_E), revenue will cover investment and variable costs. When demand is q_A the concessionaire will benefit from supernormal profits (segment *cd*). In this case, the only way to reduce profits is cutting the price, as far as demand-price elasticity is less than one.

When demand is q_B the operator will not cover total costs (losses equal to *fg*) therefore he will try to force the renegotiation of the concession contract, unless some mechanism of revenue guarantee has been established previously. Contract renegotiation can follow different ways: subsidies, enlarging the concession life, raising prices or a combination of them. In any case, the operator knows this in advance, so incentives to minimize costs are weak.

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6 Weustefield and Regan (1981), Goodwin (1992), Jones and Hervik (1992), Oum et al. (1992), Hirschman et al. (1995), Mauchan and Bonsall (1995), Matas and Raymond (1999).

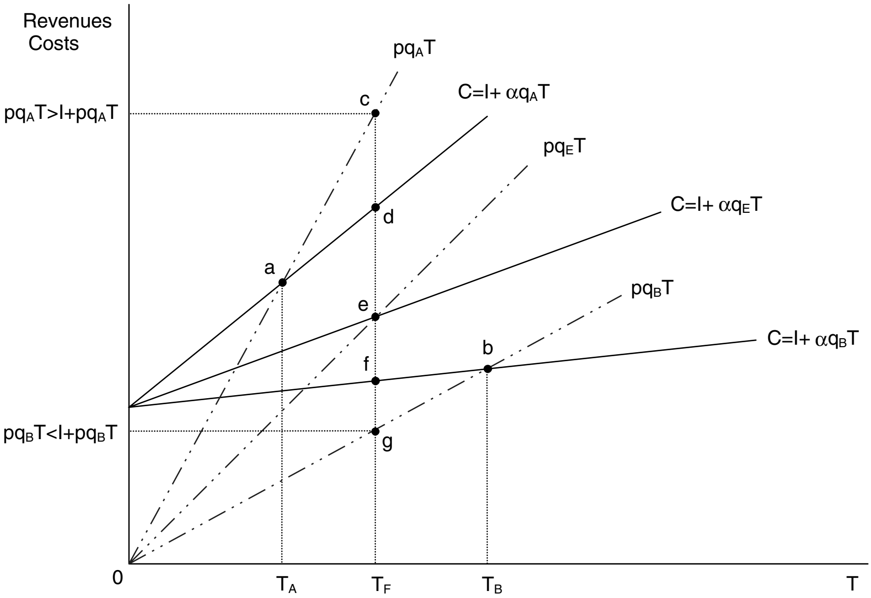

Fig. 1. Fixed term versus variable term concession

Figure 1 illustrates that, with fixed term concessions, profits or losses are unavoidable when actual demand deviates from the expected level. Price adjustments translate into changes in the slope of the revenue and cost lines and the break even point (*e*) is reached again for a predetermined concession life of T_F years.

When the concession life is variable, T changes with the actual level of traffic. Therefore, the concession period is extended to T_B when demand is low to allow the operator a longer concession life. In this case, the private firm can collect the required revenue to cover costs. It should be noticed that this extension of the concession term is automatic. No renegotiation is needed. Similarly, when demand is high, concession life expires earlier, in T_A. A key point is that as long as the concession term is adjusted automatically, prices recover their fundamental role in the allocation of road capacity.

When demand is expected to be permanently below capacity (no congestion), price is equal to α according to expression (7); hence it would be impossible to recover the investment; i.e., T tends to infinite according to (15). This may imply that the social benefits on that uncongested road are below social costs. Nevertheless, the opposite could be true and a subsidy or second best pricing would be required to provide the necessary capacity. Cost-benefit analysis is the standard economic instrument to decide whether road capacity should be provided.

4.2. Variable demand during the concession term

If one relaxes the assumptions of a constant level of demand and constant prices, it is easy to show that a cost coverage price structure exists, as long as the concession term is variable and the willingness to pay is higher than the average variable cost.

The maximization of net social benefits subject to the break even constraint (assuming a discount factor equal to one), is the following:

$$\max Z = \sum_{t=1}^{T(q)} \left[\int_0^{q_t} g(z)dz - c_u(q_t, K)q_t - K \cdot CFI(K) - \alpha q_t \right]$$

$$\text{s.t.} \sum_{t=1}^{T(q)} [p(q_t)q_t - K \cdot CFI(K) - \alpha q_t] = 0. \tag{18}$$

The first order conditions lead to a demand function, which depends on road tolls and concession length:[7]

$$q_t = f(p_t^*, T^*). \tag{19}$$

It is not possible to solve simultaneously for T^* and q_t . Multiple solutions appear, because the demand level compatible with cost coverage is a function of the road toll or, alternatively, the concession period.

So it is possible to reduce the toll in exchange of a longer concession period. In the vector of possible solutions, there is one that allows economic efficiency: pricing according to expression (7). Once the optimal road tolls have been set, the concession life T has to be determined to allow the concessionaire to cover costs. With this aim, a budget constraint is imposed, where q_t^* represents the unrestricted problem solution:

$$\sum_{t=1}^{T(q)} \left[p(q_t^*)q_t^* - K \cdot CFI(K) - \alpha q_t^* \right] = 0. \tag{20}$$

The solution is a vector of prices for each period as a function of the traffic level. When congestion is permanently low and first best prices lead to an extremely long concession term, prices could be modified following second best pricing rules.

5. Conclusions

The growing participation of the private sector in constructing, maintaining and operating road infrastructure has been justified for its positive effects on public budgets and cost efficiency in the provision of the required transport capacity. Private involvement in public transport infrastructure has taken place through concessioning, and specifically through fixed term concession agreements.

In a situation in which a government procures for a new road with a fixed term concession, there will almost certainly be an adverse selection effect, that will lead to the selection of a "optimistic" bidder who expects a high level of demand (or one who speculates in a "soft" government compensating for a lower demand). This will result on offers with prices which are optimal for a higher level of demand.

[7] In practice, users would be classified by vehicle type (heavy and light usually) and time period.

The history of private investment in toll roads has been full of financial difficulties basically due to demand uncertainty. A typical road has a long lifetime, long enough to make an accurate demand forecast impossible. Initial contract agreements have to be revised during the concession term, and prices are usually modified to allow the operator to break even.

Evidence on demand price elasticities for toll roads shows that demand is relatively inelastic, so when demand is below the expected level, prices are adjusted in the opposite direction of what economic efficiency dictates. With persistent low demand the operator will call for higher prices. Conversely, with high demand the public opinion will claim for price cuts.

It is well established in the economic literature on road pricing that prices should be set according to road damage caused by the vehicle, the level of congestion and the external costs. It is also a well known result that, when optimal pricing and investment rules are followed and constant returns to scale characterizes the provision of capacity, an extra charge to recover the fixed costs of the infrastructure is not necessary

In the real world, the presence of indivisibilities, demand uncertainty and the nature of fixed term concession contracts make very difficult to apply optimal pricing. Variable term concessions could help in the introduction of optimal road pricing without compromising private involvement in the construction, maintenance and operation of roads.

References

Bousquet F (1999) Road infrastructure concession practice in Europe. Working Paper, World Bank. Washington, D.C

de Rus G, Nombela G (1999) Least present value of net revenue: A new proposal for highway concessions. Documento de trabajo. Departamento de Análisis Económico Aplicado. Universidad de Las Palmas de Gran Canaria

de Rus G, Romero M, Trujillo L (2000) Participación privada en la construcción y explotación de carreteras de peaje. Documento de trabajo, 159. Fundación Fondo para la Investigación Económica y Social. FIES

Engel E, Fischer R, Galetovic A (1997) Highway franchising: Pitfalls and opportunities. American Economic Review 87 (2): 68–72

Engel E, Fischer R, Galetovic A (2001) Least-present-value-of-revenue auctions and highway franchising. Journal of Political Economy, 109: 993–1020

Estache A, Carbajo J (1996) Designing toll road concessions-lessons from Argentina. Viewpoint, World Bank, Washington, D.C

Fishbein G, Babbar S (1996) Private financing of toll roads. Discussion Paper Series No. 17. World Bank, Washington, D.C

Fowkes A, Nash C, Tweddle G (1992) Harmonising heavy goods vehicles taxes in Europe-A British view. Transport Reviews 12 (3)

French Higway Directorate (1999) Analysis of highway concessions in Europe. Ministry of Public Works, Transportation and Housing, Paris

Gómez-Ibáñez JA, Meyer JR (1993) Going private: the international experience with transport privatisation. Brookings Institution,Washington D.C

Gómez-Ibáñez JA, Bastin J, Ichsan F (1992) Private sector involvement in toll road development in Indonesia: A critical review of current experiences. Directorate General of State Enterprises, Ministre of Finance, Indonesia

Gómez-Lobo A, Hinojosa S (1999) Broad roads in a thin country. Infrastructure Concessions in Chile, World Bank

Goodwin PB (1992) A review of new demand elasticities with special reference to short and long run effects of price changes, Journal of Transport Economics and Policy. 26(2): 155–169

Hirschman I, McNight C, Puscher J, Paaswell RE, Berechman J (1995) Bridge and tunnel toll elasticities in New York. Some recent evidence. Transportation, 22: 97–113
Jansson J (1984) *Transport system optimization and pricing*. Wiley, New York
Jones P, Hervik A (1992) Restraining car traffic in European cities: An emerging role for road pricing, Transportation Research A 26(2): 133–145
Keeler T, Small K (1977) Optimal peak-load pricing, investment, and service levels on urban expressways. Journal of Political Economy. 85(February)
Knight F (1924) Some fallacies in the interpretation of social costs. Quarterly Journal of Economics, 22: 103–121
Kraus M (1981a) Indivisibilities, economies of scale, and optimal subsidy policy for freeways. Land Economics. 57(1. February): 115–122
Kraus M (1981b) Scale economies analysis for urban highway networks. Journal of Urban Economics.(9, January)
Matas A, Raymond JL (1999) Elasticidad de la demanda en las autopistas de peaje. Papeles de Economía Española, 82: 140–165
Mauchan AD, Bonsall P (1985) Model predictions of the effects of motorway charging in West Yorkshire. Traffic Engineering and Control 36(4): 206–212
Mohring H (1965) Urban highway investment. In: Dorfman. R.(ed) Measuring benefits of government investments. The Brookings Institution, Washington D.C.
Mohring H, Harwitz M (1962) Highway benefits: An analytical framework. Northwestern University Press, Evanston III
Newbery DM (1988) Road user charges in Britain. The Economic Journal (Conference 1988): 161–176
Newbery DM (1989) Cost recovery from optimally designed roads. Economica 56(222, May): 165–85
Newbery DM (2000) Road pricing and road Finance, In: Preston J, Smith HL, Starkie D (eds) Integrated transport policy: Implications for regulation and competition. Aldersho. Ashgate
Newbery DM (2002) Road user and congestion charges, Paper presented to the conference Excise Taxation, The Haghe
Nijkamp P, Rienstra SA (1995) Private sector involvement in financing and operating transport infraestructure. The Annals of Regional Science. 29: 221–235
Nombela G, de Rus G (2003) Flexible-term contracts for road franchising. UCTC Working Paper, University of Berkeley
Oum TH, Waters WG, Young JS (1992) Concepts of price elasticities of transport demand and recent empirical estimates. Journal of Transport Economics and Policy. 26(2): 139–154
Pigou AC(1920) Wealth and Welfare. Macmillan, London
Ruster J (1997*)* A retrospective on the Mexican toll road program (1989–94). September, Viewpoint, World Bank, Washington, D.C
Small K, Winston C, Evans C (1989) Road work. Brookings Institution, Washington, D.C.
Strotz R (1965) Urban transportation parables. In: The public economy of urban communities. Resources for the Future, Washington, D.C
Thomson JM (1998) Reflections on the economics of traffic congestion. Journal of Transport Economics and Policy 32(January): 93–112
Transportation Research Board (1985) Highway capacity manual. Special Report 209, Washington D.C
Vickrey W (1969) Congestion theory and transport investment. American Economic Review 59 (2, May): 251–260
Walters AA (1961) The theory and measurement of private and social cost of highway congestion. Econometrica. 29(4 October): 676–699
Weustwfield NH, Regan EJ (1981) Impact of rate increases on toll facilities. Traffic Quarterly. 34(4): 639–655
Winston C (1985) Conceptual developments in the economics of transportation: An interpretative survey. Journal of Economic Literature. 23(1, March) 57–94
Winston C (1991) Efficient transportation infrastructure policy. Journal of Economic Perspectives 5(1, Winter): 113–127