Road Pricing, Traffic Congestion and Economic Welfare: A Note

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Summary

Only recently, the subject of road pricing to reduce traffic congestion gained increasing importance in Europe. This paper uses a standard microeconomic approach to show that road user price charging to avoid traffic congestion is optimal from a society's point of view as it improves economic efficiency of allocating a scarce resource (road space) by reducing the welfare loss (as being measured by a loss in consumer surplus) for everyone in the society.

1 The question

In Switzerland (and elsewhere in Europe), the subject of road pricing to reduce traffic congestion was not a primary matter of public or academic interest until recently. However, as the number of congested hours per year keeps growing and information about successful experiences abroad become available (see the London Congestion Charge), the mentalities begin to change slowly. Road pricing is more and more considered as an alternative to "just keep waiting in the traffic jam" [UK Department for Transport; Ahlstrand; Willoughby; Grieco and Jones ; Raux and Souche][1]

As road pricing is an exchange of money for "time lost", it is discussed if and how beneficial and welfare-enhancing road pricing is from the society's point of view. A good example of this controversial discussion is the immediate reaction of the TCS (Touring Club Suisse) to a conference on road pricing organized on 30.04.2004 by the VCS (Verkehrsclub der Schweiz; Swiss Traffic Association) in Bern, Switzerland. On 01.05.2004 an article entitled « Payer pour entrer en ville? » was published in „*Le Matin*". The report contained the following quotation: "Pour le TCS, le péage urbain est inadapté et anti social".

This paper is concerned with the following question: Is the use of road pricing to reduce traffic congestion really "anti social"? Does it produce socially harmful results? We hereby limit the application of the concept of road pricing only to its effect on traffic congestion. Its application to other uses like financing infrastructure, covering social costs, etc. has been extensively discussed elsewhere in the literature [Levinson]. We are also aware that pricing

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[1] A number of initiatives have been introduced by the European Commission, for example, PRoGRESS (Pricing Road Use for Greater Responsibility, Efficiency and Sustainability in Cities) has been developed under the fifth Framework Programme of the European Commission. It aims to 'demonstrate and evaluate the effectiveness and acceptance of integrated urban transport pricing schemes to achieve transport goals and raise revenues. The project centres on eight demonstration sites: Bristol, Copenhagen, Edinburgh, Genoa, Gothenburg, Helsinki, Rome and Trondheim. Across these sites a number of road pricing concepts and technologies are being developed and demonstrated. PRoGRESS is co-ordinated by Bristol City Council. CUPID is the EC funded thematic network on urban transport pricing running in parallel to PRoGRESS. It is a partnership of six European expert organisations working together to promote state of the art knowledge on urban transport pricing schemes. See: http://www.transport-pricing.net/links-urban.html for the relevant links on CUPID, the European Transport Pricing initiative.

is certainly not the only device for allocating road space – but within the process of the workings of markets it is maybe the most effective one.

2 Economics of road pricing to reduce congestion

2.1 Internalizing external costs

If a traffic system is approaching congestion, each new driver will contribute to reduce the speed of all. This is a classic example of the "Tragedy of the Commons"[2]: he/she disturbs all other drivers by increasing their travel time and therefore their generalized costs. As these delays to other vehicles represent a negative externality (that is, external costs) for the other drivers, the internalisation would consist in having each new driver paying all others for the additional costs produced to them.

2.2 Transport supply

In individual transport the supply side is mainly determined by the capacity of the infrastructure (junctions and roads). The relation between travel time or costs (which are proportional to the effort needed to use this infrastructure) and use of this capacity is defined with so called "volume delay functions" [Branston]. Such functions describe the relationship between travel time t[h] and traffic volume q[vhc/h]. Widely used is the volume delay function of the US Bureau of Public Roads [Chu]:

$$t(q) = t0 \, [1 + a \, (q/q_{max})^{b}]$$

where :

$t0$ = free flow travel time [h]

q = traffic volume [vhc/h]

q_{max} = maximum capacity of the road [vhc/h]

a, b = parameters, e.g. $a = 0.15$ and $b = 4$

Many of such functions exist and they all look very similar. As long as the traffic flow q[vhc/h] is below the capacity q_{max}, the travel time increases only slowly as a function of the number of drivers. But as soon as the capacity is reached, the total system collapses. Traffic congestion arises and time (and costs) incrases sharply for all drivers in the system.

The limit between "free flow" and "congestion" is so narrow that a simple kinked supply curve (S) (containing these two parts) will suffice for our analysis (Fig. 1).[3]

[2] Mankiw (2004), ch. 11, p. 231ff.

[3] In standard microeconomic analysis, the short-run supply curve is represented by the firm's marginal cost curve. Therefore, pricing schemes follow the marginal cost pricing pattern.

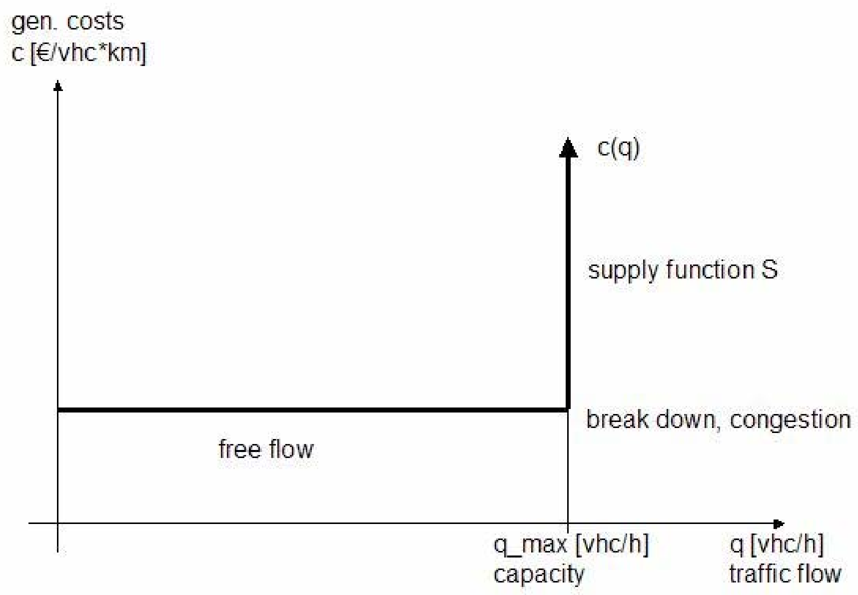

Fig. 1

2.3 Traffic demand and consumer surplus

The demand function (D) in Fig. 2 shows how drivers are using the infrastructure: The lower the costs, the more they will drive. Drivers tend to make more and/or longer trips as costs decrease and traffic [vhc*km/h] increases gloablly. (The business model of the airline company EasyJet is based on this principle)

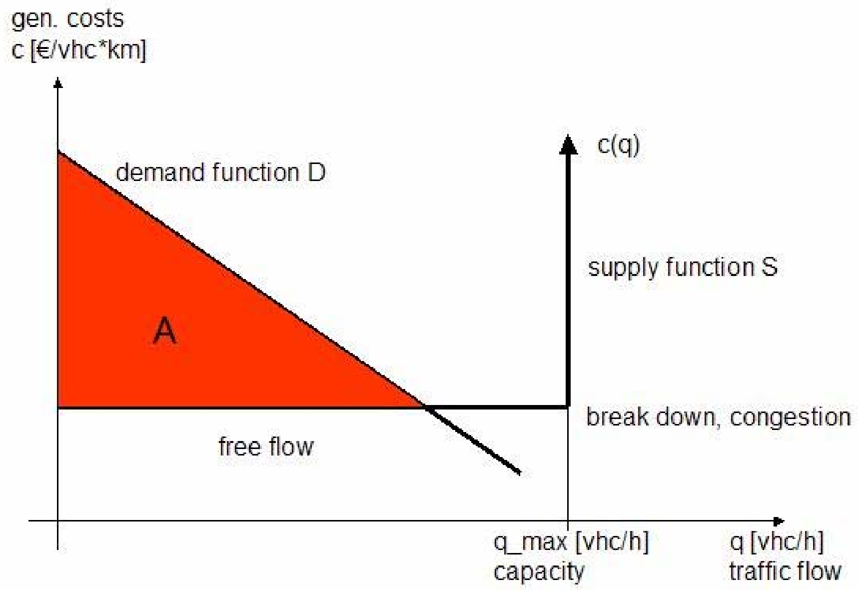

Fig. 2

The consumer surplus is the difference between the maximum willingness to pay (demand) and the price actually paid (supply). Surface A between both the supply and the demand curve is the consumer surplus summed over all drivers in the system. The consumer surplus is largest when surface A is largest.

2.4 Optimal road pricing with free flow traffic

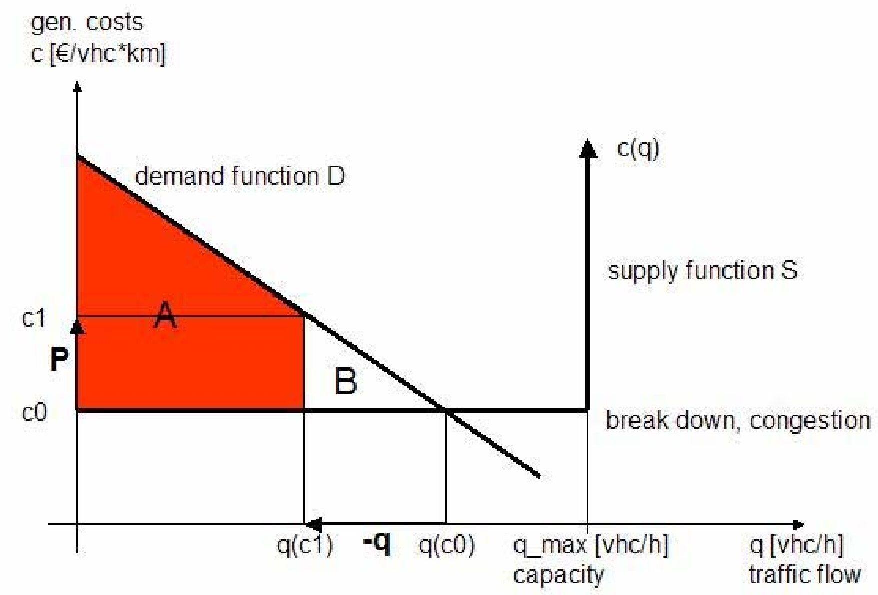

Fig. 3

Fig. 3 shows that road pricing P increases the costs from c0 to c1. This cost increase induces a decrease of traffic from q(c0) to q(c1), inspite the fact that there is enough capacity available. Road pricing P reduces the surface A of the consumer surplus. Surface B is a corresponding loss of welfare. The situation is identical to a monopoly, where a price is increased from c0 to c1 [Böbel]. As the surface A is a maximum when P = 0, we can state:

Optimal road pricing with free flow traffic is equal to zero.

A direct consequence of this is that road pricing must be variable in space and time. Road pricing must only be used when and where it helps to reduce congestion. All other applications are similar to any tax, toll, etc.[Shepherd]

2.5 Optimal road pricing with congestion

We consider 3 cases with diminishing road prices P1, P2, P3

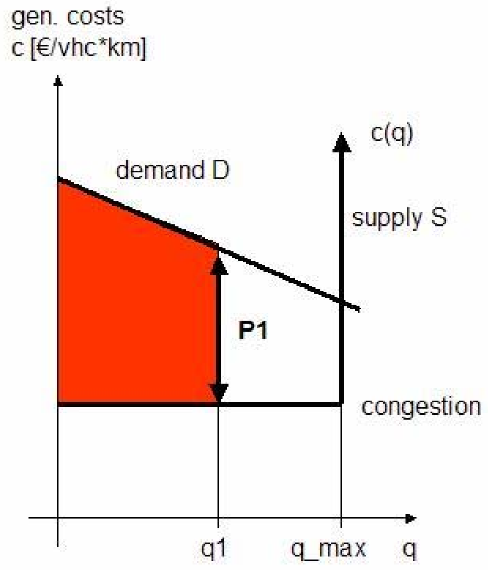

Fig. 4

Case 1 (Fig. 4): Price P1 > P2 reduces the demand unnecessarily, capacity (q_max – q1) remains unused. It is the case without congestion.

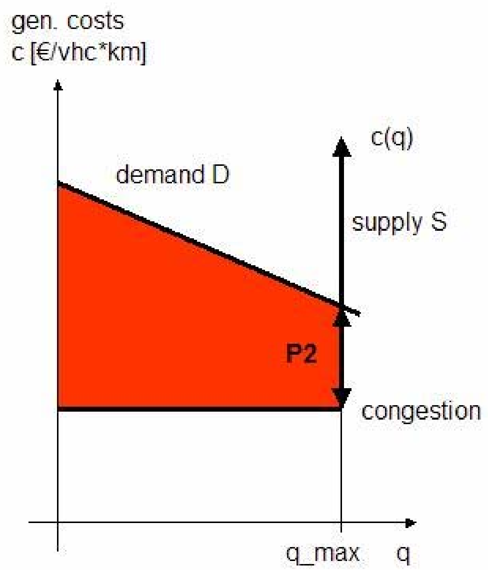

Fig. 5

Case 2 (Fig. 5): Price P2 is just high enough to avoid congestion. It produces the largest area and the largest consumer surplus (and therefore the largest economic welfare).

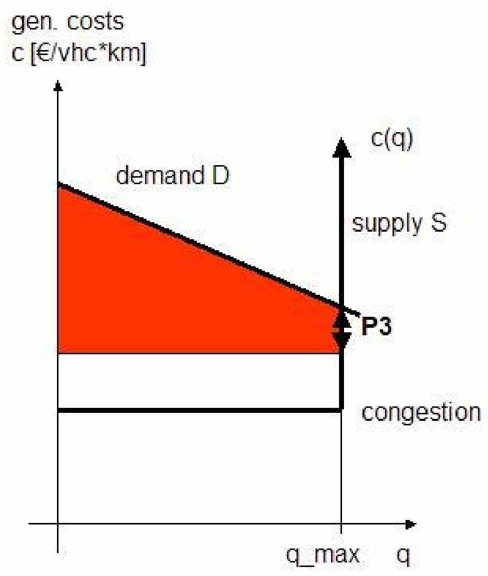

Fig. 6

Case 3 (Fig. 6): Price P3 < P2 works only partially, congestion will diminish but not disappear.

Therefore we can conclude:

Road pricing is optimal when congestion is just avoided

This result has important practical implications. The road pricing regulating authorities must possess the flexibility to instantly adjust price P2 to the changing external conditions – as in the case of the city of Singapore [Singapore Land Transport Authority] where the electronic road pricing system works astonishingly well since 1998[4]

2.6 Some additional remarks to the "optimal price - case 2":

[4] L. C. Thurow (1995)

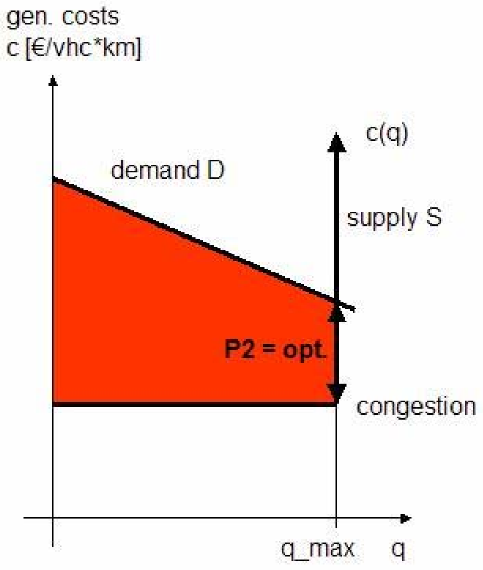

Fig. 7

In the case of congestion (Fig. 7), the increase in consumer surplus equals the optimal road pricing. This leads to the apparent paradox that the price P2 paid by each driver is individually seen as a loss, but in fact represents an avoided loss of welfare for everyone.

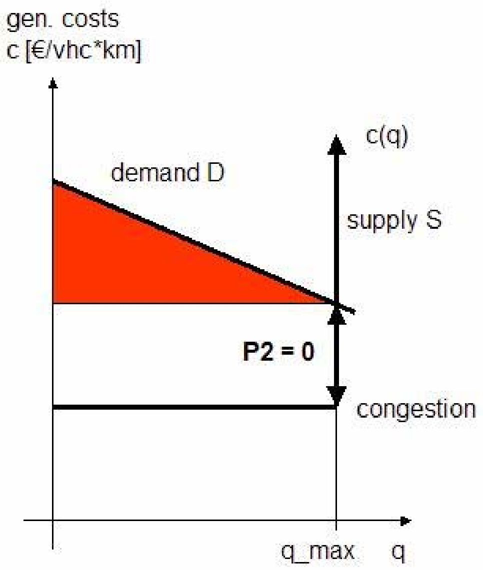

Fig. 8

This can be seen in Fig. 8. If road pricing P = 0, all drivers induce a waiting time to all others. The value of this time is definitively lost, it is a welfare loss for everyone. If, on the other hand, *some* drivers pay the price P2, this price has an economic value which can be reused elsewhere. It is not lost, the welfare loss is avoided and each individual is made better off.

3 The answer

In the absence of road pricing, all drivers will wait in traffic jams. This waiting time is definitively lost for everyone, it is a net loss of social welfare or value, like burning bank notes. It is what we could call a “deadweight loss of traffic congestion”.

With road pricing the waiting time will be exchanged for money. The value of this money can continue to flow in the economy. It is not lost, it must not be earned again from scratch.

This is the answer: The “more social” (and therefore, the least anti social) solution is that one that minimizes the welfare loss. Therefore:

CONGESTION WITHOUT ROAD PRICING IS WELFARE REDUCING AND THEREFORE ANTI-SOCIAL.

4 Conclusions

- Road pricing to reduce congestion must only be applied when it really reduces congestion.
- Road pricing with free flow traffic must be equal to zero. If not, it represents just another tax, toll, etc.
- The price level should be dynamically adjusted. The price should adjust in a way that congestion is just avoided. This represents the optimal economic solution.
- The differentiation between city, agglomeration, motorway, tunnel, bridge, etc. is artificial and brings unnecessary complexity into the discussion. Road pricing is justified as soon as traffic congestion shows up, independently of the type of infrastructure.

REFERENCES

[Ahlstrand] Ahlstrand I., The Politics and Economics of Transport Investment and Pricing in Stockholm, Journal of Transport Economics and Policy, 1 September 2001, vol. 35, no. 3, pp. 473-489

[Böbel] Böbel, I., Wettbewerb und Industriestruktur, Berlin-Heidelberg-New York (Springer) 1979

[Branston] Branston, D. Link Capacity Functions: A Review, Transportation Research 10, 1976, p.223-236

[Chu] Chu, X., Alternative congestion pricing schedules, Regional Science and Urban Economics, November 1999, vol. 29, no. 6, pp. 697-722

[Collectif CETUR], Péage Urbain, CETUR, Bagneux 1994

[Grieco and Jones] Grieco M.; Jones P.M., A Change in the Policy Climate? Current European Perspectives on Road Pricing, Urban Studies, November 1994, vol. 31, no. 9, pp. 1517-1532

[Levinson] For an excellent graphical explanation of congestion pricing see David Levinson's paper http://www.ce.umn.edu/~levinson/ce8214/pricing.pdf as well as Levinson's extensive publications on this subject of Road Pricing under http://www.ce.umn.edu/~levinson

[Mankiw] Mankiw, N. G., Principles of Economics, 3e., New York (Thomson) 2004

[Raux and Souche] Raux C.; Souche S, The Acceptability of Urban Road Pricing: A Theoretical Analysis Applied to Experience in Lyon, Journal of Transport Economics and Policy, 1 May 2004, vol. 38, no. 2, pp. 191-215

[Shepherd] Shepherd, S. P., Towards marginal cost pricing: A comparison of alternative pricing systems, Transportation, November 2003, vol. 30, no. 4, pp. 411-433

[Singapore Land Transport Authority] Singapore Land Transport Authority, www.lta.gov.sg ERP (Electronic Road Pricing)

[Thurow] Thorow, L. C., The Singapore Solution, The Boston Globe, February 28, 1995, p. 40

[Willoughby] Willoughby C., Singapore's motorization policies 1960-2000, Transport Policy, April 2001, vol. 8, no. 2, pp. 125-139

[UK Department for Transport] Study Report available under : http://www.dft.gov.uk/stellent/groups/dft_roads/documents/divisionhomepage/029798.hcsp