City Tolls – One Element of an Effective Policy Cocktail*

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For almost fifty years, following William Vickrey's lead (1959, 1963), urban transport economists have been advocating congestion pricing as *the* way of dealing with urban auto congestion.[1] Their advocacy was based on the standard analysis of the Pigouvian internalization of an externality. Drivers impose an external congestion cost on other drivers by slowing them down. If this congestion cost is internalized by means of a Pigouvian tax/congestion toll, then traffic congestion will be at the right level. Vickrey's original (1959) proposal was to equip each car with a transponder that would send a signal to roadside receptors, which would be relayed to a central computer. The computer would record the driver's movements, calculate the congestion externality cost imposed by him in his travels and bill him for this amount.

This congestion pricing scheme was criticized on many grounds: it would compromise privacy; by making people pay with money rather than with time, it would hurt the poor; it would be impractical and excessively costly to administer; and it would be political poison since it would make people pay for a commodity – public road space – that had previously been provided free of charge, and would be regarded as a tax grab. For many years, congestion pricing was simply dismissed by policy makers. That was phase I.

In phase II, a number of changes occurred. Urban transport economists, acknowledging the validity of many of the criticisms of Vickrey-type schemes, modified their congestion pricing proposals. Privacy issues would be dealt with through the use of prepaid smart cards; concerns about equity and a tax grab would be addressed by transparently redistributing toll revenues in a way that would benefit all major stakeholders (Small (1992, 1993)); and congestion pricing would be applied more coarsely, through cordon pricing or through charging for travel on only urban freeways and highway, for example.

Policy makers, meanwhile, were getting increasingly frustrated by the failure of standard policies – building more roads and later encouraging mass transit – to stop the seemingly inexorable worsening of traffic congestion.[2] The results of Hong Kong's congestion-pricing experiment and the increasingly refined congestion-pricing schemes employed in Singapore were widely discussed; they demonstrated that drivers do respond predictably to congestion prices and that congestion pricing is technologically feasible and can be implemented at reasonable cost. There was also political momentum to privatize transport systems, which for highways requires road pricing. By the end of phase II, many freeways around the world had more or less sophisticated tolling structures. Singapore had a generally successful cordon pricing scheme in place, several Norwegian cities had implemented cordon tolls, and a number of jurisdictions (Hong Kong, Cambridge, Berkeley, the Randstad area of the Netherlands, and Stockholm) had given serious consideration to the implementation of congestion pricing but had backed down in the face of political opposition.

* Many of the themes in this article are found in Chapter 1 of *Alleviating Urban Traffic Congestion* (2005). This notwithstanding, my co-authors on that book, Tilmann Rave and Ronnie Schöb, may not share the opinions I express in this article. I would like to thank Robin Lindsey and Ronnie Schöb for providing comments on an earlier draft, and Robin Lindsey for updating me on the literature.

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[1] This is of course an exaggeration. Urban transport economists instead say, "Get the prices right through congestion pricing, and other elements of urban transport policy will be easy to optimize." If all prices are right, then urban land use will be efficient, and infrastructure will be chosen efficiently if the intuitive, first-best investment rules are followed. As a bonus, if as is argued in footnote 4 urban auto transportation is characterized by increasing long-run average cost, then the revenue raised from the optimal tolls will be more than enough to finance optimal capacity (Mohring and Harwitz (1962), Strotz (1965) and Arnott and Kraus (1998)).

[2] For US metropolitan areas, the steady rise in congestion levels has been documented by the Texas Transportation Institute (The "2005 Urban Mobility Report" is available at http://mobility.tamu.edu/ums/report/). The Institute measures the degree of urban auto congestion by the number of hours of vehicle delay in rush-hour traffic per year experienced by the average driver. For other countries (except perhaps the United Kingdom) the steady rise in congestion levels is not well documented but is asserted by almost all experts.

The highly visible London area pricing experiment has been more successful than almost all the experts had predicted. It has succeeded in substantially reducing the level of auto congestion in central London, without a marked increase in congestion on the Inner Ring Road just outside the congestion charging zone. And unexpectedly, by substantially reducing travel time variability on city streets, the modal shift has been from car to bus. The success of the London experiment has prompted many cities around the world to initiate a congestion pricing planning process. We are now entering phase III, in which urban auto congestion tolling is being widely discussed in policy circles and may come to be implemented on a widespread basis. The topicality of urban auto congestion pricing is the primary reason for the focus of this issue of the journal on "City Tolls".

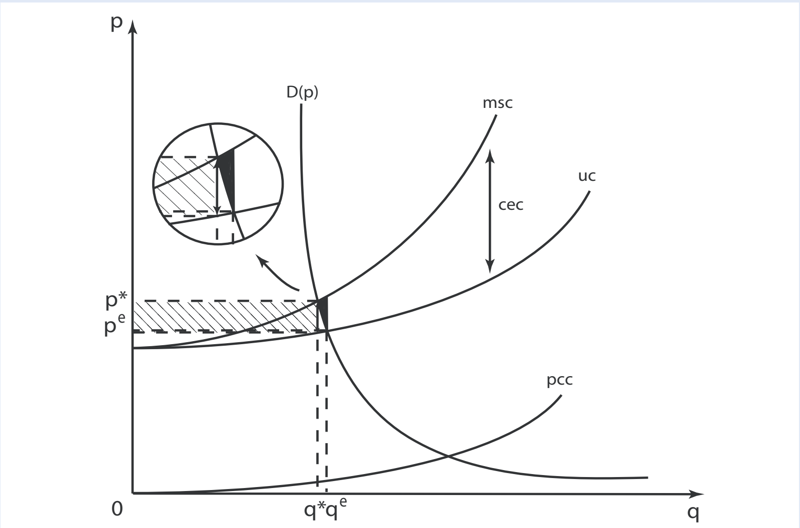
This article has three aims. The first is to summarily review the economic theory of congestion tolling as background for this and other articles in the issue. The second is to sound a cautionary and somewhat heretical note: Look before you leap; the net benefits from urban auto congestion tolling may not be as considerable as its ardent supporters claim. The third is to urge urban transport economists to move beyond their preoccupation with urban auto congestion pricing and to become more active in bringing economics to bear on the wide range of complementary policies that could be effective in alleviating urban traffic congestion.

The economic theory of congestion pricing

The Figure presents the standard diagram for the economic analysis of traffic congestion. The analysis is done in price-quantity space, where p is the full price of a trip, including money costs, time costs and where applicable the toll, and q is the number or flow rate of trips. Capacity is taken to be fixed; the analysis is therefore short run. The demand function plots the quantity of trips demanded as a function of price, D(p). There are two relevant cost functions. The first, sometimes termed the user cost function and sometimes the marginal private cost function, relates the private cost of a trip to the flow on the road; congestion increases as flow increases, increasing trip time and user cost. User cost (uc) in excess of free-flow user cost is termed private congestion cost (pcc). The second is the marginal social cost (msc), which gives the social cost of an extra trip as a function of flow. This equals the user cost plus the congestion externality cost (cec) – the cost a driver imposes on others by slowing them down.

In the absence of congestion pricing, the equilibrium occurs at that flow level, q^e, for which marginal private cost equals trip price – where the marginal private cost curve intersects the demand curve. The optimum however occurs at that level of flow, q^*, for which marginal social cost equals marginal social benefit. On the assumption that marginal social benefit equals private willingness to pay, the optimum is given by the point of intersection of the demand curve and the marginal social cost curve. Imposing a congestion toll equal to the congestion externality cost, evaluated at the optimum, τ^*, causes the trip cost function to shift up such that it intersects the demand curve at the optimal flow level. The revenue from the optimal toll is shown as the cross-hatched area. At a particular flow level, marginal deadweight loss, the increase in deadweight loss from an additional driver, equals marginal social cost minus marginal social benefit at that level of flow. The total deadweight loss from imposing no congestion toll, shown as the solidly shaded area in the Figure, equals the integral of marginal deadweight

URBAN TRAFFIC CONGESTION:
THE DEMAND FOR AND COSTS OF CITY AUTO TRIPS



loss from the optimal to the equilibrium level of flow. Capacity expansion results in a downward shift of both the user cost and marginal social cost curves.

Some cautionary notes

In this section, I explain why I am more restrained in my advocacy of urban congestion tolling than most other urban transport economists.

The efficiency gains from even first-best congestion tolling may not be large

When we think about traffic congestion, our instinctive reaction is to think about all the time miserably wasted in traffic, and how great the benefits would be if this time could be substantially reduced. But this is not thinking like a well-trained economist. Traffic congestion is so high because of the spatial concentration of economic activity in cities. Everyone benefits from this spatial concentration through new and more varied products, lower prices for many consumer goods and higher economic growth, and city residents additionally through higher wages, ready access to experts, urban amenities and a richer set of social contacts. Traffic congestion is simply one of the costs we pay to enjoy these benefits. It is excessive congestion that should be our principal concern. Due to underpriced auto travel, traffic congestion is indeed excessive. Efficient congestion pricing would therefore reduce the amount of time wasted in traffic, but its implementation might not reduce congestion by much or result in sizeable efficiency gains or slow down the growth in congestion.[3]

As the diagram is drawn, the efficiency gains from congestion tolling are only a modest fraction of the toll revenues collected. By redrawing the Figure, it can be seen that the gains are increasing in the demand elasticity for rush-hour auto trips and the elasticity of private congestion cost with respect to traffic density. Empirical evidence suggests that the former elasticity is low,[4] while the magnitude of the latter is subject to considerable disagreement (Arnott, Rave and Schöb 2005, Ch. 5). Because the basic model ignores many margins of travel choice (of which the timing of trips is probably the most important (Arnott, de Palma and Lindsey (1990 or 1993)), as well as the endogeneity of urban spatial structure, its application may result in considerable underestimation of the efficiency gains from first-best congestion tolling, but we simply do not know.

The costs of implementation may be substantial

In the design of any congestion pricing scheme, there is a tradeoff between the fineness of the scheme and implementation costs. At one extreme are schemes similar to the one originally envisioned by Vickrey that attempt to charge the driver his marginal congestion externality cost at each point in time, taking into account his time and route of travel, and even actual traffic conditions. Such schemes are typically technology intensive, with high fixed costs, and can be intrusive and expensive to administer, though Singapore's electronic road pricing scheme and the responsive pricing on Interstate 15 in California have been cost effective. At close to the other extreme is a time-invariant cordon toll. Such a tolling scheme would be effective in reducing the amount of traffic crossing the cordon but would do nothing to encourage efficient driving behavior inside or outside the cordon, or efficient trip timing, and would cause traffic to divert around the cordon, perhaps to such an extent that overall congestion would increase.[5]

What proportion of the potential efficiency gains (those that would be achieved with perfect Pigouvian tolling and no administrative costs) would be achieved under various practical tolling schemes? Even when the potential efficiency gains are sizeable, the actual gains that can be achieved might be small or even negative.[6] The theoretical models

[3] The introduction of congestion tolling will result in a one-time reduction in congestion, after which congestion will likely continue to grow. Since centrally located urban land, the most important input into urban road construction, is in fixed supply, urban auto travel is likely characterized by increasing long-run average cost (Small 1999). The continuing trend towards increased urbanization and larger cities caused by technological changes in both production and consumption has given rise to a steady increase in the derived demand for urban auto trips and typically, too, in average trip cost and congestion. (Gordon, Kumar and Richardson 1989, 1990 point to a possible counterexample – that despite rapid growth, average commuting times in Los Angeles did not increase over a twenty-year period because of changes in urban spatial structure deriving from job growth in exurban areas.)

[4] The elasticity of rush-hour auto travel has probably been rising. First, an increasing proportion of the workforce has flexible work hours, allowing travel away from the peak. Second, an increasing proportion of rush-hour trips are non-commuting trips, for which the demand elasticity is higher.

[5] Apparently this phenomenon occurred when Singapore first installed cordon pricing around the central city (Chin 2002; Santos, Li and Koh 2004).

[6] There is quite a large academic literature that calculates, for both simple theoretical models and more realistic computer simulation models, the proportion of the potential efficiency gains that would be achieved under various coarse tolling schemes. This literature has considered tolling only a subset of roads – urban freeways and highways but not city streets (Verhoef, Nijkamp and Rietveld 1996; Mohring 1999), constraining the variation of tolls over time and space (Chu 1999; Mohring 1999), varying cordon placement (May, Liu, Shepherd and Sumalee 2000), and pricing on the basis of expected travel time, actual travel time and distance traveled (May and Milne 2004)). Taken as a whole, the literature has generated two valuable insights. First, ignoring implementation costs, the benefits of a congestion pricing program are sensitive to its details. Second, in evaluating benefits, it is important to treat driver heterogeneity (Small and Yan 2001; Verhoef and Small 2004).
There has also been extensive discussion and analysis of the efficacy of the gas tax in alleviating urban traffic congestion.

ignore the costs of developing and applying the technology to implement congestion pricing, and then of administering and enforcing the program. These costs can easily exceed the efficiency benefits achieved with practical congestion pricing schemes.

One issue that deserves special mention is the choice of technology. High technology systems, which tend to be advocated by engineers, are expensive to implement and rapidly become outdated; low technology systems are more flexible and easier to implement, but enforcement and administrative costs tend to be higher once the system is in place.[7] The London experiment provides an interesting case study. On one hand, the experiment has been more successful than most of the experts expected (Shafer and Santos 2004). On the other, careful ex post cost-benefit analysis (Prud'homme and Bocarejo 2005), employing standard methodology, suggests that the program's net benefits lie in the range of small to negative, principally due to unexpectedly high administrative and enforcement costs.[8] Some proportion of these costs should be amortized since they have the character of fixed costs, while another proportion is offset by the social benefit from learning from London's mistakes. Even taking these factors into account, and despite the high overall quality of the experiment's design, the net benefits are not large, however.

The political barriers to implementation are high

Congestion pricing programs were for many years regarded as political poison. Modern programs are designed to deal with many of the objections raised against the earlier programs. Nevertheless, the political attractiveness of congestion pricing remains open to question. The politics of the London scheme were, if not unique, at least particular to very large cities. Crudely put, the scheme has suburbanite car drivers pay for improvements to central city residents' mass transit. Since it is the central city residents who vote, it is not surprising that the experiment has been politically successful. In many other cities, the political calculus is not as favorable – as evidenced by the recent rejection by referendum of a double cordon scheme in Edinburgh.

Congestion pricing may exacerbate other distortions

The theory of the second best tells us that it is often desirable to distort a price in market A to offset a distorted price in market B. One of the earliest applications of this principle was in the context of urban transportation (Lévy-Lambert 1968). Setting the mass transit fare below the congestion externality cost imposed by a passenger offsets the distortion associated with underpriced auto congestion. Commuters divert from car to mass transit, with the reduction in the deadweight loss associated with underpriced auto congestion more than offsetting the deadweight loss generated by underpricing mass transit. In the context of urban auto travel, two distortions other than underpriced auto congestion are particularly important: income taxation and agglomeration externalities. The substitution effect of the income tax distorts the labor-leisure choice decision, encouraging leisure. Since labor is a complement to travel on the journey to work, raising the price of rush-hour auto travel through congestion tolling exacerbates the labor-leisure distortion. The current empirical wisdom is that this effect is quantitatively important (Parry and Bento 2002).

The nature of agglomeration externalities and how they relate to traffic congestion requires more explanation. It is widely believed that many of the productivity benefits from the spatial agglomeration of economic activity derive from non-market interaction and are external to the individual firm (Fujita and Thisse 2002). Each firm has a horizontal marginal cost curve, and the curve falls the greater the amount of non-market interaction. Because the amount of non-market interaction increases with city population size, the marginal product of labor exceeds the average product. And because the agglomeration benefits are external to the individual firm, workers are paid the average rather than the marginal product. Thus, the market generates insufficient interaction. Since people need to travel to interact, congestion pricing would exacerbate this distortion unless toll revenues were spent in ways that neutralize this effect. No one has attempted to quantify the importance of this effect,[9] but it could

[7] A related issue is technological standardization. On one hand, the best technology and the best congestion pricing system to employ depend on city size and local conditions; for example, Schöb (this issue) argues that, because of its simplicity, a multi-mode ticket, that charges drivers entering the city center a fee equal to the bus fare, is a promising policy for small cities. On the other, a proliferation of congestion pricing systems will lead to technological incompatibilities that will make the treatment of out-of-towners more difficult.

[8] London decided to employ a reliable, low technology system. The license plates of all cars driving within the charging zone are photographed and compared to the license plates of cars for which the fee has been paid. Violators are then sent warnings or are fined.

[9] Because non-market interaction does not, by its nature, leave a paper trail, its importance can be inferred only indirectly. The degree of returns to scale to population can be inferred from cross-city differences in wages. But the effect here is more subtle, entailing holding population constant and measuring the elasticity of interaction with respect to the cost of transportation.

be substantial. Taking both income taxation and agglomeration economies into account could result in second-best congestion tolls being so low that the benefits from even the best congestion-tolling scheme would be more than offset by implementation costs.

Alternatives to congestion pricing

Urban transport policy making used to be dominated by planners and engineers. Economists stood on the sidelines waving the banner of "congestion pricing". But times have changed. Planners and engineers are better trained in economics than they were a generation ago and, through an accumulation of evidence and frustration at the inability of traditional policies to stem congestion, are coming to recognize that pricing has an important role to play in the efficient management of urban traffic. They are therefore far more receptive to economists' ideas than they used to be, and economists are playing an increasingly important role in urban transport policy debates. Now that urban transport economists are getting more engaged in policy decisions, they need to develop a more balanced and sophisticated view of urban traffic management. Congestion pricing by itself is not enough. What is needed is a balanced portfolio of policies, which includes both congestion pricing and the policies traditionally favored by engineers and planners, as well as novel policies that have been unjustly neglected because they do not fit neatly into the disciplinary conceptualizations of the urban transportation problem. Urban transport economists should also recognize that they can contribute to improving road traffic management policy in many ways other than advocating congestion pricing.

Building our way out of the problem

The approach of traffic engineers in the 1960s was to build our way out of the problem, by constructing more and better-engineered freeways, highways and roads. The standard cost-benefit rule employed was to expand capacity when the discounted value of travel time savings from doing so exceeds construction costs. Application of this rule results in efficient choices when prices are right.[10] But urban auto travel was substantially underpriced.[11] In this situation, application of the standard rule results in too much capacity. To see this, consider the effects of an incremental road expansion. If traffic flow is fixed at the pre-expansion level, the expansion reduces congestion and trip price, inducing additional drivers to use the road. The increase in flow that accompanies an increase in capacity is known as latent demand. With underpriced congestion, trip price is below marginal social cost. The marginal social benefit from these additional drivers using the road is simply the trip price. Thus, the additional drivers who use the road add to the deadweight loss due to underpriced congestion, which dissipates the benefit from the road expansion. Latent demand therefore weakens the effectiveness of road building in reducing traffic congestion when congestion is underpriced[12] but not when it is properly priced. Traffic engineers should therefore support congestion pricing since it renders road construction more effective. They should also welcome economists' expertise in cost-benefit analysis and in the analysis of irreversible investment decisions under uncertainty (Dixit and Pindyck 1994).

Upgrading existing infrastructure

Confronted by strong opposition from environmental and neighborhood groups and faced with sky-rocketing land costs, traffic engineers have been pushing road building in already built-up areas less strongly and are now emphasizing expanding capacity through upgrading existing infrastructure. Here too economists can contribute valuable advice.[13] Traffic engineers' current fascination with vehicle information systems seems to me somewhat misguided, but again economists have a role to play in emphasizing that more information is better when the prices are right but not generally otherwise – congestion pricing and vehicle information systems are complements too.

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[10] This can be intuited by imagining the adjustment to an incremental capacity expansion as occurring in two steps. In the first, flow is held fixed; in the second, flow adjusts to its new equilibrium level. The welfare gain from the first step is simply the value of travel time savings to existing drivers. The welfare gain from the second step is the net social benefit from the increase in traffic flow, or alternatively the net social benefit associated with those drivers who choose to travel after the capacity expansion but not before. The social benefit associated with each of these drivers is the private benefit or trip price; the social cost is simply marginal social cost. Since these are equal under Pigouvian congestion pricing, the additional welfare gain in the second step is zero.

[11] Not only was urban auto congestion directly unpriced but it was also indirectly subsidized. The excessive suburbanization resulting from underpricing urban auto travel was further encouraged by paying for suburban infrastructure out of general revenue. Most parking was provided free as well, and in the United States the price of gasoline was set below the world price.

[12] In the basic model, the proportion of the benefits dissipated through latent demand depends on the same two elasticities that determine the magnitude of the deadweight loss due to underpriced congestion, the demand elasticity and the elasticity of private congestion costs with respect to traffic density. On a network, latent demand can be so serious that the addition of a link can have negative gross benefits (the Braess Paradox; Braess 1968).

[13] In designing roads, traffic engineers draw heavily on design standards. These design standards are often drawn up on the basis of inferior statistical analysis, are rarely informed by economics and tend to be applied without consideration to traffic conditions. Economists have an important role to play in rationalizing the choice and application of design standards.

Encouraging alternative modes of travel

Environmentalists and planners have their own favored remedies. One is to encourage alternative, "less wasteful" modes of transportation, another to alter land use patterns in a way that reduces the amount of travel. Economists often find themselves at odds with planners; economists favor prices, planners regulations; economists favor consumer sovereignty, while many planners seem eager to impose their vision of the good life on the citizenry. Nevertheless, many of the policies that planners advocate merit inclusion in the policy cocktail, and economists can offer useful advice on how these policies can be more effectively designed. If pricing were efficient, governments making capacity decisions based on first-best rules, together with individuals making decisions based on full prices, would result in full efficiency. But since pricing is not efficient, in particular since car travel is underpriced, sound economic arguments can be made for encouraging travel by modes that generate less distortion. In most European cities, schemes to promote bicycling (Arnott, Rave and Schöb 2005, Ch. 3) and the high levels of transit subsidies are probably justified. In the United States, the pricing sins of the fathers have been visited upon the sons. The heavy subsidization of auto travel in the decades after World War II resulted in suburbanization at densities too low for mass transit to be viable. Because of their preoccupation with congestion pricing and auto travel, urban transport economists have rather neglected mass transit; it is time that imbalance was redressed.

Encouraging higher density and more mixed land use

Planners, especially the new urbanists, are advocating policies to increase densities and to mix land uses. Land use regulation to promote higher densities reduces the amount of travel but that travel is slower and more congested. Land use regulation to mix uses has the beneficial effect of getting people to walk rather than drive on short trips but is unlikely to have a major impact on traffic congestion. Because their training is so suitable, urban economists can contribute far more than they have done to policy issues at the intersection of transportation and land use.

Parking policy

There are many promising congestion alleviation policies that have been neglected because they do not fall neatly into the domain of economics, engineering or planning. One is parking policy.[14] Here there are vast, untapped efficiency gains. While the right level of second-best congestion pricing is much contended, it can confidently be asserted that providing free or nearly-free on-street parking in heavily-trafficked areas is grossly inefficient. The full price of on-street parking has two components, the parking fee and the cost of time spent cruising for parking. Consider the situation with no off-street parking.[15] The full price of on-street parking is determined by the intersection of the parking demand curve and the parking availability constraint. Raising the parking fee has no effect on the full price but simply replaces time wasted cruising for parking with parking fee revenue. There is the additional benefit that reducing cruising for parking reduces traffic congestion; the revenue is therefore raised with negative burden!

Freight delivery management

Another area in which potentially huge efficiency gains can be achieved is urban freight delivery management. Oversized trucks block traffic when backing into loading docks and get stuck negotiating turns on narrow streets; vans block traffic when double parking to deliver a small package. Freight delivery would contribute far less to congestion if it were required that all deliveries be made by vans in the morning hours, and if during these hours some curbside were restricted to van deliveries.

Outside-the-box policies

Other, outside-the-box policies should be explored. Since it is the value of time lost due to congestion that matters, congestion costs can be reduced by making driving more pleasant;[16] traffic noise, a curse of life in many urban areas, can be reduced by mandating quieter cars; urban road construction, a major contributor to non-recurrent congestion, can be done at night under sound-absorbent tents;[17] the time loss due to road accidents, another major con-

[14] Donald Shoup, a planner trained as an economist, is an exception. He has done excellent work documenting the high social costs of subsidizing parking (Shoup 2005).
[15] With off-street parking as well, the same argument goes through but with the modification that the full price of on-street parking is determined by the off-street parking rate rather than by the intersection of the parking demand curve and the parking availability constraint.
[16] Improved car audio systems and the expanded range of talking books have already contributed to this.
While reducing congestion costs associated with a given volume of traffic and level of capacity, making driving more pleasant will also stimulate demand and increase the deadweight loss associated with underpriced congestion.
[17] This is already done in London.

tributor to non-recurrent congestion, can be reduced by introducing no-fault insurance and immediately towing the cars involved in an accident; and aggressive driving, that not only greatly impedes traffic flow but also makes driving considerably more dangerous and less pleasant, can be discouraged by equipping all new cars with electronic devices that monitor horn-honking, frequent lane changes, tailgating, etc.

Conclusion

Urban transport economists are entering a brave new world in which – finally, after fifty years of crying in the wilderness – urban congestion pricing schemes may become commonplace. On one hand, I look forward to seeing what schemes are put in place and how well they do, and sincerely hope that urban congestion pricing proves to be worth the wait. On the other, I have my doubts that urban congestion pricing will be as effective as most other urban transport economists believe. Whether or not my doubts prove well founded, city tolls are only one element of an effective policy cocktail for dealing with urban traffic congestion. Urban transport economists should broaden their horizons beyond congestion pricing to give due attention to the myriad other congestion-relief policies whose effectiveness can only be improved by the application of sound economics.

References

Arnott, R., A. de Palma and R. Lindsey (1990), "Economics of a Bottleneck", *Journal of Urban Economics* 27, 111–30.

Arnott, R., A. de Palma and R. Lindsey (1993), "A Structural Model of Peak-period Congestion: A Traffic Bottleneck with Elastic Demand", *American Economic Review* 83(1), 161–179.

Arnott, R. and M. Kraus (1998), "Self-financing of Congestible Facilities in a Growing Economy", in D. Pines, E. Sadka and I. Zilcha, eds., *Topics in Public Economics*, Cambridge University Press, Cambridge, 161–85.

Arnott, R., T. Rave and R. Schöb (2005), *Alleviating Urban Traffic Congestion*, M.I.T. Press, Cambridge, MA.

Braess, D. (1968), "Über ein Paradoxen der Verkehrsplanung", *Unternehmensforschung* 12, 258–68.

Chin, K. K. (2002), "Road Pricing: Singapore's Experience", essay prepared for the third seminar of the IMPRINT-EUROPE: Thematic Network: Implementing Reform on Transport Pricing: Constraints and solutions: Learning from best practice. Brussels, October 23–24. http://www.imprint-eu.org/public/Papers/ IMPRINT3_chin.pdf.

Chu, X. (1999), "Alternative Congestion Pricing Schedules", *Regional Science and Urban Economics* 29, 697–722.

Dixit, A. K. and R. S. Pindyck (1994), *Investment under Uncertainty,* Princeton University Press, Princeton, NJ.

Fujita, M. and J.-F. Thisse (2002), *Economics of Agglomeration: Cities, Industrial Location and Regional Growth*, Cambridge University Press, Cambridge

Gordon, P., A. Kumar and H.W. Richardson (1989), "The Influence of Metropolitan Spatial Structure on Commuting Time", *Journal of Urban Economics* 26(2), 138–51.

Gordon, P., A. Kumar and H.W. Richardson (1990), "Peak-spreading: How Much?" *Transportation Research* A 24A(3), 165–75.

Lévy-Lambert, H. (1968), "Tarification des services à qualité variable: Application aux péages de circulation", *Econometrica* 36, 564–74.

May, A. and D. Milne (2004), "The Impact on Network Performance of Drivers' Response to Alternative Road Pricing Schemes", in G. Santos, ed., *Road Pricing: Theory and Evidence, Research in Transportation Economics* 9, Elsevier Science, 61–85.

May, A. D., R. Liu, S. P. Shepherd and A. Sumalee (2002), "The Impact of Cordon Design on the Performance of Road Pricing Schemes", *Transport Policy* 9, 209–20.

Mohring, H. (1999), "Congestion", in J.A. Gomez-Ibanez, W.B. Tye and C. Winston (eds.), *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer*, Brookings Institution Press, Washington DC, 181–221.

Mohring, H. and M. Harwitz (1962), *Highway Benefits: An Analytical Framework*, Northwestern University Press, Evanston, IL.

Parry, I. W. H. and A. Bento (2002), "Estimating the Welfare Effect of Congestion Taxes: The Critical Importance of Other Distortions within the Transport System", *Journal of Urban Economics* 51, 339–65.

Prud'homme, R. and J. Bocarejo (2005), "The London Congestion Charge: A Tentative Economic Appraisal", *Transport Policy* 12, 279–87.

Santos, G., W. W. Li and W. T . H. Koh (2004), "Transport Policies in Singapore", in G. Santos (ed.), *Road Pricing: Theory and Evidence, Research in Transportation Economics* 9, Elsevier Science, 107–31.

Shaffer, B. and G. Santos (2004), "Preliminary Results of the London Congestion Charging Scheme", 83rd Annual Meeting of the Transportation Research Board, conference CD.

Shoup, D.C. (2005), *The High Cost of Free Parking*, APA Planners Press, Chicago.

Small, K. A. (1992), "Using the Revenues from Congestion Pricing", *Transportation* 19, 359–81.

Small, K.A. (1993), "Urban Traffic Congestion: A New Approach to the Gordian Knot", *The Brookings Review* 11(2), 6–11.

Small, K.A. (1999), "Economies of Scale and Self-financing Rules with Non-competitive Factor Markets", *Journal of Public Economics* 74, 431–50.

Small, K. A. and J. Yan (2001), "The Value of 'Value Pricing' of Roads: Second-best Pricing and Product Differentiation", *Journal of Urban Economics* 49(2), 310–36.

Strotz, R. H. (1965), "Urban Transportation Parables", in J. Margolis (eds.), *The Public Economy of Urban Communities,* Resources for the Future, Washington DC.

Texas Transportation Institute (2005), *Urban Mobility Report*, TTI Publications, College Station, TX.

Verhoef, E. T. and K. A. Small (2004), "Product Differentiation on Roads: Constrained Congestion Pricing with Heterogeneous Users", Journal of Transport Economics and Policy 38(1), 127–56.

Verhoef, E. T., P. Nijkamp and P. Rietveld (1996), "Second-best Congestion Pricing: The Case of an Untolled Alternative", *Journal of Urban Economics* 40(3), 279–302.

Vickrey, W. S. (1959), "Statement on the Pricing of Urban Car Use", Hearings: US Congress, *Joint Committee on Metropolitan Washington Problems*, November, 454–77.

Vickrey, W. S. (1963), "Pricing in Urban and Suburban Transport", *American Economic Review* 53, 452–65.