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DO ECONOMISTS REACH A CONCLUSION?

Do Economists Reach A Conclusion on Road Pricing? The Intellectual History of an Idea

ROBIN LINDSEY*

Abstract

ADAM SMITH WROTE SEVERAL PAGES ABOUT TOLL ROADS, AND Jules Dupuit developed a rich analysis of road pricing, but the English-language work by economists does not really get going until after Pigou (1920). The historical pattern of interest might reflect contemporary practice. During most of the nineteenth-century, toll roads were commonplace in Britain and the United States. They advanced social and economic goals. Although rail transport had displaced many of the trunk-line toll roads, what snuffed out the toll road was government policy. It is in the era of free-access highways, and especially after 1920 with the rise of the automobile and congestion, that economists had a growing problem to solve.

For decades after 1920, road pricing remained an ivory-tower idea. But in the 1990s interest grew significantly. Governments around the world became more supportive of road pricing. For example, the European Union has been promoting the application of marginal-cost pricing in

* Department of Economics, University of Alberta. Edmonton, T6G2H4.
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transportation, and it has issued a number of policy papers[1] and funded a series of research projects. And in the United States the cause of road pricing has been advanced by the Value Pricing Pilot Program which funds innovative road and parking pricing measures for alleviating congestion.[2] The change in political attitudes towards road pricing may have been part of a broader ideological acceptance of market mechanisms. But another factor was technology: During the 1990s electronic toll collection was developed and implemented. The high transaction costs of old-fashioned toll collection and motorist delay were largely eliminated. Yet other reasons for the new interest in road pricing may have been the growing (or anticipated) revenue shortfalls from fuel taxes and other traditional sources, as well as recognition that other, indirect means of mitigating highway congestion were inadequate.

To get an idea of how the volume of research on road pricing has evolved over time, a search on a cluster of terms representing the idea of road pricing was performed using the ECONLIT database from its inception in 1969 through 2004.[3] Figure 1 shows a trickle of papers from 1969 to 1994 (annual mean 4.2), followed by a sharp increase to a much higher level for 1995-2004 (annual mean 21.4).[4]

The counts in Figure 1 do not fully reflect a number of recent books about road pricing, including studies of public and political acceptability (Schade and Schlag 2003, Ison 2004), case studies of the implementation process (Mylvaganam and Borins 2004, Richards 2005), an edited volume of contributions (Santos 2004) and mathematical/theoretical studies (Arnott, Rave and Schob 2005, Yang and Huang 2005), and ambitious scholarly

[1] See in particular European Commission (1995, 1998, 2001).

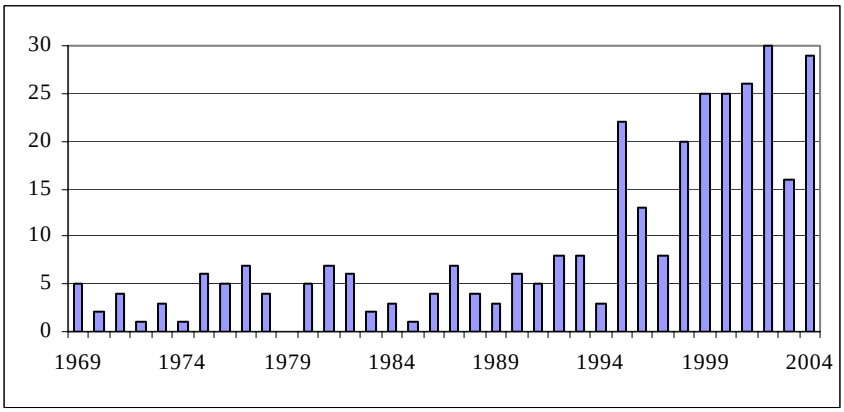
[2] See Value Pricing Pilot Program (2005), Transportation Research Board (2003) and DeCorla-Souza (2004).

[3] See Appendix A for details of the search procedure and coverage of the ECONLIT database. Year 2005 is excluded because entries for 2005 in the ECONLIT database were incomplete as of the end of January, 2006.

[4] Appendix B summarizes the coverage of road pricing in selected transportation economics textbooks since 1975. In contrast to Figure 1, the textbooks show no clear upward trend in the number of pages devoted to road pricing except for the incomplete draft of Small and Verhoef (2006). Button (2004) conducts a survey of research by all professions on road pricing and congestion in the United States and Europe. Over the period 1994-2002 he finds (Table 5.1) that of 953 doctoral dissertations on transportation in the US, only 50 relate to congestion. And for the category "social and behaviour studies on transport congestion in Europe" from 1996-2001 (Table 5.4), 60 percent of the studies dealt with measures to relieve congestion, but only 5.4 percent with road pricing. These statistics indicate that road pricing has not experienced any great upsurge of attention among transportation researchers as a whole over the last decade.

argumentation for toll roads (Roth 1996, Roth 2006).[5] The counts also do not include all of several recent special journal issues on road pricing.[6]

Figure 1: Publications on road pricing (1969-2004)



Source: ECONLIT database search on a cluster of terms representing the idea of road pricing

The flurry of interest in road pricing over the last decade or so might suggest that road pricing is an idea whose time has come (or, rather, come back!). Intercity toll roads are prevalent today in Western Europe, Mexico, Japan, China and other countries. And a number of projects are now either under development, or have been proposed, including area-wide tolling for Britain and the state of Oregon using Global Navigation Satellite Systems (GNSS) technology. Yet, despite the historical tradition of tolls and the longstanding theoretical argument for road pricing, only a few cities have

[5] In addition there is Shoup's (2005) authoritative and encyclopaedic book on parking which covers the technology and policies of parking pricing as well as the link between parking and road congestion.

[6] See "Recent studies on key issues in road pricing" (*Transport Policy*, 9(3), 2002), "Road pricing problems: Recent methodological advances" (*Networks and Spatial Economics*, 4(2), 2004), "Road pricing in practice and theory" (*Review of Network Economics*, 3(4), 2004), "The theory and practice of congestion charging" (*Transportation Research A*, 39A(7-9), 2005), "Road user charging: Theory and practice" (*Transport Policy*, 12(5), 2005), and "Research challenges in modelling urban road pricing" (*Transport Policy*, 13(2), 2006).

implemented road pricing in any form, and the number of schemes designed to control traffic congestion is even fewer.[7]

Although the idea wins intellectually, political acceptability remains a great challenge, and diverse attempts to introduce road pricing have failed politically.[8] The political dimension affects economists' judgments. Clarence Philbrook (1953) and W.H. Hutt (1971) favoured pursuit of the desirable regardless of political acceptability. But practical considerations lead many economists to focus on politically palatable reforms. The classic tension between the desirable and the politically acceptable is particularly relevant for highways, as we find ourselves in a freeway status quo that is difficult to undo.

The goal of this article is to assess whether economists, in their published judgments, agree that road pricing is a good idea.[9] An economist is defined to be someone with a postgraduate degree in economics or a job with a title of economist such as a teaching or research position at a university economics department.[10] Road pricing is defined broadly to include any form of direct user charges (e.g. tolls and area licenses), charges on urban and intercity roads, charges on any form of motorized transport, and charges for any purpose.[11]

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[7] The major operational schemes (and their inception dates) are Singapore's electronic road pricing system (1998; a follow-on to the area-licensing scheme that began in 1975), toll rings in Norwegian cities (1986), London's congestion charge (2003), a handful of High-Occupancy Toll (HOT) lane projects in the US (1995), urban toll roads in Brisbane, Sydney and Melbourne (1999), and Highway 407 in Toronto (1999). On January 3, 2006, a toll cordon was launched in Stockholm. After a seven-month trial a referendum will be held, September 17, on whether to make the charge permanent.

[8] Notable failures include Hong Kong in the mid-1980s (Borins 1988), Rekening Rijden (Bill Riding) for the Randstad area in the Netherlands (Small and Gómez-Ibáñez 1998, §10.5.1), Cambridge UK (Oldridge 1995, Ison 2004), Edinburgh (McQuaid and Grieco 2005), several false starts in London prior to 2003 (Richards 2005), attempts during the 1970s to initiate congestion pricing demonstration projects in US cities (Elliott 1986, Higgins 1986), the Maine Turnpike (Colgan and Quinlin 1997), a section of the Trans-Canada Highway in New Brunswick (2000), and New York City (2002). Trondheim launched a toll ring in 1991, but the policy package in which the toll ring was embedded expired at the end of 2005, and the toll was terminated. Trondheim thus became the first city in modern times to stop collecting tolls.

[9] It is frequently claimed that they do agree; e.g. Small, Winston and Evans (1989, 86-87), Boyer (1998, 8), Thomson (1998, 99), Mohring (1999, 193).

[10] Articles in *The Economist* magazine are included although the authors are anonymous and may not have postgraduate economics degrees.

[11] See Appendix A for details on what is included as road pricing, and what is excluded. Various terms are used in the literature besides "road pricing," including "tolls," "road-use pricing," "road-user charging," "congestion charging," "congestion pricing" and "congestion

In short, economists do agree that highway congestion should be solved by pricing. Beyond that primary insight, however, there is much disagreement. Economists disagree over how to set tolls, how to cover common costs, what to do with any excess revenues, whether and how "losers" from tolling previously free roads should be compensated, and whether to privatize highways. These disagreements fill a lot of pages, while the main point of agreement is largely taken for granted.

It is not easy to assess agreement on the fine points. An economist may approve of road pricing in principle, but balk at particular schemes because of high administration costs, inequity, or other reasons. Another difficulty is that many authors never voice a judgment about road pricing, but develop results that seem to point toward a judgment. Another problem is that there is a bounty of material, and anything short of a book must be selective. Yet another frustration is that major analytic and practical advances have been made by scholars from elsewhere, notably civil engineering. Also, there have been exchanges between economists and others that have influenced the progression of thinking. Here, some of the work of non-economists will be mentioned while taking care to identify them as such.

There have been a number of surveys of attitudes towards road pricing. Most of these are opinion surveys of the public and/or policy-makers.[12] I am aware of two recent surveys of economists: one by Ison (2004, Ch. 3), an economist, and one by Gulipalli, Kalmanje and Kockelman (2005), who are engineers. The literature survey here differs in covering a larger number of economists and in adopting a historical approach. It also assesses opinions on the basis of published work, whereas Gulipalli et al. (2005) use written attitudinal questionnaires.[13]

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metering." I use "road pricing" to encompass all these terms. Although freight transport charges and the land-use effects of road pricing were included in the survey, they do not appear in the paper. In part this is because understanding of these important topics is still immature, and (in the case of freight transport) because relatively little about it has been written by economists.

[12] See for example Harrington, Krupnick and Alberini (2001), Berg (2003), Johansson et al. (2003), Ison (2004) and Farrell and Saleh (2005).

[13] Three results of the Gulipalli et al. (2005) survey will be mentioned later. Although neither Ison (2004) nor Gulipalli et al. (2005) offer systematic comparisons between economists and other people, their results are consistent with received wisdom that economists are more favourably disposed towards the use of economic instruments such as road pricing. This was confirmed by Brittan (1973) in a survey of attitudes towards peak-period public transport fares—a close cousin of congestion pricing. Baumol and Fischer (1987, 383) summarize Brittan's findings: "Some years ago, Samuel Brittan (1973, p.93) conducted a survey on a

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Other scholars have reviewed the theory of road pricing.[14] My review treats Adam Smith and Jules Dupuit, and then dives into the twentieth century and continues to recent developments.

Adam Smith

Adam Smith devoted several pages of *The Wealth of Nations* to transportation projects, notably "high roads," which in his day were operated individually by a "trust," a local, independent authority voluntarily financed by bonds. Smith clearly favoured that all such "publick works" "be so managed, as to afford a particular revenue for defraying their own expence, without bringing any burden upon the general revenue of the society" (1937, 682). The first argument made by Smith is one of equity: "When the carriages which pass over a highway or a bridge ... pay toll in proportion to their weight … they pay for the maintenance of those public works exactly in proportion to the wear and tear which they occasion of them. It seems scarce possible to invent a more equitable way of maintaining such works" (683). But Smith also makes several practical arguments. First, he makes a kind of knowledge and accountability argument in matching supply to demand: "When high roads, bridges, canals, &c. are in this manner made and supported by the commerce which is carried on by means of them, they can be made only where that commerce requires them, and consequently where it is proper to make them" (683). Smith elaborates on how financial independence is a guard against extravagance and misplacement (687). He examines the proposal to

variety of policy issues, questioning 102 economists and 91 Members of parliament in Great Britain. When asked 'in order to make the most efficient use of a city's resources, how should subway and bus fares vary during the day?' predictably, 88 per cent of the economists agreed that 'they should be relatively high during rush hour to minimize the amount of equipment needed to transport the daily traveller'. But 60 per cent of the Conservative MPs and 39 per cent of the Labour MPs chose the answer that "they should be the same at all times' and 40 per cent of the Labourites felt 'they should be relatively low during [the] rush hour'. This is one of many examples where policies recommended enthusiastically by economists on grounds of efficiency are not quite as welcome to other people, who often question them because of their apparent inequity."

[14] See in particular Hau (1992) reprinted as Hau (2005a,b), Roth (1996, Annex to Chap. 4), Thomson (1998), Ison (2004), Richards (2005), and Toll Roads News.

have the central government take over operation of the turnpikes. He opposes the proposal on the grounds that the state would grow dependent on the toll revenues and increase the tolls unduly, encumbering commerce and driving up prices to the final consumer, and that the government is more likely to neglect maintenance. Smith says that it will sometimes be the case that a project is socially desirable and yet unable to finance itself entirely by tolls. In such cases he again presses the principle of local authority and financing, for virtues in accountability, local knowledge and consideration, and correction of errors (689). Throughout, Smith reminds us that if a work does not support itself, then it must be supported by other means that pose "a very considerable burden" (768).

Smith's discussion represents a comparative-institutions approach. The main principle in his discussion seems to be the independence and autonomy of the facility. Consistently applied, the principle would seem to point to full propertization of the facility. Smith describes (684) how a canal in France was turned over to the project's engineer, apparently essentially as private property, and how his residual claim and authority induced good maintenance and good results, better than if the canal had been in the hands of commissioners that would have no such interest. In turning to the case of high roads, however, Smith changes his tune. Unlike a canal, a road wanting in maintenance does not become altogether impassable. "It is proper, therefore, that the tolls for the maintenance of such a work should be put under management of commissioners or trustees" (684). Smith's reasoning here is odd. He seems to believe that private ownership will deliver adequate maintenance if doing nothing would make the facility unusable, but not if skimping on maintenance merely degrades the quality of service.[15] Furthermore, private ownership does not preclude accountability to local public officials concerning maintenance.

Jules Dupuit

Dupuit was one of a group of French engineers who wrote extensively during the nineteenth century about transportation and other areas of economics. Ekelund and Hébert (1999, 3) sum up their contributions: "It is fairly easy to make the case that the state engineers of

[15] This reasoning is at odds with that of Knight (1924) and later writers mentioned below.

the Corps des Ingénieurs des Ponts et Chaussées pioneered the field of transport economics."[16]

Dupuit understood most of the ideas underlying Pigouvian tolls and other aspects of road pricing, including consumer's surplus and the importance of product quality generally—as well as travel time specifically. He built formal models and derived the toll that would recover costs and the profit-maximizing toll for a monopoly, and analyzed at length the potential for price discrimination to boost revenues. He identified the danger that tolling one (congestion-free) bridge would divert traffic onto an alternative less attractive bridge (Dupuit 1952 [1844], 105). Dupuit also showed an appreciation for the wider public finance implications of tolls: "if I had wished to treat exhaustively of only one question, namely, whether or not to establish tolls, I would have had to examine by what new tax or what increase in taxation tolls could be replaced and what would be the effects of these taxes; I would have been led into a full-fledged theory of taxation" (1952 [1844], 30-31).

Dupuit did not appreciate the distinction between short-run and long-run marginal cost, and did not address congestion (which presumably was a much smaller problem given the vehicles of the day). He saw tolls more as a means of covering long-run costs than of managing efficient usage: "If… the bridge is public property, the government will want to recover from the toll merely a fixed sum representing interest on the capital spent for construction, maintenance cost and perhaps amortization" (1962 [1849], 11).[17]

Thus, we might interpret Dupuit as being in the company of later economists who favoured average-cost pricing. And, given Dupuit's support of markets and the principle of user pays, he appears to be an early sympathizer—if not a proponent—of private toll roads.

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[16] Ekelund and Hébert (1999) refer to Dupuit and others of the school as "engineers," "econo-engineers" and "economists". Derycke (1998) also refers to "economist-engineers". Thus, it seems reasonable to classify Dupuit as an economist for the purpose of this survey.

[17] As quoted by Ekelund and Hébert (1999, 180). Derycke (1998, 63) draws a similar conclusion: "While the first school, which dates back to the mid-19th century but has much earlier roots, has developed what is more a theory of *funding tolls*, the second, founded sixty years later in Britain, has focused on *decongestion tolls*."

Twentieth century leaders

Arthur Pigou

It appears that Pigou deserves credit for suggesting tolls on public roads to alleviate congestion. Pigou's (1920) famous example of two parallel roads occupies just one paragraph:

> Suppose there are two roads ABD and ACD both leading from A to D. If left to itself, traffic would be so distributed that the trouble involved in driving a 'representative' cart along each of the two roads would be equal. But, in some circumstances, it would be possible, by shifting a few carts from route B to route C, greatly to lessen the trouble of driving those [sic] still left on B, while only slightly increasing the trouble of driving along C. In these circumstances a rightly chosen measure of differential taxation against road B would create an 'artificial' situation superior to the 'natural' one. (Pigou 1920, 194) [18]

Frank Knight and others

Knight (1924) criticized Pigou on the grounds that an efficient outcome in his two-roads example would result without a tax if roads were privately owned. Knight built on Pigou's example by assuming that route B is smooth—but narrow and congestible, while route C is rough—but wide enough to accommodate all potential traffic without delays. Knight then observed:

> If the roads are assumed to be subject to private appropriation and exploitation, precisely the ideal situation which would be established by the imaginary tax will be brought about through the operation of ordinary economic motives….the owner of the narrow road can charge for its use a toll representing its "superiority" over

[18] The two-roads example is sometimes incorrectly attributed to Pigou (1912); e.g. Buchanan (1956, 163), Derycke (1998), Mills (1981, fn 1), Newbery (1988 and 1989).

> the free road, in accordance with the theory of rent, which is as old as Ricardian economics. (Knight 1924, 586-587)

As Buchanan (1956), Edelson (1971) and Mills (1981) showed decades later, Knight is correct only under stringent assumptions. Mills provides a helpful summary:

> It has long been known that Knight's claim for the generality of this result was excessive. James Buchanan showed that it held in the road example only because there was an alternative route to the congestion-prone road, and that ownership rights could be conferred without simultaneously, and inadvertently, conferring monopoly power. After describing some alternative institutional arrangements where the result fails to hold, he concluded that private ownership can be relied upon to achieve efficient resource use '[o]nly in those cases where the extent of commonality of usage is limited to a relatively small proportion of the total resource supply…' (p.315). That is, there must be a sufficient supply of alternatives to the facility in question to prevent monopoly power from existing if it is owned privately. Later, working with a variation of the road example, Noel Edelson qualified Knight's claim in another way. He showed that it depended on all users of the two roads having the same imputed value of time spent in transit. Otherwise, over- or undercongestion would result. (Mills 1981, 493)

Little further was written about road pricing until the mid-1950s. Clark (1923, 304) advocated user charges in response to problems of highway damage, unfair competition vis à vis railroads, and the need to pay for highways. Peterson (1932) maintained that roads should be priced like other commodities. Buchanan (1952) covered many of the pros and cons of tolling. He emphasizes the potential role of tolls in improving usage: "[C]oncentration on the allocation of benefits and thus the equitable means of distributing total highway costs has all but obscured the far more important problem of adjusting user charges in order to promote an optimum utilization of an existing highway system" (Buchanan 1952, 98).

Hold it! Ronald Coase's comparative-institutions challenge

In his 1946 article "The Marginal Cost Controversy," Ronald Coase took exception to marginal-cost conclusions arising from the model-based work of Harold Hotelling, Abba Lerner, James Meade, and J.M. Flemming. This literature does not treat highways in particular, but the general discussion applies to highways.

Model-based discourse boils reality down to a model, solves for optimality, and then tends to emphasize the implications of that optimality exercise. Coase's approach, also characteristic of Adam Smith, is that of *comparative institutions*, whereby scholars formulate and compare institutional alternatives one against another, in light of whatever considerations seem relevant and important, including especially the limitations and likely failings of the governing institutions themselves (see also Demsetz 1969). The comparative assessment appeals to broad, never-fully-identified sensibilities, rather than to a formal model that presumes to capture all that matters to coming to a judgment.

The thrust of Coase's article is to suggest that there are knowledge and accountability advantages to organizing the facility in such a way that it must support itself. That assures that only projects likely to pay for themselves will be undertaken. Coase emphasizes that such arrangements provide a substitute for the need of masterful knowledge, and cites Hayek on socialism (170). Such arrangements focus the mind and enhance the planning accuracy of those accountable. The alternative "marginal-cost"/subsidization arrangement involves not only distortions and troubles in taxation of incomes etc. (178-9), but does not provide, even after the fact, a basis for judging the worthiness of the facility (176). As Smith noted, subsidized facilities will be subject to political factors and overproduction. Coase recognizes that self-financing might result in some facilities not being built that should have been (181). His preferred form of self-financing—multi-part pricing[19]—would however provide a more refined method of appropriating value than simple average-cost pricing, and therefore would reduce the bias towards underproduction. Coase feels that the self-financing principle is so important, however, that even if it came down to a choice between marginal-cost pricing (and subsidies) and average-cost pricing (no subsidies), there should be no presumption in favour of marginal-cost pricing.

[19] Coase notes that this solution was suggested earlier by C.L. Paine (1937) and by E.W. Clemens (1941).

In Coase's article, the question of ownership is somewhat vague. He seems to say that if the facility is a government enterprise, then the facility ought to have to pay for itself, and its managers ought to look to multi-part pricing. Coase is silent on whether he would prefer private ownership, and on whether privately-owned facilities ought to be regulated by the government. His other works, however, certainly seem to favour private ownership.

Mid-twentieth century models and practical proposals

During the late 1950s and early 1960s, the cause of road pricing was advanced by models and practical proposals, with economists at the vanguard. Beesley and Roth (1962-63) described the emergence of a new role for economists: "Growing traffic congestion and recent advances in computing techniques have induced economists to look at the problem in detail, and thus to move into a field that has hitherto been the preserve of engineers and town planners" (Beesley and Roth 1962-63, 184).

Looking back at the period Thomson (1998, 94) writes:

> Until the 1960's roads were regarded as the province of engineers. The planning of urban roads and road traffic was carried out by civil engineers, with occasional assistance from architects. The professions of urban planning and transport planning were in their infancy. Engineers were in control and saw no need for economists. The intrusion of economists into teams of transport planners was often treated with a mixture of suspicion and amusement. (Thomson 1998, 94)

William Vickrey

Drèze (1994) and Arnott (1998) provide incisive appraisals of Vickrey's extensive writings on marginal-cost pricing and traffic congestion. Between 1948 and his death in 1996, Vickrey wrote some 40 articles that treated most road-pricing issues. His 1948 paper conveyed two ideas that ran through all his later work. One was that price should be set at short-run marginal cost (SRMC) rather than either long-run marginal cost (LRMC) or

average cost (AC).[20] The second was that random demand fluctuations should be met with responsive pricing whereby prices are adjusted to match SRMC as closely as practical. Vickrey was also interested in the technology for road pricing, and in 1959 he proposed a system of network-wide tolls for Washington, DC. His interest was spurred by the great waste that he saw in pricing of road transport:

> I will begin with the proposition that in no other major area are pricing practices so irrational, so out of date, and so conducive to waste as in urban transportation. Two aspects are particularly deficient: the absence of adequate peak-off [sic] differentials and the gross underpricing of some modes relative to others. In nearly all other operations characterized by peak-load problems, at least some attempt is made to differentiate between the rates charged for peak and for off-peak service. Where competition exists, this pattern is enforced by competition: resort hotels have off-season rates; theaters charge more on weekends and less for matinees. Telephone calls are cheaper at night. . . . But in transportation, such differentiation as exists is usually perverse. (Vickrey 1963, 452)

Alan Walters

Like Vickrey, Walters supported SRMC pricing, but in his early writings (Walters 1954) he focused more on the fallacy of AC pricing and misguided investment. Walters' most widely cited work is his 1961 article on congestion and congestion pricing. Perhaps surprisingly, his support there for road pricing is rather qualified (683-5), and at one point (685) he remarks "Fuel taxes are probably the most useful form of deterrent."

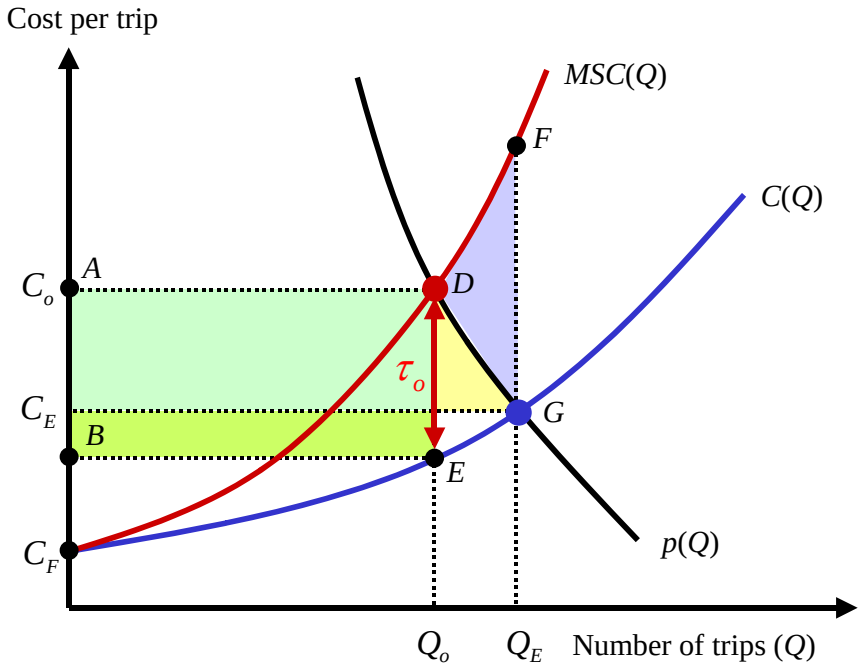
These misgivings notwithstanding, Walters (1961) serves as a useful landmark. His approach, which will be referred to here as the *basic model*, can be illustrated with what is called the *conventional diagram*, shown in Figure 2.[21] Individuals are assumed each to make one trip, one person per vehicle, along a single stretch of road between a common origin and a common

[20] A good summary of his arguments is found in Vickrey (1987).

[21] The presentation here follows Lindsey and Verhoef (2001). Figure 2 is a highly modified version of Walters (1961, Figure 1).

destination. The number of trips, measured as an hourly flow, is plotted on the horizontal axis. The cost per trip, which includes vehicle operating costs and the opportunity cost of travel time, is plotted on the vertical axis. As the number of trips increases, congestion forces drivers to slow down and the average cost of a trip, $C(Q)$, rises. Because each motorist accounts for a negligible fraction of flow and all trips are identical in cost, the motorist's marginal cost coincides with average cost. The function $C(Q)$, then, represents both the average cost and the private marginal cost.

Figure 2: The basic road pricing model



Demand for trips is described by a conventional downward-sloping inverse demand curve, $p(Q)$. Without a toll, equilibrium occurs at the point of intersection, G. Q_E trips are taken each at a cost C_E. The equilibrium is inefficient because individuals disregard the delay they impose on other

travelers. The total social cost of Q trips is $TC(Q) = C(Q) \cdot Q$, and the marginal social cost of a trip is $MSC(Q) = \partial TC(Q)/\partial Q = C(Q) + \partial C(Q)/\partial Q \cdot Q$. The social optimal is found at the point of intersection, *D*, of $MSC(Q)$ and $p(Q)$. The optimal number of trips, Q_o, is less than Q_E. To support the optimum, travellers must be made to face a cost of C_o. This can be accomplished by imposing a toll of $\tau_o = MSC(Q_o) - C(Q_o) = \partial C(Q_o)/\partial Q_o \cdot Q_o$ equal to the marginal external congestion cost of a trip. The welfare gain from imposing the toll as measured by the increase in social surplus is given by area *DFG*.

The basic model is attractive in several respects. It is straightforward and amenable to graphical description. The welfare gain is represented visually. The toll is familiar to contemporary readers as a Pigouvian toll. And the formula for the optimal toll is intuitive since it equals the marginal delay imposed by a driver on each other driver, $\partial C(Q_o)/\partial Q_o$, times the number of other drivers, Q_o. These aspects of the basic model have no doubt helped to sell economists on road pricing. But further inspection of Figure 2 reveals four sobering facts:

> (1) Tolling raises drivers' private costs, as indeed it must if travel is curtailed. The revenue from the toll accrues to the toll-road operator, which is usually assumed to be a government agency. Unless the government uses the revenue to expand road capacity, to improve an alternative form of transport, to reduce other user charges, or to provide rebates to drivers in some lump-sum fashion, drivers end up worse off.
>
> (2) Toll revenues are just a transfer from travelers to the operator, but toll collection entails infrastructure, operating and administration costs as well as inconvenience for travelers. Furthermore, as Figure 2 is drawn, the toll revenue, *ADEB*, is large compared to the welfare gain, *DFG*, which is likely to be the case if travel demand is price inelastic as it typically is at peak times. Hence, unless the costs of toll

collection per dollar of revenue garnered are small, the net social benefit from tolling will be negative. [22]

(3) Congestion is not eliminated because the cost of travel at point *E* exceeds the cost under free-flow conditions, C_F. Consequently, tolling can only be marketed to the public as a way of reducing congestion, not eliminating it.

(4) The optimum at point *D* cannot be deduced just by observing the no-toll equilibrium at point *G*. To solve mathematically for *D* and the supporting toll τ_0, it is necessary to know, or to estimate, the *C*(*Q*) and *p*(*Q*) curves.

The basic model is very simple, including as it does a number of simplifying assumptions:

- a single road connecting one origin to one destination;
- one individual per vehicle;
- vehicles contribute equally to congestion;
- individuals are identical except for their reservation price to make a trip;
- traffic flow, speed and density are uniform along the road, and are independent of time;
- congestion is the only market failure; i.e. there are no other transport externalities or distortions elsewhere in the economy; and
- there are no shocks due to accidents, bad weather, special events, etc.

It is not surprising that these simplifying assumptions, combined with the discouraging properties of the equilibrium, left the basic model open to criticism from engineers as well as some economists.

[22] However, most other sources of public revenue are also costly to collect, and unlike congestion tolls they create deadweight losses. From this wider perspective congestion pricing may be beneficial even if the collection costs are significant.

An aside on hypercongestion

Figure 2 omits one element of Walters' basic model, namely, the backward-bending or hypercongested branch of the average cost curve, $C(Q)$. This omitted branch corresponds to travel conditions, frequently observed on highways, in which travel speed and flow (treated as number of trips in Figure 2) are positively correlated—and travel time (and cost) and flow are correspondingly negatively correlated. In other words, congestion is so heavy that flow declines. The speed at which flow peaks depends on lane width, geometrics, spacing between on-ramps and off-ramps and other highway characteristics. Because of considerable scatter in speed-flow data it is often difficult to identify a precise value.[23] The circumstances under which hypercongestion occurs are still not fully understood although reductions in capacity downstream of the point of observation and turbulence created by vehicles entering from on-ramps and exiting from off-ramps have been identified as contributory factors.

Hypercongestion cannot be captured by a static model of the sort depicted in Figure 2. Small and Chu (2003, 342) explain the logic: "Hypercongestion is a real phenomenon, potentially creating inefficiencies and imposing considerable costs. However, it cannot be understood within a steady-state analysis because it does not in practice persist as a steady state. Rather, hypercongestion occurs as a result of transient demand surges and can be fully analysed only within a dynamic model. Even if the dynamic model is converted to a static one through the use of time averaging, the appropriate specification of average cost depends on the underlying dynamics. In virtually all circumstances that specification will portray average cost as a rising function of quantity demanded, even when hypercongestion occurs."[24]

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[23] Various empirical studies and speed-flow models are reviewed in Small and Verhoef (2006, Chapter 3).

[24] These arguments notwithstanding, it does appear that tolling may be particularly beneficial at times when hypercongestion would otherwise occur. (Simulation results by several authors using different dynamic models are reviewed in Small and Verhoef (2006, Chapter 4).) Moreover, traffic count data on State Route 91 in California show that the High Occupancy Toll (HOT) lanes support higher hourly traffic flows per lane than do the toll-free general-purpose lanes (Poole and Orski 2003, 6). However, this behaviour has yet to be systematically analyzed and explained, and the idea that congestion pricing can increase throughput on roads generally is controversial. One consideration is that, unlike the HOT lanes, the toll-free lanes have intermediate entrances and exits between their end points that could create turbulence in the traffic stream.

Martin Beckmann, Bartlett McGuire and Christopher Winsten

Having presented the conventional model of Walters (1961), I now step back in time to a more comprehensive work of 1956. In a pathbreaking monograph that covered rail as well as road transport, Beckmann, McGuire and Winsten (1956) showed how mathematical programming methods could be used to solve for traffic equilibrium on a road network and how to use tolls to manage route choices and an optimal number of trips.[25] In a sense, their work extends the insights of Walters (1961) to a network. Like Vickrey and Walters, Beckmann et al. were interested in tolls to manage efficient usage of roads rather than to finance them:

> In this discussion, tolls are looked upon, not as a means of financing road construction, but as a means of bringing about the best utilization of the highway network. This is in keeping with the growing acceptance among modern economists of the proposition that best use of facilities requires methods of pricing the services of these facilities that reflect the incremental cost attributable to each service demanded by an individual user. Because of the non-linearity in the relation between amount of use and cost, such pricing does not necessarily produce revenues equal to the total cost of operating and financing the facility. (Beckmann et al. 1956, 8 [Introduction by T.C. Koopmans])

Herbert Mohring

A theme that underlies Mohring's extensive writings on transport economics is that economic principles of price and value are applicable to transportation generally, and highway travel specifically.[26] Like other leaders of the era, Mohring was a strong advocate of SRMC pricing. His most celebrated result, derived in Mohring and Harwitz (1962), is the *cost-recovery theorem* that the revenues from SRMC pricing just suffice to pay for optimal capacity if capacity is perfectly divisible and supplied at constant marginal

[25] Boyce, Mahmassani and Nagurney (2005) provide an insightful review of the impacts of Beckmann, McGuire and Winsten.
[26] See, for example, Mohring (1976, Ch. 1).

cost, and user costs are homogeneous of degree zero in usage and capacity. The cost-recovery theorem is especially noteworthy for establishing that, despite the misgivings of Beckmann et al. noted just above, there may be no conflict between SRMC pricing and AC pricing.[27] Put another way, there may be no conflict between Dupuit and Pigou.

Anthony Downs

Downs' writings on traffic congestion span more than 40 years. His attitudes towards road pricing will be discussed later. In Downs (1962) he describes why attempts to alleviate congestion by building new roads or expanding existing ones are likely to be frustrated as travellers shift from other routes, other times of day and other modes until the new capacity is clogged. Downs formalized this behaviour as: "Downs's Law of Peak-Hour Traffic Congestion: *On urban commuter expressways, peak-hour traffic congestion rises to meet maximum capacity*" (Downs 1962, 393).

Although Downs did not analyze tolls, his article helped to motivate road pricing because Downs's Law seemed to apply to all policies that improve traffic conditions except policies that operate via the price mechanism.

The Smeed Report

In 1962 the UK Ministry of Transport assembled a panel of experts and asked them to examine different forms of road taxes.[28] The result was the Smeed Report (UK Ministry of Transport, 1964).[29] Like Vickrey, the

[27] In the same year, Nelson (1962, 435 [italics added]) had complained that "the loosening of all constraints of user revenue coverage of total costs on wasteful investment under the marginal-cost pricing scheme would work against a more efficient resource allocation; and *it has yet to be shown* that sufficient investment in economically-justifiable public transport facilities could be assured without the revenue-coverage criterion." As Mohring (1964, 1) observed after citing Nelson, "This and similar charges that fiscal irresponsibility is involved in advocating congestion pricing for highway services have been strongly refuted."

[28] The authors considered it outside their terms of reference to discuss the disposition of surplus revenues from road pricing. I am grateful to Gabriel Roth for making this point.

[29] The Smeed Report is included in this survey because many of the panel members were economists who reportedly thought along similar lines. Braybrooke (1974), a political scientist, describes the Smeed Committee members as advocating the same proposal (p.24): "I shall treat Beesley and his fellow-economists as one station, in spite of their not being

Smeed Report emphasized the practical aspects of road pricing, although it put more emphasis on user-friendliness. The conclusions of the report were upbeat:

> When we started our work, we set out a list of 17 requirements which we considered desirable for a road pricing system. Some at least of the six meter systems show promise of satisfying all these requirements. The main conclusion that emerges from our work, therefore, is that there is every possibility that at least one of these proposals could be developed into an efficient charging system and could yield substantial benefits on congested roads. (UK Ministry of Transport 1964, 42) [30]

Gabriel Roth

Roth was trained as a civil engineer and as an economist, and served on the Smeed Committee panel. Several themes run through all his major works (e.g. Roth, 1966, 1967, 1996):

- economic principles should be applied to roads;
- road pricing should be used both as a Pigouvian tax and as a means of funding road construction and maintenance;
- roads should be controlled by a roads authority that behaves like a competitive market; and
- problems should be approached as an issue of comparative institutions, not solving a model.

Roth did not endorse private roads in his early writings, but he later became more favourable towards them (e.g. Roth 2006).

organized as a group, since they were throughout the period in close touch with one another, supporting each other's arguments and advocating … the same proposal."

[30] The Smeed Report was not universally welcomed. Goodwin (1997, 2) remarks how "a now retired civil servant told me that as a young man he found in the Ministry of Transport files a note, in the personal hand of the Prime Minister, Sir Alec Douglas Home, saying 'let us take a vow that if we are re-elected we will never again set up a study like this one'."

Late twentieth-century extensions

The insights into congestion pricing were extended in various directions over the next thirty years or so. One important extension was to develop dynamic models that treat in a conceptually satisfactory manner temporal peaking of travel demand and the transitory nature of congestion that can be manifest as hypercongestion. Another stream of research explored the robustness of the cost-recovery theorem to relaxation of assumptions.[31] An especially significant contribution was to add road damage to the basic model, and to derive rules for efficient pricing of pavement damage and optimal pavement durability in combination with rules for efficient pricing of congestion and optimal road capacity. The key pieces are Newbery (1988 and 1989), Small and Winston (1988), and Small, Winston and Evans (1989). Roughly speaking they established that, under plausible assumptions, the sum of congestion and road damage charges just pay for the combined costs of optimal highway capacity and maintenance.

A question of practical interest that arose was whether a social optimum can be supported by tolling road links, or whether tolls need to be differentiated according to the origins and destinations of travellers. Dafermos and Sparrow (1971), two specialists in operations research, claimed that origin-destination-based tolls are required. As Littlechild (1973), an economist, pointed out (195) this would "render totally impracticable a road pricing system". But Littlechild showed that the Dafermos-Sparrow result holds only if travel times are equalized on all feasible travel paths, which is unlikely to be the case in practice.

Yet another stream of research examined under what conditions efficient pricing can be implemented with anonymous link tolls; i.e. tolls that do not depend on the characteristics of vehicles, motorists or trips. A key result, derived by Arnott and Kraus (1998) using a dynamic model, is that anonymous link tolling is efficient if tolls can be varied freely over time. These and other developments strengthened the modeling foundations of SRMC pricing as well as the case for launching road congestion pricing experiments.

Reluctance to do the obvious

The research on road pricing in the early 1960s was taken seriously enough by the US Highway Research Board that it organized a panel

[31] See Hau (1998 and 2005b) for a review.

session on congestion pricing and several papers were published in the 1964 *Highway Research Record*. Two of the papers were distinctly hostile. Grubbs (1964), an economist, targeted his critique at Walters (1961) and concluded that "assumptions underlying the proposition are too improbable to serve as a foundation for public policy … for highways in the United States" (Grubbs 1964, 15).

St. Clair (1964), a highway engineer, asked "three economists of the Bureau of Public Roads" (82) to comment on Walters' article.[32] The economists each raised a number of concerns. Selected and representative passages from their assessments follow:

> Professor Walters on page 677 assumes that traffic is homogeneous, all drivers are the same, and all vehicles have the same costs and speed, etc. He agrees that this is wholly unrealistic, but pursues his model in terms of these assumptions as though these were not people with individual preferences but water moving through a conduit pipe. (*Sidney Goldstein*, quoted by St. Clair 1964, 83)

> Presumably the purpose underlying the toll suggestions is to maintain and increase concentration of activity at the urban core. I doubt if a more self-defeating proposal—in the long run—could be devised. (*E.L. Kanwit*, quoted by St. Clair 1964, 84)

> [T]here is no way possible to even make a reasonable estimate of the necessary data. Hence, no practical purpose is served—neither is any theoretical validity obtained. (*John Rapp* [regarding the feasibility of using Walters' equations], quoted by St. Clair 1964, 85)

In the same issue of *Highway Research Record*, Zettel and Carll (1964)—two engineers—provide a more balanced assessment of road pricing. Nevertheless, after several pages of analyzing the various possible impacts of tolls, they remark:

[32] St. Clair does not say whether the economists had postgraduate degrees. But it seems reasonable to suppose that they had a job title of "economist" and therefore meet the definition of an economist adopted for this survey.

> At this point, one suffers mental indigestion trying to picture the tolled, the tolled-off, and the untolled, the users and the nonusers, bouncing around among the alternatives, all the while a blinking giant of a computer is fixing and refixing tolls, shadowing users, and redistributing income to promote the general welfare through an optimal arrangement, not only of travel, but also of nontravel. (Zettel and Carll 1964, 60)

Turvey (1968, 101) voiced similar criticism of the simplifying assumptions used in the standard peak-load pricing model: "[T]hey remove from the discussion some of the most interesting and important issues—in the field of electricity supply, at any rate." And "[W]hat follows is an attempt to bring [the authors] down from their ivory towers." In his concluding paragraph, Turvey remarks (113): "The theoretical 'solutions' to the peak-load problem are a beginning, not an end, serving to dispose of past confusion about the principles of allocating cost. While the matters which then have to be examined are less suited to the tools of the armchair economist, they are both important and fascinating. The only practicable method of securing quantified analysis is to engage in large-scale long-term experiments of the type now being pioneered in Britain." Turvey's remarks reveal some clear parallels between electricity and road pricing.

These and other criticisms were mostly focused on the practical relevance of the model. As already noted, the modeling literature has been elaborated considerably since the 1960s. Technology has advanced greatly too. But implementation of road pricing in urban areas is still quite limited. Economists have been perplexed by this failure:

> Seldom has applied economics produced an idea with such unanimous professional conviction in both its validity and its political unacceptability. A.A. Walters's article on 'congestion' in the *New Palgrave Dictionary of Economics* states flatly, 'The best policy to deal with urban road congestion is likely to be some form of road pricing. However, road pricing is the exception rather than the rule.' The consensus among professional economists in favour of this approach on economic grounds is strong. The theory is now refined and standard; implementation has been widely explored; numerous empirical studies have predicted its effects; and the whole package has made its

> way into standard textbooks in urban and transportation economics. (Small, Winston and Evans 1989, 86-87)
>
> It has been a commonplace event for transportation economists to put the conventional diagram on the board, note the self-evident optimality of pricing solutions, and then sit down waiting for the world to adopt this obviously correct solution. Well, we have been waiting for 70 years now, and it's worth asking what are the facets of the problem that we have been missing. Why is the world reluctant to do the obvious? (Lave 1995, 465)

Maybe part of the problem has been the emphasis on models. When the intellectual focus is on capturing the universe in a model and solving for optimality, the intellectuals tend to neglect many practical human and institutional arguments that ought to weigh heavily in a judgment between alternative arrangements. The model-based road-pricing literature has neglected the points of Smith and Coase about the organizational, accountability, and knowledge virtues of an independent facility that must recoup its expenses itself. Coase's sensible suggestion of multi-part pricing has not received much attention, probably because it is not so amenable to graphical representation or simple mathematical formulation. Since the 1960s, model-based discourse has enjoyed great prestige, leaving others such as Gabriel Roth less heeded and less influential.

ATTITUDES TOWARDS ROAD PRICING ON PUBLIC ROADS

Economists have exhibited diverse attitudes about the various aspects of road pricing. This section is organized by such aspects.

Treating roads like other market goods

One argument for road pricing is simply that roads should be treated like other goods, and road users impose costs on other users as well as on society as a whole. As noted above, this argument underlies Mohring's

work. It is also apparent in the following quotes, arranged in chronological order, including passages written by Murray Rothbard and Walter Block—strong proponents of private roads.

> While there are those who maintain that transportation is so peculiar an industry that it is not properly amenable to the principles underlying the price mechanism, the majority of economists probably accept the view that, in general, a transport facility to be justified must be able to pay its way. (Peterson 1932, 425) [33]

> This book attempts quite simply to apply to the commodity 'road space' the economic principles on which we rely for the allocation of most of our goods and services. Its objects are to show that traffic congestion can be sensibly dealt with only if the economic factors that underlie it are understood, and to stress a number of points, which, though not new, are not generally recognized. (Roth 1967, 11)

> Frantically increasing the supply while holding the price of use far below the market simply leads to chronic and aggravated congestion. It is like a dog chasing a mechanical rabbit. (Rothbard 1973, 213)

> [O]n the *market*, people are continually choosing between (usually) lower-priced but more crowded conditions, and more expensive, less congested alternatives. They do this in their daily choices to patronize, or not, a crowded fast food chain, a bargain sale at a local department store which they expect will attract large crowds, etc. The problem with our road network, in this regard, is that there is no functioning market in which the consumer can make his preferences known: there are no congested but cheaper highways, competing alongside more expensive but emptier ones. (Block 1980, 305)

[33] A similar statement appears in Peterson (1950, 200).

> Road pricing is a simple concept that extends the common practice that is virtually ubiquitous in every other sector of a market economy whereby prices are used to reflect scarcity, and to allocate resources to those that can best use them. In most places road space, even in such supposedly market orientated societies as the U.S. is in actuality allocated in a manner more akin to the general practices employed in pre-1989 communist Russia, namely by waiting in queues and lines. (Button 2004, 3)

> Are externality charges unfairly redistributive? They are not aimed at poor people but at voluntary activities: if you decide to stop causing trouble for others, you don't have to pay an externality charge. It is true that the rich can afford to drive more than the poor, but it is just as true that the rich can afford to eat more than the poor. This is unfair too, but if you accept the workings of the price system for typical goods like food, why not road space or clean air? We recognize that food, clothes, and houses cannot be free or we would quickly run out of them. It is because roads are free that we have run out of spare road space. (Harford 2006, 88-89 [writing for a general audience])

Marginal-cost pricing of roads

The tension between SRMC pricing to induce "efficient" usage of roads, and AC pricing to finance them has been evident since Dupuit and Pigou.[34] The choice matters to the case for road pricing inasmuch as marginal-cost pricing requires differentiation of charges with respect to space, time and vehicle characteristics, and thus calls for finer pricing instruments than does average-cost pricing. A uniform vehicle registration

[34] An early example is Clark (1923, 304-305) who discusses "the paradox of overhead cost" and the conflict between charging traffic enough to cover the overhead and the typically minimal charges (in his era) required to cover the marginal costs of their usage. This lesson is also central in Coase (1946) who advocated second-degree price discrimination. By contrast, Ramsey's (1927) solution for a set of products entailed third-degree price discrimination, and Ramsey pricing has been the more prominent as a policy candidate in both the peak-load pricing and road pricing literatures.

tax might recover costs at the aggregate level. The fuel tax could do so, too, and it would be more efficient and equitable than registration fees since payment of fuel taxes varies with amount traveled.[35]

The attitudes of some economists towards marginal-cost pricing of transportation have, no doubt, been influenced by the marginal-cost pricing controversy that was debated at length by Coase (1946) and others in the early and middle part of the twentieth century. Blaug (1985) reviews the "tortured history" of marginal-cost pricing (MCP)[36] and three passages are worth quoting:

> MCP is one of those orthodox doctrines that has been continually criticized and rejected by experts in the field of public utility pricing but nevertheless remains part and parcel of the corpus of received economic ideas. Even now, the precise status of the concept is a matter of frequent misunderstanding. (Blaug 1985, 16)

> The case for MCP, or, as we should now say, the case for making MCP a point of departure for a set of optimal prices, stems basically from the fundamental conditions for Pareto-optimal efficiency; and, of course, Pareto optimality is defined only with reference to a particular distribution of income or, rather, resource endowments. If we are unwilling to divorce efficiency from equity, at least for the sake of argument, neither the concept of MCP nor that of optimal deviations from MCP makes any sense . . . it is the willingness to analyse efficiency arguments apart from problems of income distribution that divides the advocates from the critics of MC(Blaug 1985, 25)

> MCP requires empirical judgements on a product-by-product basis about market structure, indivisibilities, externalities and elasticities of demand and supply; in short, it is a systematic check-list of what to look for in pricing a public service. It does not, therefore, furnish any

[35] Tolls can be used to internalize external costs besides congestion and road damages, but the case for doing so is not as clear. Greenhouse gas emissions, for example, can be effectively targeted with a carbon tax.

[36] See also Ekelund and Hébert (1999, Ch. 7) in the context of transportation.

> simple pronouncements about public pricing, except perhaps that public enterprises should not necessarily be expected to break even and that almost any pricing rule is better than average cost pricing. (Blaug 1985, 29)

The second passage from Blaug highlights the importance of attitudes towards equity, which will be covered later in this section. And the third passage points to difficulties in implementing MCP which will also be reviewed.

The competing demands of allocative efficiency, cost recovery, adherence to the user-pays principle, and equity were clearly identified by Beckmann, McGuire and Winsten (1956):

> From the point of view of the best overall expansion and utilization of a network, the constraint that each toll road should pay for itself must be dropped. Instead the problem becomes one of finding the most 'equitable' allocation of road costs to sources of tax revenue. To what extent should finance be sought in the form of taxes on vehicle ownership at particular locations on gasoline consumption (and hence total mileage, approximately) and on the use of particular roads (tolls)? (Beckmann et al. 1956, 5.12)

> While a case can be made for some use of general funds for this purpose, since an efficient road system contributes to the general welfare, the intensity of communication, and the speed of emergency help, etc., it would seem to be a point of justice that the bulk of the money should come from the road users in a form connected with road use. This would leave a considerable share to both general vehicle and gasoline taxes. The optimal apportionment—optimal, that is with respect to the combined standards of equity and efficiency—poses an interesting problem which will be the subject of discussion for a long time to come. (Beckmann et al. 1956, 5.14)

The last sentence is particularly prescient since the 'discussion' has gone on for half a century.

While most economists who wrote about road pricing in the mid-twentieth century were in favour of SRMC, there were notable exceptions.

Meyer, Peck, Stenason and Zwick (1959) focused on infrastructure costs rather than usage costs, and advocated an *incremental-cost pricing scheme* which effectively amounted to some hybrid of LRMC and AC pricing. However, their arguments (see 69-72) suggest some vacillation. Six years later, Meyer, Kain and Wohl (1965, Ch. 13) also appear undecided, but they too came down in favour of average-cost pricing:

> In essence, to adhere to marginal cost pricing in circumstances where marginal costs exceed average costs because of congestion amounts to imposing user charges on the basis of some elusive social cost concept rather than the cost of the physical resources consumed or used. Specifically, price discrimination based upon social or congestion cost concepts is quite different from price discrimination based upon differential resource costs created, say, by use of the facility during a peak period when extra and expensive capacity is needed to meet additional demands. Differential peak period charges to cover these additional capacity costs have a much sounder basis in economic theory and perhaps also in common equity as well. (Meyer, Kain and Wohl 1965, 339)

In her book on freight transportation, Friedlaender (1969, 130-135) favours basing rates on long-run costs, but is undecided whether the appropriate long-run costs are marginal or average. Smith (1975) reviews the arguments for and against SRMC pricing and AC pricing, and concludes:

> While there is a set of points upon which economists can agree, the weights given to the various points differ tremendously. The result is that reasonable men come to different conclusions when selecting the optimal pricing strategy for highways. (Smith 1975, 452)

> And Walters himself remarks: "The view that the user should pay for all the costs of the roads is strongly entrenched among many practicing transport economists" (Walters 1968, 4, paragraph 10).

These passages reflect the doubts that even leading transport economists have had about SRMC pricing. And differences of opinion still remain. This is evident from the exchange between Rothengatter (2003), who questions the practical value of SRMC pricing on various grounds, and Nash (2003) who defends SRMC pricing principles and describes progress in applying them in recent European research projects.

Importance of road pricing for investment decisions

Like Adam Smith, several economists have pointed out that implementation of road pricing would make the evaluation of highway investments both easier and more likely to be correct.

> There are . . . two aspects to the highway problem, which should be distinguished. There is, first, the short-run task of rationing the existing plant. When some semblance of efficiency has been attained in the utilization of the highways already built, the second task—that of building the optimum size plant—can be tackled more effectively and with less likelihood of over- or under-investment. (Meiburg 1963, 656)

> It will be said that it is costly to design and collect the correct charges. And because some grossness is necessarily encountered, we too lazily settle for clichés about the inefficiency involved in overpricing someone out of the market. Instead, we should be concerned about the inefficiency caused by not having the faintest idea about the true social value of the highway network in the first place and merely expanding it whenever serious damage or crowds are encountered, or the highway lobbies exert their pressure. . . . Certainly our highways are crowded. But until we attempt to price rationally, we have no way of knowing whether the market places a value on the additions to our road network that exceeds the cost of providing them. (Abouchar 1987, 53)

One longstanding question in the literature is whether the profitability of a road provides a reliable indicator whether or not it should be expanded. Roth (1967, Ch. 6) argued that roads on which revenues exceed costs should be expanded, and roads on which the revenues fall short should be contracted (or left to depreciate). In light of the cost recovery theorem, this rule is formally sound if there are constant returns to scale in investment and in usage, and first-best-optimality conditions apply elsewhere.[37] But absent these conditions, the profitability rule can be biased in either direction:

> Requiring each project to pay its own way may be the only way of making absolutely sure that the community does not persist in investing in uneconomical projects; but to adopt a policy that results in a substantial bias against undertaking increasing-return projects seems a rather costly method of insuring that errors in the other direction are avoided. (Vickrey 1948, 230)[38]

> [T]he fact that a proposed toll road may be self-supporting provides no automatic justification for its construction in boom periods. What is required in each case is an analysis of the costs and benefits vis-à-vis the costs and benefits from alternative highway policies. (Netzer 1952, 119)

Day (1998) makes the further point that environmental and other external costs should also be included in a project evaluation:

> [I]f road users are prepared to pay a price for the use of roads that is greater than the costs of providing additional road space (*including all the costs, externalities, land costs, a sensible measure of the costs of disturbing any areas with special wildlife and all the other genuine costs which can be identified*) then the additional road space should be built, and as in any other economic activity, the charge for the use of the new

[37] First-best conditions must hold since otherwise an investment will have spillover effects on traffic flows elsewhere on the network where usage is not efficiently priced. But if the whole network is efficiently priced, the envelope theorem applies, and evaluation of the costs and benefits of investment can be limited to the road link in question.

[38] Vickrey's stance contrasts with that of Coase (1946) espoused two years earlier.

> facility should be sufficient to finance its cost. (Day 1998, 7 [italics added])

Practical feasibility of road pricing

Some economists, such as Sharp (1966), have opposed widespread implementation of congestion pricing because of practical difficulties. There are several practical considerations.

Technology and administration costs

The costs of tolling roads were a major concern in the 1950s and 1960s; for example, the Smeed Report duly addressed such costs. Foster (1963, 245) expressed unease about the need for frequent and costly collection booths. Such concerns have faded, however, since the advent of affordable and reliable Electronic Toll Collection systems, which permit tolls to be varied by location, time of day and various vehicle characteristics. But for roads with low traffic volumes, the costs of tolling are inhibitive, and some economists still perceive them to be a problem generally.

> An important issue is how road users should be charged for road use. Many proposals have been made and some have recently been tried: tolls collected at toll booths, perhaps electronically; electronic metering of road use with bills sent to users at the end of the month; and fuel taxes. Each has its advantages and disadvantages; accuracy, capital costs and collection costs (both those of the collecting agency and those imposed on users) are the important ones. In the U.S., at least, an important issue would be illegal behavior to avoid fees. If users refused to pay their road use bills at the end of the month, the police would be forced to be collection agents; some people would demolish electronic gear in roads. In addition, users would become demoralized if there were many errors in charges in billing. Any sophisticated system would be several times more complex than the most complex activity of U.S. local governments. (Mills 1998, 78-79)

In addition to toll collection and billing, costs are incurred in assembling and implementing supplementary measures to make road pricing acceptable to the public. One such scheme, proposed by two engineers, Kockelman and Kalmanje (2005), and based on the idea of tradable emissions permits, is called "Credit-Based Congestion Pricing" (CBCP). CBCP entails congestion pricing on a network of urban highways. Residents of a prescribed area are each granted a monthly allowance of travel credits, and those who drive less than average can save the credit for future travel or exchange it for cash. In February 2004, Gulipalli, Kalmanje and Kockelman (2005) mailed questionnaires to transport economists and other professionals to assess their attitudes towards CBCP. The transport economists expressed general support for the scheme, but many were concerned about the costs of administering a credit system to a wide population.[39]

Pricing only selected roads

Except possibly for future satellite-based road pricing systems, it will never be practical to impose tolls on every road, and all schemes now in operation are limited either to downtown areas or selected highways. The area-based schemes either charge vehicles for moving within a charge area (London) or for crossing a toll ring (some Norwegian cities, Stockholm). These schemes catch only a fraction of trips, and the charges do not vary smoothly with distance. Some economists have objected to the crudeness of their design:

> The greatest growth in traffic in the UK over the last 10 years has been on motorways and the interurban road network. Should we be concentrating on toll road pricing on these routes rather than on city centres? Cities are themselves changing and the congestion problem may be migrating from the centre to the suburbs. The dynamic of the city is such that when road pricing becomes a reality, it is no longer a necessity and may accelerate the unsustainable city. (Banister 2002, 7)

[39] Attitudes of the economists towards the equity aspects of CBCP are noted later.

Shortly after London's congestion charge was launched, a similar cordon scheme was proposed for Sydney's central business district. Hensher (2003) expressed his misgivings:

> Although I support the notion of efficient pricing, this particular proposal is in danger of missing the mark …. The success of the London initiative as the first congestion charging program in a major European city is important for Australia in demonstrating the political feasibility of pricing …. What we must ensure however is that any congestion charging system is not selected for the convenience of an appealing cordon such as the CBD, but for broader systemwide efficiencies. (Hensher 2003)

Another drawback of both area-based charges and highway tolls is that motorists may divert onto toll-free routes, resulting in displacement rather than suppression of congestion and other external effects. However, Keeler and Small (1977, 23) downplay concern that tolling urban expressways will cause diversion to arterial streets because expressways (if well designed) will increase throughput and offer a much better quality of service.

Difficulties in computing optimal tolls

Beckmann, McGuire and Winsten (1956) showed that it is fairly straightforward to compute first-best tolls on a road network. But if tolls are restricted for any reason (e.g. only some links can be tolled, or tolls cannot vary over time) the problem becomes one of second-best. And the difficulties of computing second-best tolls have proved to be rather formidable.[40] The attitudes of economists vary. Most seem willing to support simple or crude schemes, particularly those that stand a reasonable chance of being implemented.

[40] This is true even for the prototypical Pigou-Knight two-parallel-roads network that has been analyzed extensively by economists since Lévy-Lambert (1968) and Marchand (1968). For more recent and general work see Verhoef (2000a and 2000b). Gómez-Ibáñez (1992, 354) is somewhat an outlier in considering the computational problem "manageable (and largely of esoteric interest to transport economists)."

> A comprehensive and highly differentiated system of tolls would be required to secure the 'ideal' pricing structure. Obviously, such a system would be completely unworkable from an administrative point of view, and would be uneconomic besides …. But with relatively little change or modification it appears that the system of highway user taxation now employed could be made to approach one which would achieve efficient operation of the existing highway structure. (Buchanan 1952, 102)

> As to over-simplification, I make no excuses for this. It seems to me that the complications that arise from the attempt to plan roads without a pricing mechanism are so great that over-simplification might even be welcome … If we want to obtain practical results in a real world we must use methods that can be readily understood by the civil servant and the local councillor. (Roth 1967, 13)

> [E]stimating the size of an optimal congestion tax is a considerably more complex matter than was recognised in some of the earlier literature, involving, as it does, a range of variables some of which can only be determined with a degree of uncertainty. This does not necessarily, however, weaken the case for using pricing methods to control congestion. The problem essentially stems from the difficulty of determining the optimal position, and that is a problem which would arise whatever regulatory instrument was envisaged as a means of achieving it. (Else 1986, 104)

> The best way to ration roads whose capacity cannot be increased is to charge a market price for the right to use them. Charges should be set just high enough to hold traffic down to levels that can move freely. Finding that optimum is less of a subjective exercise that it sounds: above a certain critical rate of flow, road traffic seizes up rapidly. The principle is equivalent to that of admission to a theater: it is self-defeating to let in so many people that everybody's view is spoilt, so sensible theater managers set prices that fill them to just below the point of discomfort. (The Economist 1989, 11)

> [I]t is not straightforward to calculate socially optimal congestion tolls by road sections and by time of day or day of week. However, since congestion consumes enormous amounts of a valuable resource (people's time), a reasonable approximation, which can be done quite easily, is likely to be better than completely dismissing this sound pricing method. (Gillen 1997, 211)

> Determined leadership using the available technology can deliver real benefits in the areas where they are most needed, before congestion becomes chronic with all the consequences for the quality of life and business efficiency, and thus international competitiveness. Doing something now, or very soon, is likely to serve the community better than deferring action until we can do it 'better'. . . Singapore, Austria and Switzerland reinforce the London lesson, demonstrating what can be achieved if sights are not set too high. 'Good enough' *can* be the basis of good policy. (Richards 2005, 287-8)

> Nobody knows the cheapest way of solving our traffic problems—yet. But externality pricing brings pollution, congestion, and the rest inside the world of truth, which markets create for us. As long as individuals have to face the truth, or at least our best estimate of the costs of their actions, they will find a way to reduce those costs. The longer they have to respond, the more surprising and innovative the responses can be. . . . The attractive thing about externality pricing is that it attacks the problem but makes no assumption about the solution. (Harford 2006, 95, 97)

Still, some economists have recently underscored the potential weaknesses of second-best schemes, or identified visceral resistance to them:

> [T]he amount of information required to apply a policy instrument to best advantage increases with the 'imperfectness' of this instrument. For the case considered

> here, this information includes the distribution of values of time and the demand elasticities of users having different values of time. Thus, second-best policies require considerable sophistication in order to achieve their theoretical benefits. (Verhoef and Small 2004, 154)

> [W]hen local politicians ask for low-price solutions, they are often abandoned by the scientific community. Engineers promote the most sophisticated technology available and show little enthusiasm for potential customers asking for low-cost technologies. Economists often do not dare to propose simple rule-of-thumb policies. Although such policies might reap huge welfare gains, they often fail to meet the professional standard of providing optimal or at least almost ideal solutions to actual economic problems. (Arnott, Rave and Schob 2005, 188)

As Verhoef and Small (2004) point out, the information needed to compute second-best tolls can be quite demanding. But, as noted in the previous section, even first-best tolling in the basic model requires information on demand and cost curves. To circumvent this problem many economists have suggested that tolls be set iteratively by a process of trial and error.[41] Setting tolls by trial and error was apparently anathema to the engineer St. Clair (1964) when he wrote "The user might experience some discomfort during this experimental period, but then, so does the guinea pig" (85). But periodic adjustment of tolls is now official policy for Singapore's electronic road-pricing system where tolls are adjusted every three months to maintain average vehicle speeds within a prescribed range (Singapore Land Transport Authority). Sandholm (2002, 2005, 2006) formalizes this idea by modeling an evolutionary game in which individuals adjust their travel decisions sluggishly in response to incentives, and the planner sets *variable* tolls iteratively with only limited knowledge about the individuals' preferences and behavior. As Sandholm describes it:

[41] See, for example, Hotelling (1938, 269), Friedman and Boorstin (1951, 238), Beckmann, McGuire and Winsten (1956, 19), Walters (1961, 697), Beesley and Roth (1962-63, 188,193), UK Ministry of Transport (1964, 35, 36), Roth (1967, 41), Vickrey (1967, 127; 1993, 4) and Beesley (1973, 229, 241-2).

> Variable price schemes can be viewed as generalizations of marginal-cost pricing. 'Marginal-cost pricing' usually refers to an equilibrium phenomenon: that by making agents pay for the externalities they create in equilibrium, one can guarantee the efficiency of equilibrium play. In contrast, variable price schemes set prices appropriately both in and out of equilibrium. (Sandholm 2002, 670)

> [V]ariable pricing enables a planner to ensure that efficient behaviour is an equilibrium without knowing what efficient behaviour will turn out to be. (Sandholm 2005, 887)

Complexity for users

As noted earlier a majority of economists support the principle of SRMC pricing which dictates that prices match the costs imposed by drivers as closely as practicable. Vickrey was a particularly strong proponent not only of varying prices with predictable variations in costs, but also responsively to unanticipated fluctuations. In defence of this policy he wrote:

> It might be thought that imposing charges determined after the user has very largely committed himself to the trip and the route would have little effect in improving efficiency of utilization. In this case, however, the larger part of traffic contributing to rush hour congestion is repeat traffic that tends to follow the same route at the same time day after day, and an additional portion of the traffic is a sufficiently frequent and regular user to become fairly familiar with the conditions to be expected at various points and times. Consequently, even though the imposition of a charge may come too late to affect the trip for which it is imposed, it will affect subsequent trips of a similar character, and thus is conducive to efficient utilization. (Vickrey 1971, 345)

Vickrey offers one explanation for traditional resistance to responsive pricing:

> [T]he main difficulty with responsive pricing is likely to be not mechanical or economic, but political. The medieval notion of the just price as an ethical norm, with its implication that the price of a commodity or service that is nominally in some sense the same should not vary according to the circumstances of the moment, has a strong appeal even today. (Vickrey 1971, 346)

Despite his enthusiasm for responsive pricing, Vickrey acknowledged even in his early writings the limitations of SRMC pricing in its pure form.

> [I]t is at least doubtful whether any advocate of marginal-cost pricing has ever seriously proposed that prices should slavishly follow marginal cost in every detail, without making some allowance for administrative costs involved in such detailed rate structures and for the fact that, beyond a certain point, the consumer may become so confused that the more intricate rate schedule would cease to function effectively as a guide to consumer choice, thus losing its *raison d'être*. (Vickrey 1948, 233)

Many other economists have advised against varying tolls responsively[42], or even in short time increments according to a predictable schedule.

> If the price system is complicated road users will probably find simple 'rule of thumb' methods to tell them approximately what the average prices are and roughly what the prices of particular journeys are likely to be, and they will act accordingly. If this is so the complicated system may be no more efficient than a simpler system.[43] (UK Ministry of Transport 1964, 48)

[42] To date, responsive pricing has been applied only on two High Occupancy Toll facilities in the US: Interstate 15 in San Diego, and Interstate 394 in Minneapolis.

[43] Intriguingly, Michael Beesley, a member of the Smeed Committee, appeared to back away from this position five years later: "Two other desiderata, which the Committee thought were important now seem less so. These were that 'prices should be stable and readily ascertainable by road users before they embark on a journey'; and that 'the incidence of the system on individual road users should be accepted as fair'. The first merely turns on experience and information; even now, no one can predict with certainty, when proposing to

> The toll itself must also be comprehensible. Thus a simple peak/off-peak pricing differential (marketed as an off-peak discount) is much preferred to a congestion-based variable toll. Variable tolls are conceptually elegant and technically feasible, but potentially confusing to the consumer. (Giuliano 1992, 354-355) [44]

> [S]imultaneous pricing is subject to the same sort of objection as retroactive pricing[45], because motorists would not know the price until they were committed to their trip. From an economic point of view, simultaneous pricing is inefficient because it forces consumers to make decisions on the strength of uncertain knowledge of the prices involved. Such uncertainty would probably make it unacceptable to the public. (Thomson 1998, 99)

> Without questioning the legitimacy of marginal cost pricing, the problem is that is has proved difficult to implement. In today's technologically advanced world the calculation of instant marginal cost pricing may not be very difficult to envisage. Its cost effectiveness, however, would be dubious and, most importantly, the transparency of such a system would be at least arguable, as drivers would not know the congestion charge they would be required to pay before starting their journey. Marginal cost pricing would require highly differentiated pricing systems in time

make a trip what congestion will be: certainly under road pricing expectations about congestion, and therefore prices, will be no less certain." (Beesley 1973, 234)

[44] Genevieve Giuliano does not meet the definition of an economist adopted for this review as "someone with a postgraduate degree in economics or a job with a title of economist such as a teaching or research position at a university economics department." She has a Ph.D. in Social Sciences, U. of California, Irvine School of Policy, Planning & Development, and is currently a Professor in the School of Policy, Planning, and Development, University of Southern California (http://www.usc.edu/schools/sppd/faculty/detail.php?id=11, accessed May 3, 2006). Her background is "in geography, economics and political science" (http://152.122.41.184/NYSMPOs/colloquy_bios.asp, accessed May 3, 2006). Given the overlap of her education and background with economics and her extensive publication record, I considered it fitting to include her in the survey.

[45] As Thomson defines the term "simultaneous pricing" is synonymous with responsive pricing. "Retroactive pricing" entails setting prices after a trip is completed.

> and space, which would be expensive to provide and confusing to users. (Santos 2004, 346)

Equity

Welfare-distributional considerations were addressed early on in the public utility pricing literature (Feldstein 1972). But equity was largely ignored, or dismissed, by both the pioneers and the mid-century writers on road pricing. As Beesley remarked:

> Undoubtedly the main opposition to road pricing arises from doubts as to its effects on individual's welfare. To some extent, exponents have themselves to blame for what has often been a hostile reception. Partly this is because in early expositions the case was drawn up in such a way as to eliminate the problem of inter-personal comparisons of gains and losses. The Knight-Pigon [sic] example postulated a 'narrow but good' road competing with an inferior one of infinite capacity. No one could be made worse off by tolls on the narrow but good road when congestion arose on it, because total costs rose to the level of those on the 'bad road', which acted as a perfect substitute. . . . The Smeed Committee's own calculations of 'benefits' from road pricing treated road pricing as a 'transfer payment' which represents no real cost to the community. (Beesley 1973, 279-280)

Some of the first economists to consider the welfare distributional effects of road pricing, such as Layard (1977) and Glazer (1981), concluded that tolls are regressive because those who benefit the most have the highest values of time (VOT) and VOT is positively correlated with income. Foster (1974), however, pointed out that the welfare impacts of road pricing depend not only on changes in travel time and out-of-pocket costs, but also on any improvements in public transport service, changes in the geographical incidence of emissions, accidents and other external transport costs, and so on. Economists came to appreciate the difficulties in assessing the welfare impacts as well as the practical impossibility of designing a tolling scheme that leaves everyone better off. Partly for this

reason, many economists have downgraded equity as a primary consideration for road pricing.

> Disputes over the distribution of the national income can be handled much more reasonably if they are brought into the open in discussions of rates of income tax and other deliberately income-redistributing measures. Such considerations can be excluded from rate-fixing problems only by setting rates at marginal cost. (Vickrey 1948, 236)

> Section 210 of the Highway Revenue Act of 1956 suggests 'equity' to be the basic desideratum of Congress in allocating the burden of highway finance. Unfortunately, 'equity' is not an operational concept. The word means 'fairness' and 'justice,' which are terms that do not have universally accepted operational definitions. (Mohring and Harwitz 1962, 87)

> That they are ill-fed, ill-clothed, ill-housed, and, perhaps, ill-transported is really not the basic problem that poor people have. Their fundamental problem is, rather, that they are poor. If we are genuinely concerned with how road pricing would affect their welfare, we should give them cash or marketable road scholarships. It would be the height of folly, however, to subsidize all of our private-passenger-vehicle road use in the supposed interests of helping them. (Mohring and Anderson 1994, 34)

Foster (1974, 1975) and Richardson (1974, 1975) exchanged views on the importance of equity:

> [S]ince there is a strong case for road pricing on efficiency grounds, whereas the equity arguments are murky, the issue should be decided in the light of efficiency, goal achievement and political feasibility. We should not try to make a probably unpopular but effective measure more palatable by resorting to specious social arguments. The question of the equity of the tax among road users as a whole cannot be resolved, and hence is not critical to decisions on road pricing. (Richardson 1974, 84)

> (Of course this is not to say that the state could so determine net distributional impact for each and every person as to turn the change into a Pareto improvement or any other exact distribution of the net gains as between *individuals*.) That introduction of road pricing is a potential Pareto improvement is the single most important proposition relevant to its net distributional impact.[46] (Foster 1975, 186 [after noting that the state influences the welfare effects of road pricing by choosing how to allocate revenues])

> I also support direct road pricing, though on grounds that do not require buttressing with 'murky' equity arguments, and I agree that the revenue can be used as an instrument for compensation. . . . I would like to endorse Foster's statement that aggregate measures of income distribution are of little value and his suggestion for a 'net distributional impact' approach to the evaluation of transport policy decisions. If equity objectives are relevant to transport policy, and I think they are, measures that minimize unfavourable distributional impacts on the poor merit serious attention. (Richardson 1975, 188 [now showing rather more concern for equity])

After accepting the potential Pareto improvement as a criterion for project evaluation, Glaister (1981) addresses the equity of road pricing:

> The 'unfairness' of peak pricing rests on the premise that constant prices are 'fair'. But it is neither fair nor sensible to encourage the poor or anybody else to use a facility which costs society (or travellers at other times) more to provide than the benefits they derive from it. On the other hand, it must be admitted that the imperfect nature of taxation and compensation systems in practice means that inevitably some individuals will in fact be made worse off.

[46] This echoes the passage from Blaug (1985, 25) quoted above in the section "Marginal-cost pricing of roads".

> This disadvantage has to be set against the welfare losses due to economic inefficiency. (Glaister 1981, 69)

Not all economists, to be sure, disregard equity as a desideratum for road pricing. For example, the Gulipalli et al. (2005) survey of attitudes towards Credit Based Congestion Pricing found that some transport economists considered inequitable a distribution of credits to everyone with a driver's license, regardless of how much they would use toll roads.

A number of economists have examined the relationship between efficiency and equity inherent in the design of road pricing schemes. Most have concluded that there is a tradeoff between them. Some have examined the efficiency-equity tradeoff that has been implicitly accepted in the decision to toll only some lanes of the High Occupancy Toll (HOT) lane facilities in the US. Some consider the tradeoff to be reasonable (e.g. Giuliano 1992, 354; Richardson and Bae 1998, 259). Verhoef and Small (2004) show using a simulation model that the tradeoff depends critically on how total road capacity is allocated between the toll lanes and the toll-free lanes.

Some writers claim that road pricing is no more regressive than other ways of paying for roads.

> The existing system of road financing is triply regressive. Taxpayers generally, a poorer class, support road users generally, a richer class, with municipal services like fire, police, courts, ambulances, and emergency rooms benefiting road users. Road users generally, a poorer class, support peak-hour road users by paying with their fuel taxes for roads generally sized to accommodate peak-hour users. And five out of the six taxes supporting the existing highway system are themselves regressive. (Giuliano 1994, 260)[47]

To the extent that tolls are no more regressive than other taxes, using toll revenues to reduce other taxes in a revenue-neutral manner would not harm equity.[48] This prospect is especially relevant for fuel taxes, as

[47] As quoted by Elliott (2000, 10).
[48] Cameron (1994) makes this argument forcefully for the case of gasoline taxes.

proposals for area-wide tolling in Britain and Oregon would entail reductions—or even elimination—of taxes on fuel.[49]

Allocation of road-usage revenues and earmarking

The allocation of revenues from road-user charges affects the welfare-distributional effects of road pricing as well as its public acceptability. Indeed, since charge revenues may be a large multiple of the efficiency gains from road pricing (cf. Figure 2) the allotment of revenues may be the dominant factor. According to some public finance textbooks, tax revenues should not be locked into any particular expenditure pattern because priorities can change in unforeseen ways. Nevertheless, designating or earmarking [50] revenues for particular purposes is common practice in transportation as well as other sectors and it has been justified on various second-best grounds. Economists have taken different stances towards earmarking of road-usage charge revenues. At least four camps can be identified: (a) those against earmarking, (b) those in favour of revenue neutrality (i.e. offsetting new road-user charge revenues with reductions in other charges), (c) those in favour of earmarking generally, and (d) those in favour of particular earmarked allocations.

(a) Against earmarking

> Plowing congestion tolls back into road improvements is not necessarily efficient. Presume zero population and travel growth, infinitely durable roads, and an optimally

[49] The gasoline tax is widely considered a regressive tax. Most empirical studies that draw this conclusion use data on household fuel tax outlays as a proportion of annual income. Poterba (1991) argues that because of transitory shocks and life-cycle variations in income, annual income is a poor measure of economic well-being. Using US data on annual household expenditure instead of annual income, he finds that the gasoline tax is actually slightly progressive over the bottom half of the income distribution. However, Chernick and Reschovsky (1997) criticize this approach on the grounds that annual expenditure is a poor proxy for lifetime income. To construct an intermediate-run measure of the gasoline tax burden they use eleven years of panel data on US household income and gasoline consumption. The tax burden computed this way is only slightly less regressive than the burden based on annual incomes. These disparate results illustrate the difficulties in using household incomes to assess the equity effects of gasoline taxes, tolls or other road user charges.

[50] Commonly referred to in the UK as hypothecation or ring-fencing.

> designed road network. Marginal-cost tolls would then function as a normal return on the resources that society has invested in its road network. Efficiency would dictate using road-user tolls just as any other source of government revenues. Efficiency would not dictate spending these revenues on road improvements. (Mohring 1991)
>
> It would be undesirable to return most of the proceeds to motorists by investing them in highway or transit improvement since the surpluses often may be more of an accounting artefact than a sensible signal that added capacity is needed. (Gómez-Ibáñez 1992, 358)
>
> "[I]t makes no more sense than any other scheme to hypothecate tax revenues for specific sorts of spending: if a programme is sufficiently worthy, it should be financed regardless of where the tax-money comes from; if not, the money should be spent elsewhere. A clever transport minister, in his speech proposing road pricing, will nevertheless want to make voters feel that as travelers they would benefit:
>
> 'A good transport system is the handmaiden of a healthy economy. It also allows people an essential personal freedom—to travel as they wish. The government wants to meet the demand for more travel, including car travel, not to suppress it. The money raised from city drivers will not be earmarked for particular transport projects, but you can be sure that it will make it easier for the nation to afford new road and rail links generally.'
>
> Expect such words to be intoned in many great cities before this century is out." (*The Economist* 1989, 12)[51]

[51] *The Economist* seems to take a nuanced stance by allowing that at least some revenues should be devoted to transportation as a whole.

(b) In favor of revenue neutrality

> [T]he adoption of a pricing scheme to allocate road space need not necessarily raise the total tax burden. Our argument is concerned with the *distribution* of the tax burden, not with its absolute level, and we advocate congestion taxes as a substitute for—not as an addition to—license, purchase and fuel taxes. The adoption of such a policy does require judgments to be made of the gains and losses to different groups of road users, but if the total of tax were to remain the same, there is no doubt that a more sensible allocation would benefit road users as a whole. (Beesley and Roth 1962-63, 196)

> The proposition that needs to be put to the public is that in exchange for the entire system of current road taxes (fuel taxes in excess of the rate of VAT, the special car purchase tax, and the licence fee), road-users will be charged according to their use of congested road space, at a rate which for the average road-user will be roughly the same. . . . As more than half the road-using population drives less than the average number of miles in congested areas, this should command majority support. (Newbery 1990, 31)

> I would propose . . . a much more drastic reduction in fuel tax than anyone at present envisages . . . in part counterbalanced by congestion taxes through the main congested conurbations. . . . Now is the time to reduce fuel taxes by more than the amount raised in congestion charges. (Walters 2002)

(c) In favor of earmarking generally

> The re-allocation of revenues outside the transport sector does not seem a good idea, and is likely to stimulate existing prejudices of road users as being one of the government's favourite 'cash cows'. (Verhoef, Nijkamp and Rietveld 1997, 272)

> Subject to further research, the idea of setting up a transportation (or road) fund to pursue marginal cost pricing in all its dimensions would enable us to satisfy the quintipartite principles of the World Bank's general guidelines for improving transport efficiency . . . to: (1) implement efficient pricing; (2) meet economic viability; (3) meet (to a considerable extent) financial viability; (4) achieve (some degree of) 'fairness' among beneficiaries; and (5) attain (somewhat) managerial efficiency of the public authority. (Hau 1998, 69)

(d) In favor of particular earmarking schemes

Earmarking has been gaining favour amongst advocates of road pricing, and a variety of schemes have been suggested. Goodwin (1989) proposed a "Rule of Three" whereby revenues would be allocated in equal parts to: (1) development and maintenance of new road infrastructure; (2) public transport; and (3) either to reducing the general tax burden or to increased spending. He acknowledges (p.496) that these proportions are arbitrary. But in Goodwin (1997) he argues that a scheme of this sort is essential to overcoming public opposition to road pricing:

> [R]oad pricing without explicit attention to the use of revenue streams is *inherently* unlikely to be able to command a consensus in its support. I treat this as an axiom of contemporary transport policy. (Goodwin 1997, 2-3)

Like Goodwin (1989), Small (1992) advocated a tripartite division of revenues although the goal of his scheme was less to spread benefits widely than to prevent opposition.[52] After an extensive literature review on acceptability of road pricing, Ison (2004, 74) concludes that hypothecation is "all-important". He further notes

> The research suggests that the largest proportion of the revenue generated from road user charging should be

[52] This assessment is drawn from King et al. (2006).

> utilised to improve public transport, particularly in the area in which the charge is introduced. (Ison 2004, 175)

From an efficiency standpoint, however, Button (2006) advises against earmarking to public transport:

> There would seem from the experiences of Norway and from some of the admittedly limited survey analysis conducted of road users in the UK, that if ring-fencing of revenues is done then there is at least a better case for ensuring that monies are devoted to road improvements where there is demonstrable demand, than to public transportation. Indeed, since public transportation often uses a common track there are potential synergies. (Button 2006, 239)

Most proposals for earmarking are based on the idea that road pricing schemes must create more winners than losers. King et al. (2006) argue to the contrary that gaining acceptability requires that the benefits from road pricing be concentrated, and the losses dispersed, so that the winners have enough at stake to overcome any opposition. To accomplish this they recommend that toll revenues be given to city governments where highways pass through.

> Congestion pricing cannot be sold as a policy that harms no one, nor even as a policy that helps everyone. It needs to be positioned as a policy that will help some particular group a lot. We believe that constituency can and should be the cities that host freeways. Congestion pricing in this scenario can benefit from the established strength of intergovernmental lobbyists, and can at the same time be a progressive force that compensates areas near freeways for the negative externalities they suffer. (King et al. 2006, concluding paragraph)

King et al. (2006) do not advocate that city governments spend toll revenues on any particular set of goods or services. Rather, their proposal is for earmarking revenues to particular *institutions*.

Finally, in their survey of the attitudes of transport economists and other professionals towards Credit-Based Congestion Pricing, Gulipalli et al. (2005) found some diversity of preferences among economists:

> [T]ransport economists were asked to rank a set of alternatives for uses of 'excess revenues'. Most wanted such revenues to go toward maintaining existing infrastructure and/or adding capacity. Next was development of alternative modes, such as transit. Those who strongly favored transit were not interested in reducing gas taxes—and vice versa. Some respondents suggested reducing general taxes via CBCP revenues. There was not much interest in using such revenues to improve air quality. (Gulipalli et al. 2005, 6)

In summary, economists have a range of opinions on how the revenues from road pricing should be used. A growing proportion (and perhaps now a majority) seems to favour earmarking revenues in some way. However, it may be that they support earmarking only reluctantly as a necessary concession for road pricing to move forward.[53]

In favor of road pricing, but not too hopeful

Again, concerns about political acceptability intermingle judgments of desirability. Some economists support road pricing but are less than sanguine that it will ever be implemented on a large scale. The following statements are listed in chronological order.

> The Hong Kong experiment has shown the rest of the world that the hardware can readily be designed for electronic road pricing. However, overcoming the political implementation problems is much more difficult. If they cannot be overcome, then electronic road pricing may forever sit unused on the economist's shelf. (Borins 1988, 44)

[53] If so this would be an example of the classic tension between the desirable and the politically acceptable noted in the introduction.

> After more than 35 years I am still involved in these arguments [about the virtues of SRMC pricing]. Although… the *principle* has been largely conceded, the applications are much more timorous and messy. . . . I do not retain a faith that, because it is so rational and liberal a solution, ultimately it will be widely adopted. (Walters 1988, 20)
>
> [I]t is unlikely that congestion pricing will be implemented to any significant extent in the U.S. Public scepticism regarding the effects of congestion pricing, resistance to high tolls, and pressures to divert toll revenues to new transportation facilities are barriers to effective congestion pricing programs. More likely are tolls on new capacity, tolls for specific classes of users, and other less direct and less complex auto pricing strategies. (Giuliano 1992, 335-6)[54]
>
> [S]ome transport economists and environmental planners are encouraged to believe that motorists soon may pay, in some places at least, the marginal costs of road use. The general public, however, is not attracted to tolls and congestion pricing for the same reasons that interest economists and environmentalists. The public and its elected representatives are primarily interested in tolling as a means to finance the expansion of facilities rather than as a means to manage existing facilities more wisely. As a result, tolling is not likely to be implemented in forms that economists or environmentalists would recommend. Tolling is more likely to be implemented in a piecemeal rather than a comprehensive fashion, primarily on new or expanded facilities. Tolls are also likely to be set at significantly lower levels than either economists or environmentalists would suggest. This combination of piecemeal tolling and low prices may seriously limit gains from tolling in many situations. (Gómez-Ibáñez 1992, 343)

[54] As quoted by Richardson and Bae (1998, 250).

It would be over-optimistic to expect the sophisticated charging schemes tested in the last decade, on a small scale, to be implemented soon on a nationwide scale. This is particularly true for the less developed countries (LDCs), where even standard charges are plagued by problems of tax administration and gross evasion. In the foreseeable future it is realistic to expect that policy makers will have to rely on the standard battery of taxation tools, foremost among which is the fuel tax. (Gronau 1994, 255)

We shall probably have to wait for particularly high levels of congestion to make tolls acceptable to automobile lobbies. The relevance of the theoretical argument is therefore insufficient: a whole array of socio-political parameters involving national temperaments interfere in the question of the acceptability of urban tolls for society. (Derycke 1998, 71)

It is probable that significant portions of an urban highway and road system cannot be subjected to congestion tolls. For example, many people reside on arterial streets and highways that carry a good deal of rush-hour traffic. It is not likely that any politician will ever suggest that people should pay a toll to drive on their own streets. In our view congestion tolls are not likely to be imposed on more than the limited access portion of the urban highway and road system. (McDonald, d'Ouville and Liu 1999, 234)

Contemporary citizens dislike taxes and distrust governments. Unless (a) urban travelers can be persuaded that Bangkok-type equilibrium prevails during peak periods or (b) losers can somehow be reimbursed from toll revenues in a fashion that does not distort their travel behavior appreciably away from the with-toll optimum or (c) detailed toll-revenue-expenditure program can be found that a substantial majority agrees justifies paying tolls, congestion-pricing packages will continue to be a very hard sell. (Mohring 1999, 198)

> The more sophisticated the scheme . . . the closer it is likely to get to the Pareto optimum solution. . . . However, what is the most efficient and 'economically pure' as a road user charging scheme is also likely to be less popular politically. There is thus a dilemma in that the more sophisticated scheme is more likely to change driver behaviour, whereas the less sophisticated is likely to be more acceptable. (Ison 2004, 17, fn. 7)

Downs (2004) runs hot and cold on road pricing during the course of his recent 455-page book. He considers demand-side measures to be generally more effective at reducing congestion than supply-side tactics, and also less costly (p334-5). But he believes that road pricing will never be widespread in the United States:

> As an economist, I favor market-based approaches whenever possible. However, their political feasibility has been restricted by the egalitarian American desire not to provide any relative advantage to high-income travelers versus low-or moderate-income ones. This desire is politically potent because of the high rate of automotive vehicle ownership in America. Moreover, households considering themselves in the low- and moderate-income category vastly outnumber those considering themselves to have high incomes. (Downs 2004, 327)[55]

In one particularly negative passage Downs writes:

> If most Americans clearly understood the alternatives, they would undoubtedly regard congestion as much better than rationing space during peak hours by using tolls on all major roadway lanes, or building vastly more road space to avoid such rationing altogether, or trying to expand public transit systems enough to absorb all those 'excess drivers' seeking to use the roads in private vehicles during peak hours. (Downs 2004, 11)[56]

[55] Similar statements are found on pp. 79, 161.

[56] An interesting twist on this is the view expressed by Calfee and Winston (1998, 96-97) that road pricing should be adopted in order to preclude the other policies: "Although our

Downs's overall conclusions appear to be: (a) congestion is here to stay (Ch. 1), (b) people should learn to adapt to it (13), and (c) people should find ways to make congested time more enjoyable (354).

ATTITUDES TOWARDS PRIVATE ROADS

For three reasons the attitudes of economists towards private roads are reviewed separately from their stance towards road pricing on public roads. First, a large majority of the literature on road pricing deals only with public roads. Second, many economists support road pricing on public roads but are against private roads, whereas for other economists private roads are the preferred alternative. Third, private roads raise a number of new policy issues such as the form of ownership or contract (design, finance, build, operate, transfer), the type and stringency of toll regulation, and the exercise of powers of eminent domain. Economists may oppose private roads not on principle, but rather because they believe that all these issues cannot be satisfactorily addressed in practice.

Background

Probably the most common reason for economists to oppose private roads is that they see roads as natural monopolies that confer private operators with market power to raise tolls above efficient levels. Several economists have shown that under conditions of perfect competition the market equilibrium will coincide with the social optimum (Buchanan 1956, Vickrey 1968, DeVany and Saving 1980). But it is typically argued that the scope for competition is in practice rather limited (e.g. Gómez-Ibáñez and Meyer 1993).

Two arguments in favor of private roads are often made. One is that private owners have a greater incentive than do public institutions to achieve productive efficiency and to seek innovative ways to cut costs

findings cast doubt that the (direct) net benefits from congestion tolls are large, policymakers should still pursue the policy, if only to head off other—very costly and far worse—approaches to reducing congestion."

and/or improve service quality. The other argument is that government agencies themselves may succumb to the temptation to boost revenues; by raising tolls above first-best (or second-best) levels, by restricting capacity, or (if compensated via fuel-tax receipts) by making roads rough in order to increase fuel consumption (Smith 1937, 686; Foster 1963, 252-3; Evans 1992, 234; Roth 1998, 13).

The economists surveyed here are organized into three groups: those that support private roads with little or no reservations, those who are ambivalent or cautious, and those who are opposed. Each group is sampled in roughly chronological order.

A. Supportive of private roads

As has been discussed, Dupuit and Knight appear to have been favorably disposed towards private roads, but their views are open to interpretation. The first clear and unequivocal support for private roads appears to be an essay by Milton Friedman and Daniel Boorstin (1951). Because of the article's perspicacity and scope it is worth summarizing. Friedman and Boorstin begin with the statement

> The building and maintenance of our highway is today almost exclusively a governmental operation. We have become so used to this that whenever the question arises how to solve our highway problems, we take it for granted that we are simply asking how we can improve government planning of roads and government financing of them. (Friedman and Boorstin 1951, 223)

Friedman and Boorstin identify three main obstacles to efficient operation of private roads: (1) the technical difficulty of charging for the use of roads; (2) monopoly power; and (3) the 'neighborhood effect' of roads; i.e. since residents benefit from the access provided by roads it is unfair for through-traffic to bear the full cost of maintenance. Friedman and Boorstin consider these obstacles least important for turnpikes. They recommend (232-233) turning turnpikes over to private enterprise and giving it free reign in setting tolls. To reduce unfair competition from toll-free public roads, the state would rebate to the firms the approximate fuel tax revenues paid by motorists while driving on their turnpikes.

Friedman and Boorstin see greater difficulties for ordinary inter-city roads in charging for use and containing monopoly power. As a means of charging they suggest (238), rather fancifully, painting radioactive material on the centre lines of roads, equipping vehicles with Geiger counters, and charging according to the radioactive intensity recorded at a rate dependent on the type of road. Should no practical means of charging be devised, they recommend that private enterprise be allowed to compete for traffic on the quality of maintenance and other services provided, with compensation paid by the state equal to the taxes collected on gasoline consumption (239). Finally, Friedman and Boorstin admit to being unable to devise a workable plan for private operation of urban roads.

Amongst the other supporters of private roads Rothbard (1973, 203-204, 214-215) describes how private road owners would impose congestion tolls that encourage travelers to respond in beneficial ways including carpooling, shifting to public transport, changing work hours or place of residence, etc. Profits would encourage firms to expand capacity, maintain safe operations and efficient police protection. Similar arguments are presented in Block (1979, 1980, 1996) and Cadin and Block (1997).

Fielding and Klein (1993) assume that highways will be franchised, rather than outright privatized: "We are optimistic about competitive bidding for highway franchises, but viability will depend on *how* the bidding is organised" (Fielding and Klein 1993, 114). They offer a mixed assessment of the need for toll regulation, voicing more concern about excessively high tolls during off-peak periods than during peak periods when reductions in congestion are desirable.

Several chapters by economists in the recent volume on private roads (Roth 2006) assess the advantages of the private sector in building, maintaining and operating roads. Three chapters will be mentioned here. Klein and Majewski (2006) review the history of turnpikes and other forms of private toll roads in the US. They document how private companies provided a higher quality service at a lower cost per mile than did comparable public roads, and succeeded in developing extensive networks of highways.

> Looking back, one might say that the American people ran an experiment: 100 years with extensive privately managed toll roads, and then another 100 years primarily of government managed 'freeways'. The historical record suggests that road provision is another case where the advantages of private ownership relative to government

> ownership, and of user-fees, relative to tax financing, apply. Learning from the mistakes of both epochs, Americans and people in other countries should embark on a new century of road provision. (Klein and Majewski 2006, 300)

Button (2006) and Foldvary (2006) provide more contemporary views:

> If roads were provided privately and competitively then the inefficient congestion problem would not exist. Road owners would price to maximize profits and in so doing would take into account the costs of congestion each driver imposes on other drivers. In addition the issue of net investment would also be taken care of as prices would accurately convey information about where and when to build new roads. (Button 2006, 226)

> [P]rivate streets are not merely economically feasible, but superior in efficiency and service in the financial and organizational context of the decentralized, competitive, and responsive private communities in which they would be provided. From a purely economic and ethical perspective, it is not private streets but governmental streets financed by forceful means that require justification and explanation. (Foldvary 2006, 323)

Klein (1998, 14) argues that the organizational advantages of the private sector for tolling roads also apply to the provision of urban transit services:

> Imagine the city streets and roads divided up into segments or small districts. Each separate unit would be under the control and management of a private entity. . . . Just as shopping malls allow free parking, street owners might make road access one of the gratis attractions to visitors, residents and businesses. Just as proprietary communities often provide minibus service gratis, the road-owner might provide free bus service. Alternatively, the road-owners might implement electronic road pricing. . . . The

> natural incentive is for the road owner to work with associations and agents that coordinate the interdependent parts of the road and transit system. In private industry, such standards for matters of technology, product design, product safety, and insurance emerge from voluntary machinations—both competitive and cooperative. We could expect the same for transit coordination. The natural incentive is for the road-owner to form contracts that will enhance his road as a place to shop, work, and reside.

An important point regarding cost recovery that comes out in the excerpt from Klein (2006) is that private owners can decide whether and how to charge explicitly for the use of their roads. In some cases it may be unnecessary to recover all costs through tolls. For example, in the case of a privately developed gated community the costs of local roads can be built into housing prices and homeowner association dues. Likewise, merchants can recover the cost of access roads to their establishments in the prices of the goods they sell.

B. Agnostic, ambivalent or cautious about private roads

Roth is included in this category because his early writings leaned against private roads. Over time, however, his attitude became more positive.

> [W]hile it is possible to envisage competition in the provision of roads connecting points at great distances apart—as occurred on the railways in the early days—it is not possible to envisage competition in the provision of access roads in towns and villages, for most places are served by one road only. A highway authority is in practice in a monopoly position. If any of its roads were to make large profits, we could not expect other road suppliers to rush in to fill the gap. If losses are made on some roads, there are no road suppliers to close them down and transfer their resources to other sector of the economy. (Roth 1967, 63)

> After the introduction of road pricing in Singapore, Walter Block was writing revolutionary articles suggesting that

> roads should be privatized, and warning that the imposition of congestion pricing on roads without including them in the market sector was unlikely to result in optimal solutions to transport problems (Block, 1979). It was this seed, planted by Walter, that eventually brought me to write this book. The question it asks is to what extent the concepts of ownership, free prices and voluntary exchange—concepts that govern the provision and allocating of scarce resources in free societies—can usefully be applied to roads. The book discusses the possibilities of public roads being privately provided, but its thrust is directed more at the *commercialization* than the *privatization* of roads. This is because I see the commercialization of roads . . . as a major objective in its own right, as well as a necessary step on the road to privatization. (Roth 1996, xix)

> On the one hand, where a public road is privately provided as a result of voluntary transactions — where, for example, no governmental powers are used to purchase land, and where providers of new roads are given no protection from competitors. In those circumstances, it is difficult to justify government interference in the rights of the owners to set any fees they please. On the other hand, where government powers are used to obtain land, or where a private supplier is given protection from competition, an arrangement to limit the profits of the enterprise would seem to be reasonable. (Roth 1996, 102)

In the introductory chapter to Roth (2006), Roth comes even closer to an endorsement of private roads by listing the advantages of privatization (11-13) and opening his chapter with the statement:

> Will Rogers is reported to have said that the way to end traffic congestion is to have the government build the cars and private industry the roads. The purpose of this book is to demonstrate that only the latter recommendation is necessary. (Roth 2006, 3)

In discussing private roads, David Friedman (1989 [1969], 72-74) describes the advantages of peak-period tolls and the feasibility of electronic tolling, but explains the challenges in guaranteeing road access for homeowners and defining legal rights and responsibilities with regard to access roads.

Beesley (1973) addresses the potential role for the private sector in financing new investment. In favour he remarks

> Its real merits, one suspects, may well be simply that of opening the road system to innovatory enterprise—new standards of safety, attractive driving conditions, more competitive tendering for contracts, the spread of new standards for construction and maintenance, etc. (Beesley 1973, 251)

But Beesley (1973) also identifies capacity indivisibilities as a constraint on competition, and expresses doubts that investments will be made at the best locations on road networks (251).

Beesley and Hensher (1990) adopt a stance similar to Beesley (1973). They offer a balanced and "speculative" (331) assessment of private sector involvement in ownership and operation of tolled facilities. In their concluding remarks they write

> The most important issues include the extent to which competition or price control provide the best mechanism for protecting the consumer, and aiding efficient supply of road space; the desirability of establishing independent regulation and rivalry amongst operating authorities, the need to have a clear understanding of the cost of capital and the sources or risk; and the extent to which turnkey or termination deals are really a desirable strategy. (Beesley and Hensher 1990, 340)[57]

The following passage by James Buchanan expresses doubts about the political acceptability of private roads:

[57] A similar attitude is expressed by Hensher and Puckett (2005, 382).

> Are the arguments of the economists more likely to find receptive audiences in the post-socialist politics of the 1990s and beyond? My skeptical public-choice instincts suggests a negative answer… Separated private ownership of most components of the road network remains a dream only for the most utopian libertarians. . . . But depoliticization via commercialization is both economically and politically realizable. (Buchanan 1996, xv)

Winston and Shirley (1997) consider privatization a serious possibility, but only in the longer run: "In the absence of accumulated empirical evidence, we believe it is premature to recommend privatization of U.S. highways" (Winston and Shirley 1997, 103). Their main fears are that government agencies will regulate tolls, "discourage efficient pricing schemes" and mismanage advanced navigation and road traffic control technologies. It may be that these modern concerns contribute to their less sanguine view compared to Klein and Majewski (2006), quoted above, who examine the nineteenth century record of private roads.

Like Winston and Shirley (1997), Downs (2004) shows caution:

> Removing major roads from public ownership would by no means remove them from public concern, since they are the backbone of the nation's ground transportation system. As long as the vast majority of American drivers strongly oppose all-lane peak-hour road pricing, American elected officials will never permit its widespread adoption, no matter who owns the roads. (Downs 2004, 162)

C. Opposed to private roads

> Free competition among toll-bridge owners, of the kind necessary to make the conclusion applicable, would require that each bridge be paralleled by an infinite number of others immediately adjacent to it, all the owners being permanently engaged in cutthroat competition. (Hotelling 1938, 260)

> One may get the impression from Professor Knight's article . . . that a private enterprise road system would do the

> job much more efficiently. (I do not know whether Knight would accept this interpretation.) Or one might still have public owned roads, each with a toll gate and a separate manager for each gate; then the state would instruct the managers to maximize their profits. But it is clear that neither of these systems would lead to the ideal allocation. Some frightful state of oligopoly would emerge in both cases; some form of collusion would be likely as the ultimate outcome of the first case. (Walters 1954, 143)

> In our view, publicly provided and efficient priced highways are a better solution than franchised monopolies that tend either to set inefficiently high prices or to sink under the weight of oppressively detailed regulation. (Small, Winston and Evans 1989, 119)

> The problem is that many roads are natural monopolies, and would require regulation that may reduce most of the benefits of private ownership. There is the additional complication that the road network is a network, and investment or charges on one sector will affect the traffic flows and profitability of other sectors. The difficulties of pricing component parts of an integrated network are such that most networks have been retained intact, as with the National Grid, the gas transmission system, British Telecom and, nearer to the present, British RailTrack. (Newbery 1994, 244)[58]

> [T]he welfare gain from managerial efficiency due to private initiatives of road provision via increasingly popular build-operate-transfer (BOT) projects, for instance, should be measured against the welfare loss from monopoly abuse when parallel roads are next to nonexistent. Because many roads possess natural monopoly characteristics and since it is difficult to price various component parts of an integrated road network, the ownership of roads should best reside with the public sector (Newbery, 1994). The market failure resulting from

[58] Instead of privatization Newbery (1994) calls for a public road authority that operates under commercial principles. His arguments are elaborated in Newbery and Santos (1999).

> the common property resource problem where no one really owns the roads would still call for the diligent application of optimal pricing and investment rules by an independent public road authority. Thus commercialization is in order rather than privatization. Vickrey (1996) also insists on 'marketization'—that is, the setting of quasi-market prices which enhances efficiency and acts as signals for (dis)investment—in transport and argues strongly against privatization in transportation. (Hau 1998, 68)

CONCLUSIONS

Economists' model-based analysis of road pricing has developed over a period of decades. Practical proposals were also advanced in the mid-twentieth century, but road pricing continued to remain largely an ivory tower idea. A few operational schemes were launched late in the century, but more attempts failed than succeeded. The recent upsurge of research on road pricing reflects, in large part, belated recognition by economists (and other scholars) that a more practical and pragmatic approach is required for road pricing to take off.

This article has surveyed the literature to determine whether economists support road pricing both in theory and in practice. There is a strong consensus among economists that road pricing ought to be used to reduce and manage congestion. This position has strengthened as technology has reduced the costs of collecting and paying toll charges. Beyond that primary insight, however, there is much disagreement.

The diversity of views described in the survey defies easy summary, but some broad statements are possible.

- Again, there is a strong consensus in favor of using road pricing to manage congestion.
- Most economists now accept short-run marginal cost as the appropriate basis for pricing transportation generally, and roads specifically. However, most economists also entertain departures from SRMC pricing in its strictest sense, and there has been much interest recently in developing practical models of second-best

pricing. There also remains a residual tension between the goal of allocative efficiency, which is best served by SRMC pricing, and the goal of cost recovery which calls for average-cost pricing at some (often ill-defined) level of aggregation over modes and user groups.

- Many economists are concerned about practical aspects of road pricing. The major concerns are difficulties in computing optimal tolls, administration costs and user friendliness. There is less worry about the reliability of tolling technology or the feasibility of differentiating charges over time and space.

- Economists have mixed views on equity. A majority probably hold at least moderately egalitarian moral sentiments. But many oppose the idea of compromising the efficiency of road pricing schemes by granting discounts or exemptions to selected groups, or otherwise distorting prices in an attempt to serve some notion of equity.

- Many economists view road pricing as just one tool that should compete on the merits against other demand-side and supply-side transport policy instruments. The advantages of road pricing as a price instrument in terms of decentralization, information aggregation, etc., must in their view be weighed against its setup and administration costs, and against the proven (if limited) worth of other more direct instruments such as parking bans and pedestrian-only zones as well as fiscal instruments such as vehicle registration fees that do not vary with usage.[59]

- Attitudes towards earmarking of road-user charge revenues are decidedly mixed. Some economists are against earmarking because it reduces budgetary flexibility to respond to changing priorities. Others favour earmarking for roads, for public transport, or for some mix of uses. Still others favour rebating revenues to users, or reducing fuel taxes or fixed charges to maintain revenue neutrality.

[59] This attitude is well-articulated by Arnott (2005, 11): "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."

- Economists are divided on private roads. Those who write at length about private roads are writing about something that departs greatly from the status quo. They are probably more favourably disposed towards private roads than are economists as a whole, and the sample of authors mentioned here may not be representative partly for this reason.

- Finally, a number of economists support road pricing, but are pessimistic that it will ever become widespread. The doubters include some of the leaders in developing the theory of road pricing in the 1960s.

Several recent favourable developments have boosted interest for road pricing amongst policymakers and researchers, and new road pricing experiments or toll-road proposals are announced frequently. Some economists have caught the enthusiasm. In the preface to their book, Arnott, Rave and Schob (2005) explain how the steadfast support for marginal-cost pricing from the European Union, and success with London's congestion charging scheme, induced them to moderate the largely negative view of road pricing they held a few years ago.

Singapore's electronic road pricing scheme has demonstrated how tolls that are differentiated by vehicle type and time of day can be implemented on a network of roads using relatively sophisticated and user-friendly technology. As Christainsen (2006) notes, "In other countries, roads, medical care, housing, and many other goods and services are systematically underpriced insofar as their prices are controlled by government …. Singapore essentially broke the mold with respect to roadways, and the precise political conditions under which such breakthroughs occur, and endure, deserve more research on the part of political scientists as well as economists. With respect to roadways, one can only speculate whether those conditions are now close to being met in additional cities around the world" (Christainsen 2006, 87). The US Value Pricing Pilot program, and its centrepiece HOT lane facility projects, have also received a largely positive reception. As O'Sullivan (2003) remarks, "These recent experiences with congestion pricing are promising. Travelers respond to higher prices by changing their travel behavior in ways that

decrease traffic volume and improve the efficiency of travel" (O'Sullivan 2003, 267).[60]

The pessimistic assessment by Borins (1988) of Hong Kong's electronic road pricing initiative was noted earlier. However, Mylvaganam and Borins (2004) are more upbeat in their account of Toronto's Highway 407 toll road. They remark that both limited access highways and central cities have been successfully tolled and they "encourage transportation policy makers in Canada . . . to consider both" (131).

This is an exciting time for road pricing. Opponents may hope that present efforts will fail and another chapter in the long history of unsuccessful road pricing attempts will be written. Devotees of Pigou and Vickrey will hope that public toll roads or other forms of road pricing will flourish to tame the congestion beast. And admirers of Friedman and Boorstin will look forward to a resurrection of private toll roads that ruled in the turnpike era.

The potential for better policy is open. J. Michael Thomson suggests that it is up to economists:

> Immense developments have been made in the technology of road pricing, and there is little doubt that a sophisticated and economically efficient system of road pricing could now be introduced as soon as it was required, by a city with a sound administration and good law enforcement …. But there is still an educational gap to be bridged: the gap between economic truth and public comprehension. If it really is true that most, if not all, the people in a city will benefit from a system of road pricing, it is for economists to explain this truth so that politicians, administrators, and members of the public can understand it. Can economists respond to this challenge? (Thomson 1998, 109)

[60] Using data from State Route 91 in California, Small et al. (2006) find that with their base-case parameter values the toll price elasticity of demand to use the toll lanes is roughly one in absolute value. They also demonstrate how accounting for preference heterogeneity among motorists affects the elasticity estimate.

APPENDIX A: ECONLIT SEARCH

Figure 1 in the text was assembled using the ECONLIT database. According to the ECONLIT software the database "covers the world's economic literature. It indexes over 400 major journals as well as articles in collective volumes (essays, proceedings, etc.), books, book reviews, dissertations, and working papers." However, ECONLIT excludes a number of mainly engineering-oriented transportation journals in which articles on road pricing have been published; in particular *Highway Research Record*, *ITE Journal*, *ITS Journal*, *Journal of Transportation Engineering*, *TR News*, *Traffic Engineering and Control*, *Transport Reviews*, *Transportation Quarterly*, *Transportation Research Series C* (Emerging Technologies), *Transportation Research Series F* (Traffic Psychology and Behaviour), *Transportation Research Record* and *Transportation Science*. Figure 1 therefore does not provide a complete count of the literature on road pricing, although it probably captures most of the research by economists.

For the purpose of this survey journal articles, book chapters, comments, rejoinders and conference proceedings were included in the counts. Working papers were excluded unless they appeared in a series maintained by a well-known institution (e.g. the World Bank or the Institute of Economic Affairs) and are not known to have been published elsewhere. Books were counted as one item unless they constituted an edited volume, in which case individual chapters were counted separately. The counts exclude unpublished MA or PhD dissertations, reprints of articles that were published earlier, and editorials except journal editorials for special issues about road pricing.

The search was conducted by title. Alternative sets of keywords were tested with the goal of including known articles with unusual, or frugal, titles without including hordes of irrelevant items. The final choice was: {congestion OR cordon OR (financing AND roads) OR (highway* AND (pricing OR privat*)) OR (marginal AND cost AND pricing) OR (marginal AND cost AND tax*) OR (peak AND load) OR (pricing AND transport*) OR ((road* OR highway*) AND (pric* OR privat* OR charg*)) OR toll*}.

Hits for each year were saved and the titles (and abstracts if available) were then read to assess whether the article concerned road pricing. Any form of direct road user charges was included; i.e. tolls on individual highways or highway lanes, area licenses or charges, cordon tolls, distance-based charges, time-based charges, etc. Charges for any purpose were included; i.e. pricing of congestion, road damage, environmental or other

road vehicle externalities; tolling to raise revenue, and so on. Charges on any type of motorized vehicle were included, but not charges on bicycles, pedestrians or other forms of non-motorized transport. Indirect road charges were excluded; i.e. registration and license fees, fuel taxes, tire taxes, etc. Shadow tolls and tradable driving permits were also excluded, as were parking fines and parking charges. Theoretical studies on peak-load pricing were excluded unless they included road pricing as an extended example.

For about 10 percent of the search hits it was not possible to determine from the title or abstract (if an abstract was provided) whether the criteria described in the previous paragraph were met. In most of these cases a copy of the item was obtained to make the determination. In a few cases the item was not available from the University of Alberta library, and a request for interlibrary loan was either unsuccessful or still outstanding at the end of January, 2006. If so, a judgment call was made on the basis of the information available.

The results of the search are reported in Table 1 below. Over the 36-year period the total number of annual items in the ECONLIT database grew more than seven-fold from 4,525 to 33,724. The average number of hits obtained using the keywords was about 30 per year, and the average number of articles about road pricing was 9 per year. A linear regression against time was performed of the fraction of hits on road pricing (column [5] in Table 1). This yielded a coefficient estimate for time of 0.002 (t-statistic 2.41, P=0.0215). Another linear regression was performed for the number of articles about road pricing as a fraction of all items in the database (column [6] in Table 1).This yielded a coefficient estimate for time of $-2x10^{-6}$ (t-statistic -0.42, P=0.676). Thus, articles about road pricing became more prevalent relative to other articles that were captured by the keywords (in particular, theoretical articles about peak-load pricing or applied articles concerning time-of-day electricity pricing). But, perhaps surprisingly, entries about road pricing did not increase in number as a fraction of all entries over the full 1969-2004 period.

Table 1: ECONLIT Database Entries

[1]	[2]	[3]	[4]	[5]	[6]
Year	Database entries			= [4]/[3]	= [4]/[2]
	Total	**Keyword**	**Road pricing**	**Road pricing as fraction of keywords**	**Road pricing as frac. of total [10^{-4}]**
1969	4,525	14	5	0.36	11.0
1970	5,098	16	2	0.13	3.9
1971	5,101	17	4	0.24	7.8
1972	5,821	7	1	0.14	1.7
1973	6,147	13	3	0.23	4.9
1974	6,184	8	1	0.13	1.6
1975	6,264	14	6	0.43	9.6
1976	6,669	18	5	0.28	7.5
1977	7,332	22	7	0.32	9.5
1978	7,861	17	4	0.24	5.1
1979	8,123	18	0	0.00	0.0
1980	8,662	17	5	0.29	5.8
1981	8,959	23	7	0.30	7.8
1982	8,982	17	6	0.35	6.7
1983	9,916	24	2	0.08	2.0
1984	14,896	23	3	0.13	2.0
1985	15,345	24	1	0.04	0.7
1986	17,475	20	4	0.20	2.3
1987	18,481	18	7	0.39	3.8
1988	21,988	27	4	0.15	1.8
1989	21,920	22	3	0.14	1.4
1990	23,496	33	6	0.18	2.6
1991	26,200	27	5	0.19	1.9
1992	27,407	24	8	0.33	2.9
1993	27,504	27	8	0.30	2.9
1994	28,670	28	3	0.11	1.0
1995	31,126	43	22	0.51	7.1
1996	33,261	58	13	0.22	3.9
1997	34,609	45	8	0.18	2.3
1998	35,385	62	20	0.32	5.7
1999	38,307	59	25	0.42	6.5
2000	39,651	48	25	0.52	6.3
2001	37,947	68	26	0.38	6.9
2002	38,125	75	30	0.40	7.9
2003	39,276	62	16	0.26	4.1
2004	33,724	54	29	0.54	8.6
Mean		**30.3**	**9.0**	**0.26**	**4.7**

Sources: Author's compilation

APPENDIX B: COVERAGE OF ROAD PRICING IN TRANSPORTATION ECONOMICS TEXTBOOKS

Thomson (1998, 93) notes that early transportation textbooks (1941, 1946, 1958) did not even mention urban traffic congestion, let alone road pricing. Table 2 summarizes the coverage and assessments of nine more recent transport economics textbooks.[61]

Table 2: Coverage of road pricing in selected transportation economics textbooks (chronological order)

Textbook	Coverage of road pricing	Attitudes
Gwilliam and Mackie (1975)	Chaps. 6&10. 3-4 pp.	Agnostic. Road pricing should be assessed against a range of policy instruments.
Mohring (1976)	Chaps. 3&6 ~7 pp.	Does not explicitly advocate tolls. Implicitly identifies their benefits.
Frankena (1979)	Chap. 4. 14 pp.	Relatively favourable.
Glaister (1981)	Chap. 5. 5-6 pp. Considerable additional space on peak-load pricing and 2nd-best pricing of public transport with unpriced auto. congestion.	Relatively favourable. Advocates tolling. Against private roads in absence of congestion.
Small (1992)	Chap. 4. ~18 pp. Devotes some of this space to comparison of results from different models.	Favourable towards road pricing, although no explicit statement to this effect.

[61] Road pricing is also covered in other economics textbooks; notably those about urban economics.

Small (1992) (Cont.)	Private highways: 3 pp.	Private highways: reservations about optimality of pricing and investment strategies of a profit-maximizing highway owner with market power
Boyer (1998)	Chap. 10. 5 pp.	Enthusiastic. Considers some form of congestion pricing in the future as inevitable
McCarthy (2001)	Chaps. 10&11: ~45 pp. Nothing on private roads	Reviews selected academic studies in detail. Shows approval of pricing highway congestion and infrastructure damage.
Quinet and Vickerman (2004)	Chaps. 7&10. 5 pp.	Moderately favourable.
Small and Verhoef (2006) (Revised edition of Small (1992), in process.)	Chap. 4. 60 manuscript pp. Private ownership of highways: Covered in Chap. 6. Draft incomplete	First-best pricing, second-best pricing and congestion pricing in practice. Generally favourable.

Source: Author's compilation

Except for McCarthy (2001), who adopts a case-study approach by summarizing in detail several articles about road pricing, there is no obvious trend over the 30-year span between Gwilliam and Mackie (1975) and Quinet and Vickerman (2004) in either attitudes towards road pricing or the amount of space devoted to the subject. Small and Verhoef (2006) stand out in providing a much more comprehensive and detailed treatment of road pricing—mainly in the role of pricing congestion. Chapter 5 on

investment devotes further attention to pricing in the context of the link between pricing and capacity choice decisions. Chapter 6, which covers industrial organization in urban transportation, includes private ownership of highways. Chapter 6 was incomplete when the final version of this review was prepared.

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ABOUT THE AUTHOR

Robin Lindsey is a professor of economics at the University of Alberta where he has worked since 1982. He received his PhD in economics from Princeton. His academic specialty is transportation economics, and his current research interests include traffic congestion, road pricing and private toll roads. He has also published research on pricing of parking, advanced traveller information systems, retail market competition, predatory pricing and the economics of exhaustible resources. He has published in *American Economic Review*, *Economica*, *European Economic Review*, *International Economic Review*, *Journal of Public Economics*, *Rand Journal of Economics* and various other general interest, transportation, industrial organization and regional science journals. In 2001-2002 he was awarded a McCalla Research Professorship from the University of Alberta. His email address is: rlindsey@ualberta.ca.