Journal of the History of Economic Thought,
Volume 42, Number 3, September 2020

THE TRANSITION FROM PIGOU'S IDEAS ON ROAD PRICING TO THEIR APPLICATION

BY
KENNETH BUTTON

A century ago Arthur Pigou published The Economics of Welfare. Within this volume are a few lines relating to the pricing of traffic congestion. Over the years, these lines have attracted the attention and thoughts of some of the leading economists of their day. These have included Knight, Clapham, and Robertson in the 1920s; Kahn and Viner in the 1930s; Ellis and Fellner in the 1940s; and Buchanan, Vickrey, Solow, Friedman, Walters, Demsetz, Newbery, and Allais in the post-World War II period. Here, I look at the academic arguments from the 1920s concerning how roads should be priced and by whom. I then move to consider the continuation of the intellectual debates after World War II and their implications for policy design and implementation. Finally, I briefly look at the extent to which some of the existing road congestion pricing systems meet the requirements of the economic theory.

I. INTRODUCTION

Over the years, economists have devoted considerable thought to the pricing of roads. Traditionally this was directed at the financing of an infrastructure that was seen to embrace public service elements; it serves military and administrative functions that are normally treated outside of market mechanisms. In some cases, and notably in urban areas, non-road-related taxation revenues have been used for financing this. In the interurban case there has been extensive use of tolling with the revenues from commercial traffics used to cross-subsidize activities of public services. What has seldom been done is to adopt economic pricing in the sense that road charges allocate the available capacity optimally and, through the revenues collected, indicate where capacity should be expanded or contracted.

Schar School of Policy and Government, George Mason University. The author would like to thank both the editor of the *Journal* and two referees for extremely useful comments. The final product remains my responsibility.

ISSN 1053-8372 print; ISSN 1469-9656 online/20/03000417-438 © The History of Economics Society, 2020
doi:10.1017/S105383721900035X

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Arthur Pigou's (1920) *The Economics of Welfare* provided his intellectual answer to the optimization question and laid the foundation for the modern theory of road pricing.[1] The focus of this paper is primarily on the influence that this part of Pigou's economics has had on the way economists think about allocating road space. But it also considers the extent to which congestion pricing has permeated public opinion and, ultimately, policy making.[2] This is a topic that has gained in practical importance over time and is part of the core thinking of transportation economists but, other than for a passing comment, is seldom discussed in the mainstream literature on Pigou's contribution to economic welfare.[3]

I begin by outlining Pigou's analysis of pricing across a simple highway network with individual links experiencing differing levels of traffic congestion. I move on to consider the immediate critiques of this model, and especially issues raised by the likes of Frank Knight, Richard Kahn, and Dennis Robertson. The subsequent reformulation of Pigou's analysis by Howard Ellis and William Fellner, and later refined by James Buchanan and Alan Walters, in terms of externalities, rather than diminishing returns, offered a different way of looking at the problem. It also provided more powerful arguments against the prevailing post-World War II engineering-oriented approaches to containing traffic congestion that almost exclusively relied on such measures as road building, traffic signaling, one-way streets, parking constraints, and restricted junction access. Finally, I offer a brief discussion of the extent to which contemporary efforts at introducing economic road pricing conform to Pigou's century-old idea.

II. DISCUSSIONS OF PIGOU'S WORK

The early part of the twentieth century saw the growth of motorized transportation and, with it, the need for large-scale investment in roads. The toll roads, local levies, and statute labor (notably in France) systems that had grown from the late seventeenth century to finance intercity roads had already largely collapsed with the advent of railroads (Albert 1972; Klein 1990). Fixed-track urban public transportation, such as trams and subways, had similarly taken away the need for major urban road investment. In response to the need for more investment funds, Oregon introduced fuel taxes in 1919, with other US states quickly following, and a federal gasoline tax was created in 1932. Similarly, in the UK, the Motor Car Act 1903 introduced a registration fee for motor vehicles, which were already subject to carriage duty if not used solely for trade, and a tax on "imported fuel" was initiated in 1909. These taxes were favored over tolls because of ease of collection—they could be imposed at refineries—and avoidance of the high

[1]"Road pricing," "economic pricing," and "congestion pricing" are often used interchangeably in the economic literature. They all refer to appropriate pricing of roads to reflect the relevant economic costs and benefits of using them; see Arnott and Small (1994).

[2]The emphasis is exclusively on congestion charging as the first-best approach to the urban congestion problem. There is an extensive economic literature on second-best approaches that include, for example, dampening demand by adjusting prices of complementary goods to roads such as fuel taxation and parking fees (Inci 2015), and the use of subsidies to attract travelers to uncongested modes or routes, such as transit subsidies (Parry and Small 2009).

[3]It is, for example, not mentioned in the full-length biographies by Aslanbeigui and Oakes (2015) and Kumekawa (2017) and is not considered in the various papers on Pigou collected by Blaug (1992).

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

administrative costs and traffic delays associated with toll booths. In both countries the revenues from these taxes were initially hypothecated to roadworks, but soon got diverted to general revenues (Goel and Nelson 1999).

The French Engineering School of economists had in the 1840s and 1850s given thought to the economic charging of transportation infrastructure, including varying fees with use to make more efficient use of it (Ekelund and Hébert 1999). This, however, was largely forgotten during the Railway Age until the post-World War I growth in car and truck traffic. It was then resurrected in the 1920s in the work of Pigou (1920), who touched upon the matter of road charges in the first edition of *The Economics of Welfare* (pp. 193–194). [4] He dropped it, however, from the subsequent 1924, 1929, 1934, and the 1952 editions of the book.[5] Why Pigou did this is not altogether clear, but three interacting forces were possibly at play.

First, there was the explicit critique of Frank Knight (1924) on the need for road "taxing" in Pigou's example. Indeed, William Breit and Roger Ransom (2014, p. 197) subsequently maintained, "Knight's devastating critique of this Pigouvian argument caused Pigou to drop his road example from subsequent editions of his *Economics of Welfare*." Similarly, Steven Cheung (1973, p. 11) suggests, "The example of two roads was deleted from later editions of *The Economics of Welfare,* presumably in an attempt to avoid the criticism by F.H. Knight." Greater detail, however, sheds a nuanced light on this line of reasoning.

Pigou's explicit argument for congestion pricing was:

> 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 for those 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. But the measure of differentiation must be rightly chosen. (Pigou 1920, p. 194)[6]

In looking at this issue, Pigou was seeking to support the idea, and correct an error, he had expounded in *Wealth and Welfare* (Pigou 1912) that in competitive situations there

[4]While Pigou does not discuss highway congestion in *Wealth and Welfare*, it is to this book that Walters (1961) later credits the idea, with no mention of *Welfare*, although he had referred to the latter in his 1954 paper on track costs. McDonald (2013) later inadvertently reverses Walters's incorrect referencing. Buchanan (1956, p. 305) similarly incorrectly maintains that the road charging example "was introduced by Professor Pigou in his *Wealth and Welfare.*" Further, in his more contemporary discussion of London's congestion charging regime, Leape (2006) also incorrectly cites *Wealth and Welfare* as one of the sources for the idea. The confusion may have arisen because Pigou (1912) does discuss concessions as a way of financing highway construction (p. 151) and the role that differential pricing according to demand elasticity (a sort of Ramsey pricing approach) may be needed to finance railroad provision, using the term "road" in a generic sense in his drafting (pp. 229–230). Congestion is not mentioned in either context.

[5]Knight (1926, p. 51) approved of Pigou's 1924 edition: "To the reviewer, the book represents the science of economics at its best so far; no work in the field known to him is its equal in the combination of scholarship, analytical penetration and lucidity of exposition."

[6]Knight (1924, p. 587) provides a clearer definition of "differentiation" and of the necessary charge to correct for it: "The toll or rent will be so adjusted that the added product of the last truck which uses the narrow (congested) road is just equal to what it could produce on the broad (uncongested) road."

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

will be excess investment in increasing cost industries and deficient investment in decreasing cost industries.[7] He had little interest in roads per se (McDonald 2013). They were simply an example, as he perceived them, of an increasing cost industry that required government-administered road user charges to reflect rising congestion cost.[8]

While recognizing the logic of Pigou's case for government intervention, Knight argues that it results because Pigou's "assumptions diverge in essential respects from the facts of real economic situations."[9] He goes on to argue that average cost pricing of the limited capacity road was not an externality (i.e., a failure of market mechanisms) but a failure of government to specify and enforce property rights for scarce resources.[10]

This is a neo-Coasian type of position. If the low-quality road were provided free, but the limited capacity was in the hands of a profit-seeking, private company, then the latter would charge a user fee exactly equal to the difference between the value to a driver using the wide road and the narrow road.[11] This fee would represent the difference between the marginal and average cost of using the narrow road. In Knight's (1924, p. 558) words, "The toll or rent will be so adjusted that *added* [italics in original] product of the last truck which uses the narrow road is just equal to what it could produce on the broad road. No truck will pay a higher charge, and it is not to the interest of the owner of the road to accept a lower fee."

Knight's article came out in March 1924, before Pigou's second edition, and it is clear Knight had read the interchange between Pigou and Robertson (1924), which we discuss below, before it went to print. Indeed, he interpreted it as "Professor Pigou admit[s] the particular error in his analysis and states that it is to be eradicated in a forthcoming revised edition of his book" (Knight 1924, p. 283n2).[12] But it was not clear what exactly Pigou was admitting, and what exact changes were made regarding it.[13]

[7]Pigou does not define "capacity." Definitions, however, became important in debates between engineers and economists. The former generally think of capacity as the maximum flow of traffic a road can handle over a given time (e.g., cars per hour). Economists think in terms of capacity being reached when the marginal cost of adding lanes or other forms of capacity is equated with the marginal benefit of doing so. Button (2010a) provides a more complete explanation.

[8]Buchanan (1965) offers a different perspective on congestion and its pricing. He treats roads as a club with the users being members. As with golf clubs, use entails a membership fee to cover the costs of the infrastructure and a "green fee" related to use that varies with demand and aims at allocating the number of rounds per day.

[9]Knight was the only person at the time to pick up on the congestion problem. The review of the first edition of *Welfare* in the *Economic Journal* (Cannan 1921) said nothing. Reviews of *Wealth and Welfare* in the *Quarterly Journal of Economics* (Young 1913), *Economic Journal* (Edgeworth 1913), *Journal of the Royal Statistical Society* (Flux 1913), and the *American Economic Review* (Clark 1913), while having nothing on congestion, did raise general concerns about the idea of increasing cost industries, and Young's comment may have stimulated Pigou to have included the roads example in *Welfare.*

[10]Some took up Pigou's suggestions quickly. Clark (1923, p. 304) advocated user charges in response to problems of highway damage, unfair competition vis-à-vis railroads, and paying for highways.

[11]Walters (1954, p. 143) pointed out later that the likely outcome of this is, "Some frightful state of oligopoly would emerge in both cases; some form of collusion would be likely as the ultimate outcome."

[12]Pigou's admitting to erring in his analysis is re-emphasized in a later article by Knight (1925, p. 331): "On the same assumptions, Professor Pigou's argument in the *Economics of Welfare* would also be sound, as Professor Pigou himself has admitted that is not so."

[13]That Pigou's papers, personal and professional, were destroyed after his death, and that there is no record of correspondence in Knight's papers held at the University of Chicago Library between Pigou and himself before 1926, does not help matters.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

We thus do not know from this whether, as Breit and Ransom (2014) seem to maintain, Pigou was aware of Knight's views before he wrote the new edition.[14] As Ellis and Fellner (1943, p. 449n14) later write, Pigou omitted the

> "two roads" example from the second edition of his book which happened to appear almost simultaneously with Knight's criticism, and does not refer to the latter. No special significance should be attributed to Pigou's recantation of the "two roads" proposition because it was inconsistent with his own position and should have been dropped even if his position had not been modified.

This leads to the second possible reason for Pigou dropping congestion from his book. We do know he was influenced by John Clapham and Dennis Robertson regarding some aspects of increasing costs, although it is not clear what aspects.[15] The 1922 debate in the *Economic Journal* to which Knight alludes, according to Robertson, "raged over the practical utility of certain refinements of analytical economics: it was debated whether the theoretical sorting of industries into boxes labelled 'diminishing return' and 'increasing return' could be turned to practical account" (Pigou and Robertson 1924, p. 16). Pigou also had interchanges over the reality of increasing costs with the economic historian Clapham in the *Economic Journal* (Clapham 1922a, 1922b; Pigou 1922). The outcome of all this influenced Pigou's approach to what went into the second edition of *Welfare,* and it may have been why he excluded roads as an example of increasing costs.

But there is no certainty about the edits Pigou made. What exists is a response to Robertson's concerns over whether increasing costs is a realistic assumption in industrial economics (Pigou and Robertson 1924, p. 31): "As I have rewritten and altered my discussion of these matters in the new edition of *Welfare*, which is appearing shortly, it would be wasted labor to debate the old version in detail." While this is relevant to the congestion charging idea, Robertson makes no explicit mention of Pigou's roads example but covers a lot of other ground.[16] We simply do not know what Pigou changed in response to the "empty-box debate."

There is another element to this, and a third possible reason the road case was not in the new edition. The 1920 volume was extensively reviewed by Edwin Cannan in the *Economic Journal*, and not altogether favorably. Cannan especially criticized the fact that half of the book simply replicated material in *Wealth and Welfare*, while much of the rest was far too verbose. For example:

> In the presence of a book of a thousand pages a reviewer feels somewhat of a worm, but like that despised being, he is inclined to turn, when he finds that the author has incorporated an earlier book of his own comprising five hundred pages without troubling to make the usual statement explaining what parts are new and what old, and also the general effect of alterations and improvements. (Cannan 1921, p. 206)

[14]We also do not know Marshall's position on this. In annotated notes to his copy of *Wealth and Welfare*, which he did not show Pigou (Bharadwaj 1972), he certainly had reservations regarding the argument concerning the "marginal supply price" deviating from the supply price except when costs are constant. We do not know whether, in conversations with Pigou, Marshall subsequently questioned Pigou's counter-argument regarding the divergence using the roads example in the *Economics of Welfare.*

[15]Clapham, drawing largely on historical examples from agriculture and coal mining, argues from an empirical perspective that situations of increasing costs are not common, if they exist at all, and the concept is not useful anyway.

[16]What we also do not have is knowledge of informal conversations between Pigou and Robertson.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

And in a similar vein, we find Gustavo Del Vecchio (1921), later the governor of the International Monetary Fund, in his *Giornale degli Economisti e Rivista di Statistica* review, complimenting the book as "profound" and "original" but also considering parts of it to be "fatiguing" because of its excessive size.

In Pigou's editing down of the material to meet Cannan's, Del Vecchio's, and perhaps others' criticisms of length, something had to go. Additionally, in subsequent editions there was more focus on environmental externalities, such as the smog problem in London, and this had to be accommodated. The material on congestion may have been felt to be of lesser importance than other matters and not central to his discussion of pollution—the former being technically a user-on-user externality, and the latter a user-on-non-user externality.

Pigou's and Knight's contributions dominate the discussions of the embryonic work on road pricing, but others also reflected on Pigou's road example over the following decade, mainly to examine the conditions under which congestion externalities exist. For example, Jacob Viner (1932) explicitly uses Pigou's road example to explore the possibility of external diseconomies. He argues, however, that, while theoretically possible, it "is hard to find convincing illustrations" of roads being an increasing cost industry unless there are "higher unit highway transportation costs when an industry which provides its own transportation for materials and products expands its output and thereby brings about traffic congestion on the roads" (p. 41).

Also in the context of Pigou's example, Richard Kahn (1935), in part of a larger examination of optimal output, uses it in arguing that if roads could be regarded as having the attributes of air, there is no need to quarrel with the notion of congestion charges; "just as smoke pollutes the air, so motor vehicles may be said to pollute the roads; and the case for interference may be based on the existence of external diseconomies" (p. 17). But could they be treated this way? Kahn thought not.

He argued against the existence of external diseconomies in the road case using, according to James Buchanan's (1956) later work, "a peculiar chain of reasoning."[17] Kahn defined "marginal private productivity" as a change in a firm's output due to a change in the input of one factor (the firm's expenditure on, and the amount of, the other factors remaining unchanged), and "marginal social productivity" as the change in the output of the community under the same conditions.

> In considering the application of all other factors, treated as one composite factor, to the factor 'road,' the definition of marginal social productivity (and thus of external diseconomies), which are said to exist when marginal social falls short of marginal private productivity, requires that the amount of road space used by the firm which increases its output remains constant. The amount of road space available to other firms also remains constant. The latter's output is unaltered; and marginal social does not differ from marginal private productivity. (Kahn 1935, p. 17)

[17]Kahn (1935) also questions the practicality of congestion charging: "Practical considerations enforce the imposition of a uniform charge on motor-cars, without any regard to the economic value of the particular road service which each enjoys. Some compromise has to be sought between the rates of tax appropriate to different districts, and the congested roads will necessarily be more congested than the social interests dictate, while the uncongested roads will be too uncongested" (pp. 18–19).

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Buchanan points out, however, that any change in output must be measured in vehicle or ton-miles per time unit and must change the amount of road space utilized by the firm under consideration, as well as change the amount available to others; "Mr. Kahn was apparently trapped by his own definition into assuming an impossible situation" (Buchanan 1956, p. 309).

Ellis and Fellner (1943, p. 499n14), as noted earlier, supported arguments that the two-road case was not necessary and were largely moved to agreement with Knight—Pigou's argument "was proven to be fallacious by Professor Knight." Thus Pigou was seen by these authors as omitting the two-road case from later editions of *The Economics of Welfare* because it did not conform to a world of perfect competition with non-constant returns.[18] However, as John McDonald (2013) points out, in reality most roads are not privately owned and did suffer from congestion at the time. Congestion was just not a major concern of the 1920s when road capacity expansion was seen as a solution and was of little interest to theorists once the Great Depression came.

III. ENGINEERING ECONOMICS AND ROAD PRICING

While Pigou and Knight had somewhat different ideas about handling congested roads, implementing either approach posed practical problems.[19] This may be the reason the idea of road pricing was slow to be incorporated in mainstream economics; for example, the widely used transportation textbook of the 1940s, *The Economics of Transport* (Bonavia 1946), made no mention of it, and neither did Charles Dearing's (1941) book on American highway policy or John Sargent's (1958) on British transportation policy.

The economic conditions of the times, combined with the domination of civil engineers in making road-related policies, however, largely explain why reducing traffic congestion was not an immediate economic priority in the 1930s and 1940s. In many cities, there was still adequate capacity to handle traffic, and the move from horse-drawn to motorized transportation had, because of the greater maneuverability of cars and trucks, *de facto* increased capacity. There were also technical developments, including traffic lights and considerably improved methods of traffic management.[20] Such

[18]Demsetz (2011), when recounting the two-road example in a paper setting Pigou's and Knight's work in a Coasian context, concluded that "Knight's private roads and Pigou's recommended tax-subsidy remedy would result in an optimal amount of congestion" (p. 4). In this analysis, however, the second road becomes slightly congestible and acquired a second private toll-setter.

[19]One partial exception to this is the taximeter invented by Friedrich Wilhelm Gustav Bruhn in 1891. Taximeters, which were originally mechanical, allow cabbies to charge by a combination of distance and time —a crude congestion price. What it does not do is to charge for the congestion when a cab cruises around seeking a fare. Uber embraces "surges" in its charges to nudge both sides of the market to match the supply of drives with potential riders during periods of peak demand.

[20]Lights and traffic management was not new. For example, in the 1720s officers had the task of directing traffic on London Bridge coming in and out of either London or Southwark. One would direct traffic coming out of Southwark into London and ensure all traffic stayed on the west end of the bridge. A second would direct traffic on the east end of the bridge to control the flow of people leaving London (Sessions 1971). The first gas traffic lights were installed opposite the UK's House of Commons in 1868, but a gas leak and subsequent explosion caused them to be abandoned.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

measures, though, were aimed at increasing the useful engineering capacity of a road rather than allocating that capacity efficiently (Thomson 1967).

On the demand side, the Great Depression of the 1930s led to a slow-down in the growth of car ownership and use. Although the situation differed between countries, as may be expected, the war saw an actual decline in the US car park, from 29.6 million vehicles in 1941 to about 25.8 million in 1945, but there was a dramatic postwar increase as factory capacity was switched to vehicle production. Demand for cars was stimulated by rising incomes and a considerable increase in population. The effects of this on city traffic were magnified by the significant migration to urban areas as the country shifted away from an agricultural economy and as suburban living became more popular. By the mid-1950s, urban traffic problems were growing, but the approach to the problem did not involve road pricing.

Although its origins can be traced back to Arthur Wellington (1887), the 1950s and 1960s also saw considerable developments in engineering economics. This is a sub-discipline of economics focusing on problems related to the investment of capital over a broad array of projects, products, processes, and services. As in other areas of micro-economics, it involves defining objectives, although these, as we have seen, generally involve physical criteria such as traffic flow, and with technical ways of achieving them (Lesser 1969). While engineering economics incorporates some basic tools of cost-benefit analysis and, aided by systems management, offers "planning solutions," it does not embrace pricing as a major policy instrument. What it does do, and what was appealing to policy makers in the 1960s, was to provide what appeared to be rational ways of allocating resources in the long term across expanding road networks. But it was not normally concerned with problems of economically optimizing road use.

The focus of the early 1950s to the 1970s was thus primarily on accommodating the motor vehicle—often caricatured as "predict and provide." This engineering-dominated view was that the demand for road use was invariable with time and price, and that there was a need, therefore, for governments to supply adequate capacity or else there would be dire consequences for the economy. The practical outcome meant increasing the networks' capacity, with physical traffic management deployed to direct and restrict use.

The US Interstate Highway System, for example, was begun in 1956 but was not priced by statute.[21] There were master land-use transportation plans drawn up for American cities beginning with those for Detroit (in 1953) and Chicago (in 1956), but the broad concepts were also embraced elsewhere as in the Greater London Development Plan (Hagman 1971). Each plan obviously differed by city but broadly involved significant increases in road capacity, much of it of freeway quality, with a focus on radial configurations to facilitate flows of commuters to and from the central business district. Beltways were built to channel through traffic around the urban cores. As Stephen Plowden (1967) noted, though, there was little economics in the underlying analysis.

Even when it became clear that the Pigou-Knight-Downs paradox (Duranton and Turner 2011), as it is now known, was biting, with road traffic expanding to fill the road

[21]This did not mean that direct user-fee finance was not considered. It was rejected, partly on the findings of an earlier report, because "the construction of direct toll highways cannot be relied upon as a sound solution of the problem of providing adequate facilities for…. necessary highway transportation of the United States or to solve any considerable part of this problem" (US House of Representatives 1939, p. 4).

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

space available, and when it was appreciated that unrestrained use of infrastructure means its inefficient use, decision makers were still reluctant to adopt economic pricing.

This is not to say that congestion was treated as a trivial matter. Instead, the engineering planners' focus shifted to complement highway construction with enhanced physical traffic-management measures, including more traffic signals, one-way systems, parking limits, signposting, and improved network design. But restraint was accepted with some regret. As Colin Buchanan, a leading planner of the time, put it in *Traffic in Towns,* an influential UK government report:

> Distasteful though we find the whole idea, we think that some deliberate limitation of the volume of motor traffic is quite unavoidable. The need for it just can't be escaped. Even when everything that it is possible to do by way of building new roads and expanding public transport has been done, there would still be, in the absence of deliberate limitation, more cars trying to move into, or within our cities than could possibly be accommodated. (UK Ministry of Transport 1963, para 30)

This report recommended that road users should, by means of careful land-use transportation planning, rather than just "predict and provide," be denied too much access. In doing this, *Traffic in Towns* saw itself treating the urban transportation problem as one of achieving compromise among the environment, motorization, and investment through the design of road networks and physical traffic management. Economic ideas were not a major part of the thinking of policy makers of the time, and little was said about how prioritization of the use of roads was to be decided.

IV. FROM THEORY TO THINKING ABOUT APPLICATION

Although using pricing to tackle mounting congestion was not at the forefront of economists' concerns in the early 1950s, there were some no exceptions.[22] In 1951 Milton Friedman and Daniel Boorstin (1996) produced a paper for a graduate competition concerned with highway investment and the "desocializing" of highways. It argued that "in fairness, the people who drive on a road should be charged for the service received and in proportion to their use of the service … license fees and gasoline taxes are … very crude means" of charging. The subsequent importance of this is that the mayor of London, Ken Livingstone, who introduced road charges in 2003, claimed when discussing the origin of his thinking in the *Daily Telegraph* (Halligan 2001), "I have nicked the idea from Milton Friedman," citing the 1951 paper.

The period also saw the emergence of a more practical approach to Pigouvian pricing being advanced by a new, more pragmatic group of economists. In particular, an article in the *National Tax Journal* on highway pricing by James Buchanan (1952) provided the segue between theory and application.[23] This paper, on a subject Buchanan felt to be "a major social problem," considers the existing institutional structure of taxes in the US

[22]For an account of urban transportation philosophies of this period, see Batty (1994).
[23]Marciano (2013) provides a more comprehensive overview of James Buchanan's work on externalities.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

and indicates ways taxes could be adjusted to reflect more fully the congestion imposed by road users on each other:

> Highway services are not free. User taxes have been recognized as "prices" charged for the use of roads and streets. The pricing function of user taxes generally discussed, however, has been that of setting up some criteria for investment. The corollary function of highway prices in limiting the demand for highway services has never been considered adequately. This may be attributed to the fact that highway user taxes as "prices" have seldom been made distinct from highway user taxes as "taxes." (p. 98)

He muses over the ways that "mileage traveled" charges could be developed by adjusting fuel taxes; say, by raising them around peak travel periods of the year. He considers varying the tolls that were being charged on roads—for example, by having higher rates for trucks during the busy day periods and lower ones at night. He looks at annual licence fees and argues that mileage is also a factor in overall congestion levels and suggests having more classes of licence by weight, horsepower, etc., and with higher fees for categories seen to cause more congestion. He essentially comes up with the idea that roads are what we now often call "impure public goods"; congestion reduces their quality and in doing so results in poorer service for all users.

Buchanan began refining this analysis in 1954 and intended to produce a book. In a resultant unpublished note, Buchanan (1954), when looking at the Pigou-Knight debate, accepted that "voluntary agreement" could remove spillover effects but did not entirely agree with Knight, arguing that for an optimal allocation of resources, "it is necessary that the prices of highway services be set equal to the marginal social costs of providing such services," and that prices need to include "the incremental costs (or reduced enjoyment) imposed upon other road users!" (p. 6). More substantive was his critique of Knight in his 1956 *Southern Economic Journal* paper, where he defines externalities as interdependence between "independent utilities and productivities" (p. 309), and not only a matter of property rights. In our case,

> Road usage provides a specific, and not unimportant, example of the fourth type of interdependence mentioned by Scitovsky, the only one which he characterizes as "external economies and diseconomies". The production function of the individual trucking firm depends not only on the factors utilized by the firm but also on the output of other firms. This fits Meade's precise definition of external diseconomies. (p. 309)

His remedy for excess congestion was that "the government … own the roads and price the road services at the level of marginal cost" (p. 315).

While Buchanan was drafting his 1956 paper, cited earlier in connection with Kahn's ideas, the report of the US President's Advisory Committee on a National Highway (1955) was published. This contained ideas for expanding the American interstate road system. Financing this through the issuance of bonds, albeit with the likely outcome of considerable inflation, avoided tax increases or direct user charges. Buchanan (1955), as a reaction, drafted a note that sets out in simple terms his position regarding traffic congestion.

> The answer to the whole highway problem lies in "pricing" the highway correctly. The existence of congestion on our streets and highways is solely due to the fact that we do not charge high enough "prices" for their use. This is one of the main functions of price

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

> in our free enterprise economy.… Price relieves potential congestion around our meat counters, our hotels, and our models. (pp. 14–15)[24]

James Buchanan's work was particularly important in clarifying and fine-tuning the concepts of externalities that had caused some problems in the 1920s and 1930s.[25] Following on from this, although not always directly stemming from it, there was an outflow of material by others that, beside establishing the modern economic principles of road pricing in an imperfect world, set about educating academics, policy makers, and the larger public on the role of congestion charges. These, albeit largely uncoordinated efforts, saw seminal publications by, beside Buchanan and William Vickrey (1968, 1969), Alan Walters (1954, 1961), who also produced a "manual" for the World Bank on using road pricing in developing countries (Walters 1968).[26] Indeed, by 1965 the much used John Meyer et al.'s (1965) *The Urban Transportation Problem* was almost entirely concerned with the economic issues of traffic congestion.

Focusing on the UK, Walters (1954) had initially become involved in road efficiency as part of the ongoing debate of the time over railway track costing. His concern was that the railway network had been nationalized in 1948 as a single entity and thus its congestion costs had been internalized, whereas trucking, although initially nationalized after World War II, had been privatized in 1951; both imposed congestion costs on others and suffered from congestion.[27] The question posed by Walters was, "How can the railways engage in fair competition with road haulage and 'bus firms who do not have to pay for the highways?" (p. 135). This he framed essentially as a Pigou's initial "two-roads issue."

> If the vehicles are owned individually by a large number of firms and if no charge is made for the services of the road, the traffic level will be determined by the condition that marginal private cost equals price. But when the road is congested, an additional vehicle increases the costs of vehicles already using the road because congestion is increased.… The railways, on the other hand, will not have a similar distinction between social and private cost. The trains travelling over the rail track are all owned by the same Corporation and, in calculating the additional cost of running an extra train, the additional cost caused to other trains would be included. (pp. 142–143)

Walters does not see Pigouvian congestion charging as a panacea and neither does he see it as being without problems. He appreciates the challenges of implementation especially given the technology and knowledge of travel behavior at the time. But he does have foresight in suggesting a system akin to that introduced in London five decades later.

[24]The paper was never published, although University of Arizona's Harry Jenkins apparently suggested *Commercial and Financial Chronical* or *Freeman* may have been suitable outlets.

[25]Other important theoretical works on network economics were appearing at that time. Particularly important was Beckmann et al. (1956), whose analysis formed the basis of some of the early efforts at quantifying the effects of various road pricing policies, and notably that underlying the Smeed Report.

[26]There were also efforts to link the effects of sub-optimal levels of traffic congestion and land-use patterns (e.g., Mills 1972; Solow 1973). Major theoretical advances in the modelling of traffic congestion, important for any pricing regime, were also made. This paper only touched on these when it is of direct relevance; a more complete account is to be found in Lindsey and Verhoef (2008).

[27]Walters seems unaware of Buchanan's 1952 paper when drafting his *Journal of Industrial Economics* article. At least he does not cite it.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

> Of course, it would be very difficult to measure the marginal private cost and marginal social cost curves in practice. The ideal tax would vary between one road and another and at different times on the same road. Furthermore, the slow wide vehicles contribute much more to the degree of congestion than fast narrow vehicles. And even if we did know the pattern of the curves, it would be most difficult to devise administrative measures which would re-allocate the volume of traffic such that the deviation between marginal social cost and marginal private cost is minimized. Nevertheless, measures such as an annual licence fee for vehicles using the central areas of large towns would be a move in the right direction. For example, a special 'London licence' would have to be acquired and displayed before vehicles could use the roads of central London between 8 am. and 6 pm. (p. 143)

William Vickrey's (1955) involvement in congestion charging began from a different position. He became engaged in the debate when considering public transit pricing but pressed his views on congestion charging in evidence to the Joint Congressional Committee on Washington Metropolitan Problems.[28] His evidence dealt not only with the economics and technical issues of road pricing but also matters of public acceptability. He summed up his 100 typed pages of evidence as showing that:

> It is no use arguing that … the average motorist pays for what he uses through higher gasoline taxes or higher license fees, or even through higher property taxes or income taxes. Unless the amount he pays is made to vary specifically with the amount of his own individual rush-hour usage of the highways, the results will be disastrously expensive. (Vickrey 1959, p. 44)[29]

Vickrey's solution was clear. In the absence of any pricing of highway usage, there was a need to construct either a highway system of "extravagant proportions … much larger than users would be willing to pay for" or a "highway system that is severely congested during rush hours." There was no particularly attractive middle ground. Pricing of highway usage was needed and needed badly.[30] Given the technology of the time, he considers two feasible methods of charging for urban street use—photographic and electronic—both of which produce an automatic record of cars passing a series of checkpoints that can be transmitted to a central processor to allowing billing. As we see, experience has shown him to be correct in isolating these as practical, if far from perfect, ways of charging.

But Vickrey nuances his technical concerns with a range of political, economic, and social challenges, which advocates of road pricing needed to confront. An extensive quote from a slightly later paper offers a summary:

[28]Urban authorities in the mid-1950s began to subsidize rapid transit and buses, aiming to make them more competitive with automobiles. Such policies have been particularly disappointing with widespread overoptimism regarding their attractiveness as an alternative to car use (Kain 1990), underestimation of the investment costs involved (Flyvbjerg et al. 2002), and evidence of considerable economic capture by both supplying companies and politicians (Wachs 1989).

[29]The evidence also set road charges in a wider context and contained appendixes on curbside parking, the balance between mass transit and automobiles, a system of Ramsey-Boiteux for transportation pricing, and estimates of appropriate charging regimes for the Washington mass transit system.

[30]Vickrey had solved his own commuting problems in Manhattan by rollerblading to and from his office at Columbia University.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

> It must be decided how detailed the schedule of charges should be; what means should be used to inform the motorist of the charge he is likely to incur; whether the charges should be fixed by schedule in advance or should be made to vary with conditions actually experienced; whether they should be based on mileage or on time, or both; how to integrate charges for movement in congested areas with charges for parking and standing; to what extent weather conditions should be taken into account; whether areas favoured with new facilities representing a substantial increment in capacity should be favoured with lower congestion charges as well. There is also, to be sure, the question how to measure congestion charges, but this is not a problem raised only by the intention to levy a congestion charge: Measurement of congestion cost is an essential part of any cost benefit analysis used as a basis for intelligent planning of new facilities and the maintenance of existing ones, though perhaps congestion charges require more detailed investigations into the variations of costs between peak and off-peak periods. (Vickrey 1968, p. 116)

These contributions to the road pricing debate by Walters and Vickrey took place at a time when there were major initiatives in intercity road investment with the UK's first motorway opening in 1958 and the US Interstate Highway System being initiated in 1956. These were to be toll-free, national systems projected to have adequate capacity to meet growing traffic demands for several decades. Road pricing was not seriously considered. Pigou's example of trucks on highways had now, as seen by Vickrey's examples, effectively morphed into automobiles on congested urban streets, and in this context road pricing was beginning to be seriously considered by policy makers.

V. UPTAKE OF CONGESTION CHARGING

The early 1960s also saw an upsurge of general involvement in welfare economics at the policy level, and in making it relevant to mounting transportation questions. In addition to congestion, protection of the environment began to be of public concern, as did the costs of accidents. This aroused a broader, policy-based interest in externalities and their valuation. The question resurfaced of whether the congestion problem was an instance of external diseconomies within the industry or the misuse of a scarce resource—i.e., the zero pricing of scarce land required clarification for wider economic decision making. Ed Mishan (1965) provided a response that effectively pulled together the theory and put the pre-war debates to rest for many. He best summed it up in a later survey published in the *Journal of Economic Literature*:

> Bearing in mind that under competitive conditions the private owner is deemed to maximize his earnings by "exploiting" the supply curve—that is, by taking a curve marginal to the average cost curve—we perceive where the two explanations converge. Pigou's external diseconomy explanation elicits the marginal cost *excluding* rent concept. Knight's solution—the proper pricing of a scarce resource, road space, elicits the average cost *including* rent concept. … the curves produced by each are coterminous, being but different ways of regarding the correct competitive supply curve. (Mishan 1971, p. 5; italics in original)

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

The 1960s was also a period of revised thinking in the UK. A major inquiry into the economic usefulness of road pricing and its tractability was also initiated (UK Ministry of Transport 1964). This was stimulated by the rapid appreciation that rebuilding historic British cities to accommodate cars and trucks à la Colin Buchanan's report was excessively expensive and socially unpopular. There was also limited space to build transit systems, and rights of way associated with defunct systems were no longer available in many cases.

Road pricing was becoming a viable option but was mainly seen as a short-term measure to contain traffic while additional infrastructure was built (Thomson 1998). The ensuing Smeed Report concluded that it would be feasible to impose congestion charges on cars, using the metering of road usage.[31] The effect of speeding up congested traffic would benefit the country's economy by £100 to £150 million per annum (£821 to £1,232 million in 2017 prices). This takes no account of the non-measurable benefits such as reduction of noise, fumes, and frustration. The figures are also based on the charges being tax neutral; the revenues gained from congestion charges would be offset by reductions elsewhere.[32] However, it did question whether the government had the will to act.

The Smeed Report also had some success in influencing thinking in the European Community at the time, most notably in its report of a committee on Options in Transport Tariff Policy chaired by Maurice Allais (Allais et al. 1967). This argued, "As regard the problem of urban congestion, there does not seem to be any contradiction between a policy of reducing the excessive density of traffic in certain built-up areas and the criteria of optimal resource allocation" (p. 60), and goes on:

> The advantages of the option of economic charges are quite clear.… In cases where the infrastructure is not fully utilized in the economic sense, the absence of any charge except the cost component leads to maximum economic use of a factor of production which does not occasion any economic costs other than the marginal use cost. Imposing congestion charges on infrastructures that are fully utilized in the economic sense is an effective way of rationing demand and reducing it to a level of the available capacity.… In fact without the charge demand would fall spontaneously owing to the congestion, which would confront users with costs similar to, perhaps much higher than the congestion charge (through waiting, etc.); such congestion is a much less beneficial and efficient way of limiting overall demand at any one moment. (p. 79)[33]

The Smeed Report was not, though, without critics. Clifford Sharp (1966, 1968) was concerned that the composition of the committee was biased towards charging, a point

[31]The idea had already been put forward in a study by the town planner, Peter Hall (1963), a few years earlier: "advances in electronics had made it possible to 'meter' the movement of all vehicles and to charge them an economic rate for the use of a section of the street system," although parking fees were considered a better option.

[32]Smeed also predicted that the average speed of traffic in central London would always tend to 9 miles per hour without disincentives, because this was the minimum speed that people will tolerate. The speed had actually fallen to 8.7 miles per hour when congestion charges were introduced in 2003 and rapidly increased to 11 miles per hour, the fastest for over a quarter of a century.

[33]Despite Allais's arguments (Allais et al. 1967), the European Community did not press for congestion charging. Although a Common Transport Policy was mandated under the Treaty of Rome, it took until the late 1980s for anything of substance to emerge, and local matters were not treated as of Union interest even after that (Button 2010b).

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

he takes up from one of its members, Christopher Winsten. The latter, at the Royal Statistical Society, suggested the panel was "too much composed of road pricing enthusiasts" (cited in Thomson 1967, p. 368). There were, in fact, four economists on the committee—Michael Beesley (London School of Economics), Christopher Foster (Oxford University), Gabriel Roth (Cambridge University), and Walters (University of Birmingham)—who were strong supporters of road pricing. John Thomson, the committee secretary, was also an economist. Winsten, a graduate of Cambridge in mathematics and economics, had reservations about the practicalities of congestion pricing. Sharp's second concern was that, although he supported the idea that selective use of charges can be useful in providing a direct incentive for drivers to economize in the use of roads, on some routes there was limited scope for such economy and, on others, no justification for forcing some people to use slower roads to allow others to travel faster. Third, he was also concerned with how the revenues of a charge would be spent, suggesting a range of alternatives including the replacing of fuel taxation and support for disadvantaged groups. In this, Sharp highlights an appendix in the Smeed Report in which Thomson reveals that, although pricing reduces congestion, the bulk of the benefit comes in the revenue collected, and this is released only when this is used. It thus becomes a normative matter of how these "locked-up" benefits are spent, as well as positive one of their size.

The minister was lukewarm towards the report and initially withheld its full release to take time to consider it. It was rumored that Prime Minister Alec Douglas-Home had suggested to "take a vow that if we are re-elected we will never again set up a study like this one" (cited in Goodwin 1997). One reason for the lack of immediate concern was that car ownership was not growing as fast as forecast (Button 1974).

In a wider review of urban traffic issues completed a few years later, *Better Use of Town Roads*, UK Transport Minister Barbara Castle, in her foreword, certainly does not endorse the views of the Smeed Committee:

> There is no shortage of ideas for limiting the amount of traffic in towns. … As this report shows, most of them have serious shortcomings. With some of them, the cure could be worse than the disease. An early conclusion from this study was that direct road pricing seemed the most promising long-term approach to controlling the use of urban roads. We are now seeing whether a feasible system can be developed.
>
> It is not certain that road pricing can offer a solution; it will in any case not be an immediate one. But congestion is with us now and is becoming more of a problem all the time. Prompt action is needed. (UK Ministry of Transport 1967, p. v)

Empirical studies of the implications of congestion pricing began to emerge in the US at about this time. Theodore Keeler and Kenneth Small (1977), for example, found that (in current prices) charges ranging from 6 to 25 cents (25 cents to $1.03 in 2018 prices) in central areas and 2 to 9 cents (8 to 37 cents) for urban highways would increase San Francisco's traffic speed considerably. Likewise, Tony Gomez-Ibanez and Gary Fauth (1980), at 1975 prices, find that a charge of $0.50 to $1.00 ($2.32 to $4.64 in 2018 prices) would reduce Boston's downtown, rush-hour traffic by 10 to 20%. This work was a stimulus for the UK House of Commons Transport Committee's (1982, p. lvii) suggesting "that the benefits, costs and disadvantages of supplementary licensing can only be fully assessed by experiment and in view of the scale of the potential benefits we have concluded that an experiment may need to be undertaken."

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Likewise, interest was being shown by several US states, and the federal government, in conducting small-scale experiments (Button 1984). The Howard-Williams Surface Transportation Act 1978, for example, explicitly allocated funds to the Urban Mass Transportation Administration to support two-year demonstration projects that would employ techniques like the Singapore area licensing system that had been established in 1975, but take-up was limited, mainly for political reasons (Higgins 1981). What also emerged were the considerable legal hurdles that had to be surmounted in many contexts before congestion charging could be instigated. One of these was the exact definition of a "toll"—tolls being illegal for federal roads (Coit 1974). California was particularly active at the state level in building congestion charging into its transportation planning but met considerable opposition from motorist groups and local chambers of commerce that feared a loss of employment. It also faced a poor understanding by many of road pricing (Eckert 1979).

There was some evidence by now, however, that the public was beginning to accept the idea of road pricing as a pragmatic approach to controlling traffic congestion. As noted earlier, in 2000 Ken Livingstone was elected mayor of London on a platform espousing the introduction of cordon-based congestion charges (Leape 2006). In Stockholm, after an experimental period, the population in 2007 voted to permanently maintain an electronic system of road pricing.

The congestion schemes now in place, however, are far from the economically ideal (Santos 2004). Many, like those in London, Singapore, and Stockholm, charge drivers in different ways for bringing their vehicles into urban centers but do not affect driving behavior once the vehicles are within the cordon (Lehe 2019). Thus, while there is considerable sophistication in the Stockholm case in terms of allowing those drivers who gain most to enter the city, once they are in, there is little to limit their use of scarce road space. Another approach, mainly used on radial routes into cities, deploys sophisticated charging that reflects the degree of congestion on the corridor and adjusts the road price accordingly. The prevailing charge (called the "value price" in the US) is made known to drivers prior to entry, who then have the option of paying for a guaranteed speed or of diverting to a "free" alternative. In many cases, high-occupancy vehicles use the corridor with no charge. Although this model closely mirrors Pigou's original case, it does little to optimize traffic across a large road network (Konishi and Mun 2010). In virtually all cases, the net revenues from charges are, at least for a period, legally plowed back into the local transportation system, although this is often broadly defined. These practical examples, while acting to limit congestion, all fall well short of the theoretical economic ideals of road pricing.

Paralleling the practitioner's and politician's crawl forward in the acceptance of road pricing as viable policy, the late twentieth and early twenty-first centuries saw a significant upsurge of academic activity.[34] One reason was the increased interest in

[34]This is not the place to provide an annotated bibliography, but areas of analysis include: parking and road pricing (Graham and Glaister 2006), bottlenecks in roads (Arnott et al. 1993), mixed traffic flows (Verhoef, Emmerink et al. 1999), road pricing and urban form (De Lara et al. 2013), with substitute modes (Braid 1996), varying flows (Liu and McDonald 1998), choice of toll locations (de Palma et al. 2005), cost recovery (David Newbery 1989), second-best approaches (Small and Yan 2001; Rouwendal and Verhoef 2004; Verhoef et al. 1996), information provision (Verhoef et al. 1996), road pricing and environment (Johansson 1997), welfare distribution effects (Parry and Bento 2001), road concessions (Ubbels and Verhoef 2008), multiple congested

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

network economics, culminating in the emergence of the *Review of Network Economics* in 2002, and Nicholas Economides's (1996) seminal survey of the literature to that date. This was accompanied by a new cohort of economists interested in economic regulation. But it was also linked to the deregulation of many network industries, such as airlines, telecommunications, and energy initially in the US, but later more broadly (Button and Swann 1989). The theoretical analysis of congestion pricing now applies across a large range of activities, and particularly in the energy sector, and in many cases its application is more advanced in industries other than roads, including other transportation industries such as airports, transit systems, seaports, and freight railroads.

VI. CONCLUSIONS

Pigou's *The Economics of Welfare* is unquestionably a seminal work that has shaped economic policy over the last century. Much is made, for example, of its role in stimulating environmental debates and laying the groundwork for green accounting. But within this book's 1,000 pages, there are a few lines on one page that, in retrospect, seem to be almost misplaced and rather carelessly drafted material offering congested roads as an example of an increasing cost industry. Over the following fifty years, these few lines formed the catalyst for debates among leading economists concerning their validity and meaning, and over the next fifty years about how their policy implications could be implemented. The questions addressed here are why Pigou's idea on road pricing took so long to permeate mainstream economic thinking, and why then so long to begin to put it into practice.[35] But it also raises a secondary, implicit question of just how important people like James Buchanan, Walters, and Vickrey were in refining the theory of road pricing, and in developing ways of implementation.

Convincing people to pay for their road use was certainly not easy. As Bruno Frey (2003) put it, people in general would rather avoid paying for something if possible; this is human nature, even if people accept there are benefits resulting from changes. Peter Jones (1988) takes a similar line and raises the issue of how road pricing revenues are to be spent. Harold Barger, when he is a formal discussant of a paper by Vickrey, looks at it in a slightly different way:

> William Vickrey throws down a double challenge: to the engineers and to the politicians. He asks the engineers to devise a plan for metering the use of city streets and he wishes to persuade the politicians to accept what must at best be a complicated and unfamiliar proposal. It seems a pity to opt for these complexities until it is shown that more conventional methods will not achieve the desired result. (cited in Vickrey 1965, p. 291)

The problem of uptake was compounded by the prevailing engineering approach to urban transportation that dominated in the immediate post-World War II period. The congestion problem was viewed as one of capacity shortages rather than one that also

roads (Edelson 1971), and HOT lanes (Small et al. 2006; Hideo and Mun 2010). Button (2004) and Lindsey (2006), albeit using different metrics, quantify trends in publishing on road pricing.

[35]Reasons for failed attempts to adopt pricing are considered in Hårsman and Quigley (2010) and Jaensirisak et al. (2005).

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

involved improving operational capacity efficiency. Only when the practicality of "predict and provide" became untenable did the idea that economic pricing was needed begin to be accepted, and still very reluctantly.

REFERENCES

Albert, William. 1972. *The Turnpike Road System in England 1663–1840*. Cambridge: Cambridge University Press.

Allais, Maurice F. C., *et al.* 1967 *Options in Transport Tariff Policy [Report by a Committee of Independent Experts to the Commission of the European Economic Community]*. Brussels: European Commission.

Arnott, Richard, Andre de Palma, and Robin Lindsey. 1993. "A Structural Model of Peak-Period Congestion: A Traffic Bottleneck with Elastic Demand." *American Economic Review* 83: 161–179.

Arnott, Richard, and Kenneth Small. 1994. "The Economics of Traffic Congestion." *American Scientist* 82: 446–455.

Aslanbeigui, Nahad, and Guy Oakes. 2015. *Arthur Cecil Pigou*. New York: Palgrave Macmillan.

Batty, Michael. 1994. "A Chronicle of Scientific Planning: The Anglo-American Modelling Experience." *Journal of the American Planning Association* 60: 7–16.

Beckmann, Martin J., C. B. McGuire, and Christopher B. Winsten. 1956. *Studies in the Economics of Transportation*. New Haven: Yale University Press.

Bharadwaj, Krishna. 1972. "Marshall on Pigou's Wealth and Welfare." *Economica* 39: 32–46.

Blaug, Mark, ed. 1992. *Arthur Pigou (1877–1959)*. Cheltenham: Edward Elgar.

Bonavia, Michael R. 1936. *The Economics of Transport*. Cambridge: Cambridge University Press. Revised London: Nisbet, 1946.

———. 1946. *The Economics of Transport*. London: James Nisbet & Co.

Braid, Ralph M. 1996. "Peak-Load Pricing of a Transportation Route with an Unpriced Substitute." *Journal of Urban Economics* 40: 179–197.

Breit, William, and Roger Ransom. 2014. *The Academic Scribblers: American Economists in Collision*. New York: Holt, Rinehart and Winston.

Buchanan, James M. 1952. "The Pricing of Highway Services." *National Tax Journal* 5: 97–106.

———. 1954. "Resource Allocation and the Highway System." Mimeo. James Buchanan Archives. Fairfax: George Mason University.

———. 1955. "Painless Pavements: Highways by High Finance." Mimeo. James Buchanan Archives. Fairfax: George Mason University.

———. 1956. "Private Ownership and Common Usage: The Road Case Re-examined." *Southern Economic Journal* 22: 305–316.

———. 1965. "An Economic Theory of Clubs." *Economica* 32: 1–14.

Button, Kenneth J. 1974. "A Critical Review of Techniques Used for Forecasting Car Ownership in Discrete Areas." *Journal of the Royal Statistical Society*, Series D, 23: 117–128.

———. 1984. "Road Pricing—An Outsider's View of American Experience." *Transport Reviews* 4: 73–98.

———. 2004. "The Rationale for Road Pricing." *Research in Transportation Economics* 9: 3–25.

———. 2010a. *Transport Economics*. Third edition. Cheltenham: Edward Elgar.

———. 2010b. "Transport Policy." In A. M. El-Agraa, ed., *The European Union: Economics and Policies*. Ninth edition. Cambridge: Cambridge University Press, pp. 244–256.

Button, Kenneth J., and Dennis Swann, eds. 1989. *The Age of Regulatory Reform*. Oxford: Oxford University Press.

Cannan, Edwin. 1921. "Reviewed Work: The Economics of Welfare by A. C. Pigou." *Economic Journal* 31: 206–214.

Cheung, Steven N. S. 1973. "The Fable of the Bees: An Economic Investigation." *Journal of Law and Economics* 16: 111–133.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Clapham, John H. 1922a. "Of Empty Economic Boxes." *Economic Journal* 32: 305–314.
———. 1922b. "The Economic Boxes: A Rejoinder." *Economic Journal* 32: 560–563.
Clark, John M. 1913. "Pigou's Wealth and Welfare." *American Economic Review* 3: 623–625.
———. 1923. *Studies in the Economics of Overhead Costs*. Chicago: University of Chicago Press.
Coit, Rosanne J. 1974. "Legal Issues Surrounding Roadway Pricing on City Streets and Bridges." *Transportation Research Record* 494: 1–10.
de Palma, André, Robin Lindsey, and Emile Quinet. 2005. "Time-Varying Road Pricing and Choice of Toll Locations." *Research in Transportation Economics* 9: 107–131.
Dearing, Charles L. 1941. *American Highway Policy: The History and Culture of Roads in the US*. Washington, DC: Brookings Institution.
Del Vecchio, Gustavo. 1921. "The Economics of Welfare by A. C. Pigou." *Giornale degli Economisti e Rivista di Statistica, Serie Terza*, 61: 355.
De Lara, Michel, André de Palma, Moez Kilani, and Serge Piperno. 2013. "Congestion Pricing and Long-Term Urban Form: Application to Paris Region." *Regional Science and Urban Economics* 43: 282–289.
Demsetz, Harold. 2011. "The Problem of Social Cost: What Problem? A Critique of the Reasoning of AC Pigou and RH Coase." *Review of Law and Economics* 7: 1–13.
Duranton, Gilles, and Matthew A. Turner. 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities." *American Economic Review* 101: 2616–2652.
Eckert, Ross D. 1979. *California Transportation Planning: Examining the Entrails*. Los Angeles: International Institute for Economic Research.
Economides, Nicholas. 1996. "The Economics of Networks." *International Journal of Industrial Organization* 14: 673–699.
Edelson, Noel M. 1971. "Congestion Tolls under Monopoly." *American Economic Review* 61: 873–882.
Edgeworth, Francis Y. 1913. "Wealth and Welfare. By A. C. Pigou." *Economic Journal* 23: 62–70.
Ekelund, Robert B., and Robert F. Hébert. 1999. *Secret Origins of Modern Microeconomics. Dupuit and the Engineers*. Chicago: University of Chicago Press.
Ellis, Howard S., and William J. Fellner. 1943. "External Economies and Diseconomies." *American Economic Review* 33: 493–511.
Flux, Alfred W. 1913. "'Wealth and Welfare.' By A. C. Pigou." *Journal of the Royal Statistical Society* 76: 227–230.
Flyvbjerg, Bent, Mette Skamris Holm, and Søren Buhl. 2002. "Underestimating Costs in Public Work Projects: Error or Lie?" *Journal of the American Planning Association* 68: 279–295.
Frey, Bruno S. 2003. "Why Are Efficient Policy Instruments So Seldom Used?" In Jens Schade and Bernhard Schlag, eds., *Acceptability of Transport Pricing Strategies*. Oxford: Elsevier, pp. 63–76.
Friedman, Milton, and Daniel Boorstin. 1996. "How to Plan and Pay for the Safe and Adequate Highways We Need." Written in 1951 and reproduced as the epilogue in G. Roth, ed., *Roads in a Market Economy*. Aldershot: Ashgate.
Goel, Rajeev K., and Michael A. Nelson. 1999. "The Political Economy of Motor Fuel Taxation." *The Energy Journal* 20: 43–59.
Gomez-Ibanez, José A., and Gary A. Fauth. 1980. "Downtown Auto Restraint Policies: The Costs and Benefits for Boston." *Journal of Transport Economics and Policy* 14: 133–153.
Goodwin, Phillip B. 1997. "Solving Congestion (When We Must Not Build Roads, Increase Spending, Lose Votes, Damage the Economy or Harm the Environment, and Will Never Find Equilibrium)." Inaugural Lecture for the Professorship of Transportation Policy, University College London.
Graham, Daniel J., and Stephen Glaister. 2006. "Spatial Implications of Transport Pricing." *Journal of Transport Economics and Policy* 40: 173–201.
Hagman, Donald G. 1971. "The Greater London Development Plan Inquiry." *Journal of the American Institute of Planners* 37: 290–296.
Hall, Peter. 1963. *London 2000*. London: Faber and Faber.
Halligan, L. 2001. "Livingstone's Great Plan Will Drive London Mad." *Daily Telegraph*, July 15.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Hårsman, Björn, and John M. Quigley. 2010. "Political and Public Acceptability of Congestion Pricing: Ideology and Self-Interest." *Journal of Policy Analysis and Management* 29: 854–874.

Higgins, Thomas J. 1981. "Road Pricing: A Clash of Analysis and Politics." *Policy Analysis* 7: 71–89.

Inci, Erin. 2015. "A Review of the Economics of Parking." *Economics of Transportation* 4: 50–63.

Jaensirisak, S., M. Wardman, and A. D. May. 2005. "Explaining Variations in Public Acceptability of Road Pricing Schemes." *Journal of Transport Economics and Policy* 2: 127–153.

Johansson, Olof. 1997. "Optimal Road Pricing: Simultaneous Treatment of Time Losses, Increased Fuel Consumption, and Emissions." *Transportation Research D*, 2: 77–87.

Jones, Peter. 1988. "Urban Road Pricing: Public Acceptability and Barriers to Implementation." In K. J. Button and E. T. Verhoef, eds., *Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility*. Cheltenham: Edward Elgar, pp. 263–284.

Kahn, Richard F. 1935. "Some Notes on Ideal Output." *Economic Journal* 45: 1–35.

Kain, John F. 1990. "Deception in Dallas: Strategic Misrepresentation in Rail Transit Promotion and Evaluation." *Journal of the American Planning Association* 56: 184–196.

Keeler, Theodore E., and Kenneth A. Small. 1977. "Optimal Peak-Load Pricing, Investment, and Service Levels on Urban Expressways." *Journal of Political Economy* 85: 1–15.

Klein, Daniel B. 1990. "The Voluntary Provision of Public Goods? The Turnpike Companies of Early America." *Economic Inquiry* 28: 788–794.

Knight, Frank H. 1924. "Some Fallacies in the Interpretation of Social Costs." *Quarterly Journal of Economics* 38: 582–606.

———. 1925. "On Decreasing Cost and Comparative Cost." *Quarterly Journal of Economics* 39: 331–333.

———. 1926. "Economics at Its Best." *American Economic Review* 16: 51–58.

Konishi, Hideo, and Se-il Mun. 2010. "Carpooling and Congestion Pricing: HOV and HOT Lanes." *Regional Science and Urban Economics* 40: 173–186.

Kumekawa, Ian. 2017. *The First Serious Optimist: A. C. Pigou and the Birth of Welfare Economics*. Princeton: Princeton University Press.

Leape, Jonathan. 2006. "The London Congestion Charge." *Journal of Economic Perspectives* 20: 157–176.

Lehe, Lewis. 2019. "Downtown Congestion Pricing in Practice." *Transportation Research D*, 100: 200–223.

Lesser, Arthur. 1969. "Engineering Economy in the United States in Retrospect—An Analysis." *Engineering Economist* 14: 109–116.

Lindsey Robert. 2006. "Do Economists Reach a Conclusion on Road Pricing? The Intellectual History of an Idea." *Econ Journal Watch* 3: 292–379.

Lindsey, Robert, and Eric Verhoef. 2008. "Congestion Modelling." In D. A. Hensher and K. J. Button, eds., *Handbooks in Transport. Volume 1: Handbook of Transport Modelling*. Second edition. Amsterdam: Elsevier, pp. 353–373.

Liu, Louie N., and John F. McDonald. 1998. "Efficient Congestion Tolls in the Presence of Unpriced Congestion: A Peak and Off-Peak Simulation Model." *Journal of Urban Economics* 44: 352–366.

Marciano, Alain. 2013. "Why Market Failures Are Not a Problem: James Buchanan on Market Imperfections, Voluntary Cooperation, and Externalities." *History of Political Economy* 45: 223–254.

McDonald, John F. 2013. "Pigou, Knight, Diminishing Returns, and Optimal Pigouvian Congestion Tolls." *Journal of the History of Economic Thought* 35: 354–370.

Meyer, John R., John F. Kain, and Martin Wohl. 1965. *The Urban Transportation Problem*. Cambridge, MA: Harvard University Press.

Mills, Edwin S. 1972. *Studies in the Structure of The Urban Economy*. Baltimore: Johns Hopkins University Press.

Mishan, Ezra J. 1965. "Reflections on Recent Developments in the Concept of External Effects." *Canadian Journal of Political Science* 31: 3–34.

———. 1971. "The Postwar Literature on Externalities: An Interpretative Essay." *Journal of Economic Literature* 9: 1–28.

Newbery, David M. G. 1989. "Cost Recovery from Optimally Designed Roads." *Econometrica* 56: 165–185.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Parry, Ian W. H., and Antonio Bento. 2001. "Revenue Recycling and the Welfare Effects of Road Pricing." *Scandinavian Journal of Economics* 103: 645–671.

Parry, Ian W. H., and Kenneth A. Small. 2009. "Should Urban Transit Subsidies Be Reduced?" *American Economic Review* 99: 700–724.

Pigou, Arthur C. 1912. *Wealth and Welfare*. London: Macmillan.

———. 1920. *The Economics of Welfare*. London: Macmillan.

———. 1922. "Empty Economic Boxes: A Reply." *Economic Journal* 32: 458–465.

Pigou, Arthur C., and Dennis H. Robertson. 1924. "Those Empty Boxes." *Economic Journal* 34: 16–31.

Plowden, Stephen P. C. 1967. "Transportation Studies Examined." *Journal of Transport Economics and Policy* 1: 5–27.

Rouwendal, Jan, and Erik T. Verhoef. 2004. "Second-Best Pricing for Imperfect Substitutes in Urban Networks." *Research in Transportation Economics* 9: 27–60.

Santos, Georgina. 2004. "Urban Congestion Pricing: A Second Best Alternative." *Journal of Transport Economics and Policy* 39: 345–369.

Sargent, John R. 1958. *British Transport Policy*. Oxford: Oxford University Press.

Sessions, Gordon M. 1971. *Traffic Devices: Historical Aspects Thereof*. Washington: Institute of Traffic Engineers.

Sharp, Clifford H. 1966. "Congestion and Welfare—An Examination of the Case for a Congestion Tax." *Economics Journal* 76: 806–817.

———. 1968. "Congestion and Welfare Reconsidered." *Journal of Transport Economics and Policy* 2: 119–125.

Small, Kenneth A., Clifford Winston, and Jia Yan. 2006. "Differentiated Road Pricing, Express Lanes, and Carpools: Exploiting Heterogeneous Preferences in Policy Design." *Brookings-Wharton Papers on Urban Affairs*: 53–96.

Small, Kenneth A., and Jia Yan. 2001. "The Value of 'Value Pricing' of Roads: Second-Best Pricing and Product Differentiation." *Journal of Urban Economics* 49: 310–336.

Solow, Robert M. 1973. "Congestion Cost in the Use of Land for Streets." *Bell Journal of Economics and Management Science* 4: 602–618.

Thomson, John M. 1967. "An Evaluation of Two Proposals for Traffic Restraint in London." *Journal of the Royal Statistical Society, Series A*, 130: 327–367. [Discussion of the paper by C. B. Winsten, J. K. Welsby, G. Roth, F. C. Lloyd, J. G. Wardrop, P. W. Glassbow, A. D. J. Flowerdew, and K. W. Huddart is presented on pages 367–377.]

———. 1998. "Reflections on the Economics of Traffic Congestion." *Journal of Transport Economics and Policy* 32: 93–112.

Ubbels, Barry, and Eric T. Verhoef. 2008. "Auctioning Concessions for Private Roads." *Transportation Research A*, 42: 155–172.

UK House of Commons. 1982. *Fifth Report of the Transport Committee: Transport in London*. HC 127. London: HMSO.

UK Ministry of Transport. 1963. *Traffic in Towns*. London: HMSO.

———. 1964. *Road Pricing: The Economic and Technical Possibilities*. London: HMSO.

———. 1967. *Better Use of Town Roads*. London: HMSO.

US House of Representatives. 1939. *Toll Roads and Free Roads. On the Feasibility of a System of Transcontinental Toll Roads and a Master Plan for Free Highway Development*. H.Doc. 272. Washington: GPO.

US President's Advisory Committee on a National Highway Program. 1955. *A Ten-Year National Highway Program*. Washington, DC: US Government Printing Office.

Verhoef, Eric T., Richard H. M. Emmerink, Peter Nijkamp, and Piet Rietveld. 1996. "Information Provision, Flat and Fine Congestion Tolling and the Efficiency of Road Usage." *Regional Science and Urban Economics* 26: 505–530.

Verhoef, Eric T., Peter Nijkamp, and Piet Rietveld. 1996. "Second-Best Congestion Pricing: The Case of an Untolled Alternative." *Journal of Urban Economics* 40: 279–303.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press

Verhoef, Eric T., Jan Rouwendal, and Piet Rietveld. 1999. "Congestion Caused by Speed Differences." *Journal of Urban Economics* 45: 533–556.

Vickrey, William S. 1955. "Some Implications of Marginal Cost Pricing for Public Utilities." *American Economic Review* 45: 605–620.

———. 1959. "Evidence." In *Transportation Planning for the National Capital Region, Hearings before the Joint Committee on Washington Metropolitan Problems*. 86th Congress, Washington DC: US Printing Office, 11 November, 99, pp. 454–477. [Slightly edited version by R. Arnott and M. Kraus, in *Journal of Urban Economics* 36 (1994): 42–65, is used for citation purposes.]

———. 1965. "Pricing as a Tool in Coordination of Local Transportation." In *Transportation Economics*. Edited by Universities-National Bureau Committee for Economic Research. New York: Columbia University Press, pp. 275–296.

———. 1968. "Congestion Charges and Welfare: Some Answers to Sharp's Doubts." *Journal of Transport Economics and Policy* 2: 107–118.

———. 1969. "Congestion Theory and Transport Investment." *American Economic Review* 59: 251–260.

Viner, Jacob. 1932. "Cost Curves and Supply Curves." *Zeitschrift für Nationalökonomie* 3: 23–46.

Wachs, Martin. 1989. "When Planners Lie with Numbers." *Journal of the American Planning Association* 55: 476–479.

Walters, Alan A. 1954. "Track Costs and Motor Taxation." *Journal of Industrial Economics* 2: 135–146.

———. 1961. "The Theory and Measurement of Private and Social Cost of Highway Congestion." *Econometrica* 29: 676–697.

———. 1968. *The Economics of Road User Charges*. World Bank Staff Occasional Paper 5. Baltimore: Johns Hopkins University Press.

Wellington, Arthur M. 1887. *The Economic Theory of Location of Railways*. London: John Wiley.

Young, Allyn A. 1913. "Pigou's Wealth and Welfare." *Quarterly Journal of Economics* 27: 672–686.

https://doi.org/10.1017/S105383721900035X Published online by Cambridge University Press