Jules Dupuit and the Early Theory of Marginal Cost Pricing

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I. Introduction

The name of Jules Dupuit, the nineteenth-century French engineer, has been frequently invoked in contemporary economic literature concerned with marginal cost pricing (Hotelling, 1938, pp. 242–44; Nelson, 1964, pp. vii–viii) and cost-benefit analysis (Prest and Turvey, 1965, p. 683). Although his contributions in the area of utility theory (Stigler, 1950), consumers' surplus (Houghton, 1958), and price discrimination (Edgeworth, 1912) were, by any standard, remarkable for the time, his role as proclaimed mentor of the modern theory of marginal cost pricing and, more generally, of cost-benefit theory has been largely unexplored and often misunderstood. The result has been a general confusion among modern theorists concerning his achievement in this area.[1] Most writers have not bothered to investigate Dupuit's original works and, following Hotelling's original attribution, have simply accepted Dupuit as the first marginal cost theorist. Ragnar Frisch, Hotelling's first critic, may be placed in this camp (Frisch, 1939, p. 145). Such neglect has probably been nurtured by the relative obscurity of his writings and by the fact that, until recently, only two of his economic articles have been translated into English (Dupuit, 1844, 1849*b*).

The purpose of this article is to assess the nature of Dupuit's contribution to the welfare theory of marginal cost pricing. It will be concluded that although Dupuit has rightful claims as the first cost-benefit economist,

* This paper has grown out of a larger study of the economic theory of Dupuit. I would like to acknowledge my appreciation for a generous grant from the L.S.U. Foundation which made the translation of Dupuit's works possible. I would like to thank Professor J. P. Payne, Jr., R. F. Hebert, and L. H. Falk, as well as the editors of this *Journal*, for helpful comments on earlier drafts of this paper. Finally, a very special thanks to Professor W. J. Stober, not only for useful suggestions, but for having furnished the proof of Dupuit's theorem. I am solely responsible for final content, however.

[1] Hotelling, for example, who originally (1938, p. 242) ascribed the origins of the argument to Dupuit, later modified his position.

he was not a progenitor of the principle. Discovery of a short-run marginal cost principle in Dupuit's writings, in brief, would require a contrived and incorrect interpretation of his remarks on costs and on the efficacy of subsidies. The issues are especially timely in view of the renascence of interest in both the theory and application of cost-benefit analysis.

II. The Principle of *Utilite Perdue*

Dupuit was the first economist explicitly to state the principle of marginal utility[2] and to associate the area under the demand curve with a welfare measure *utilite absolue*. Dupuit, as did Cournot earlier, believed quantity demanded to be a decreasing function of price and, as early as 1844, he developed the concept which Marshall later called "consumers' surplus." Dupuit called this surplus "relative utility" or "utility remaining to consumers." The demand curve was used by Dupuit as a utility measure to analyze the welfare effects of tolls, tariffs, costs, or prices; and it is here that the welfare economics of Marshall finds its origins.[3]

Dupuit set out to assess the effects of taxes and tolls, though not specifically relating them to costs, on what he called *utilite perdue*, which is the difference between utility produced (producers' costs and consumers' surplus) at any quantity and the total area under the demand curve.[4] Increases in prices, taxes, and tolls would reduce output and the "utility available to society" (consumers' and producers' surplus), but Dupuit was even more precise. He pointed out that "where a tax is small relative to the cost of manufacture . . . it is legitimate to suppose a uniform rate of decrease [in quantity consumed]," and, further, that "it may thus be said that the loss of utility is proportional to the square of the tax" (Dupuit, 1844, p. 104).[5] (See Fig. 1).

[2] W. F. Lloyd (1833)—discovered by E. R. A. Seligman (1903, pp. 356–63)—is often attributed with the earliest exposition of the theory of marginal utility, but no less an authority than Alfred Marshall credited Dupuit with first "formally describing . . . small increments of price as measuring corresponding small increments of pleasure," relegating to Lloyd the role of having "anticipated" utility analysis (Marshall, 1920, p. 101). Lloyd's statement, according to Stigler, was adventitious (1950, pp. 312–13).

[3] Marshall's measures, as contrasted to those of Dupuit, were protected on all sides. Marshall assumed constancy of the marginal utility of money, to the consternation of contemporary theorists, so that the area under the demand curve would represent an unambiguous welfare measure.

[4] This *utilite perdue* later became associated with reductions in "net benefit," which was the sum of producers' and consumers' surplus.

[5] Assuming the marginal utility of money constant, the area under the demand curve in Figure 1 represents a money measure of utility. Dupuit's theorem states that the loss of utility, ΔU_m, is proportional to the square of the tax or price, P_m.

In terms of Figure 1, *utilite perdue* may be written:

$$\Delta U_m = \tfrac{1}{2} A Q_m P_m. \tag{1}$$

Now, by construction, $P_m = mP_1$ and $AQ_m = mAQ_1$ for a negatively sloped

The rationale for marginal cost pricing as a welfare tool clearly finds its roots in "Dupuit's theorem." Prices above marginal costs result in *utilite perdue*, and, as Hotelling (1938, p. 245) was later to point out, per-unit or excise taxes, by raising the marginal cost curve, have similar effects on "net benefit." Dupuit himself noted the desirability of spreading taxes over large numbers of commodities, but he did not link tolls, taxes, or prices with marginal costs or with increases in marginal costs in the *utilite perdue* argument. Here we simply find the general proposition that tolls, taxes, and so forth, effected changes in welfare.

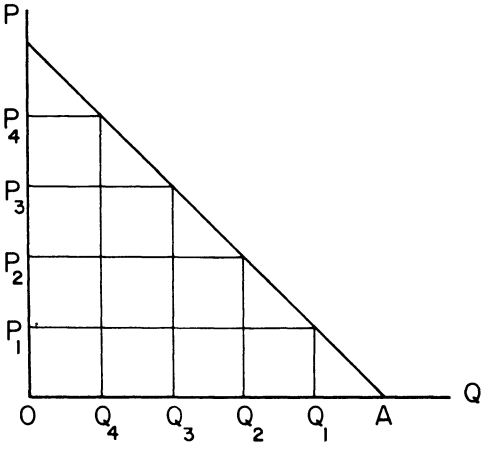

FIG. 1

III. The Case of Bridges

It is often thought that in his theoretical cost-benefit studies of bridges Dupuit invoked the marginal cost dictum as a governmental pricing guideline. Such conclusions are not warranted, however, when one considers Dupuit's writings. In this connection, it is also necessary to note the ambiguity involved in referring to Dupuit's "bridge," since there are no less than six bridge examples in his writings, some of them not even remotely suggestive of a marginal cost argument (Dupuit, 1849*b*, p. 15). Several of the theoretical bridges, however, do brush the argument. An adaptation of a representative bridge (bridge "C") from Dupuit's article "On Tolls and Transport Charges" is presented as Table 1 (1849*b*, p. 9).

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linear demand function. Making use of these relations, and multiplying numerator and denominator of (1) by P_1, the result becomes $\Delta U_m = \alpha P_m^2$, where $\alpha = AQ_1/2P_1$ is the constant factor of proportionality. This result holds for any linear demand function and approximates the loss of utility for small increments in price for a non-linear demand function.

The demand curve (or "curve of consumption") for bridge passage is given in columns (1) and (2). Column (3) shows the marginal reduction in bridge crossings due to unit toll rate increases. The total utility lost at any toll rate (column 4) is calculated for any given toll as the sum of utility lost at that rate [(1) × (3)] and the total utility lost at the previous rate. Dupuit termed column (5) "the yield of the toll," and it simply represents total revenue or receipts. Column (6), representing consumers' surplus, was not included by Dupuit, but it is calculated here for convenience.

TABLE 1

A THEORETICAL TOLL BRIDGE

Toll Rate (1)	Number of Crossings (2)	Reduction of Crossings Due to Rate Increase (3)	Utility Lost by Toll (4)	Yield of Toll (5)	Consumers' Surplus (6)	Utility Corresponding to Toll (7) [(5) + (6)]
0 . . .	100	0	0	0	445	445
1 . . .	80	20	20	80	345	425
2 . . .	63	17	54	126	265	391
3 . . .	50	13	93	150	202	352
4 . . .	41	9	129	164	152	316
5 . . .	33	8	169	165*	111	276
6 . . .	26	7	211	156	78	234
7 . . .	20	6	253	140	52	192
8 . . .	14	6	301	112	32	144
9 . . .	9	5	346	81	18	99
10 . . .	6	3	376	60	9	69
11 . . .	3	3	409	33	3	36
12 . . .	0	3	445	0	0	0

* Maximum yield.

Column (7) [(5) + (6)] is net benefit (actually gross benefit without costs of production), that is, the sum of producers' and consumers' surplus. It should be observed that Dupuit did not, at the outset, include a provision for costs. The information contained in Table 1 is solely in the province of demand.

The utility produced, evidently, is divided between the monopolist and his consumers. In order to determine consumers' surplus produced at any rate, total receipts must be subtracted from the "total utility produced" corresponding to that rate, and it is apparent that consumers' surplus will vary inversely with the toll. Producers' surplus or total receipts (in the absence of costs) increase up to rate 5 and diminish thereafter. Dupuit, referring to this example, noted that "the distribution of utility is very different" with different rates (Dupuit, 1849*b*, p. 10); yet

it was the effect of rates on the total utility produced ("utility corresponding to the toll") which was his consistent maximand.

Dupuit made it clear that the total utility of the bridge would depend on where ownership resided. "If the road or bridge or canal is private property," he pointed out that "the owner company has only one aim, and that is to get the largest possible income from the toll." The profit maximizing rate would be 5 in Table 1, producing a total utility of 276 and a *utilite perdue* of 169. The total utility produced of 276 would be partitioned into 111 of consumers' surplus and 165 of producers' surplus.

Departing from principles of profit maximization Dupuit analyzed a pricing policy under social ownership of the bridge:

> 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. Suppose, for example, that bridge C cost 150,000 francs to build and that the relative figures shown in the table for crossings are one-hundredth of the real traffic figures; the government will rest content with toll rate 1, because the proceeds of 8000 are enough to cover interest at 4 per cent and leave over 2000 francs for upkeep and amortization. The company would charge 5, the government only 1. . . . Surely, the extra 8500 francs to be paid by the consumers [under private monopoly] are reason enough to declare for public operation, yet this is a secondary consideration in the light of a comparison of the utility of the bridge in the two cases [Dupuit, 1849*b*, p. 11].

Dupuit's opinion on distribution is crystallized in his last statement. He would not be so opposed to tariffs if they had no other effect than to change the distribution of utility. But tariffs did positive harm if they diminished the total utility which commodities were capable of producing above costs. This point has been jaded all too often by a general preoccupation with Dupuit's statement of consumers' surplus. Producers' surplus in the nature of profits could also be considered part of the maximand were it not for the fact that profit maximization reduced the total utility afforded (the sum of producers' and consumers' surplus) by the bridge. But, apart from this issue, it is not at all clear where *marginal* cost pricing emerges from the statement.

A clear analysis of costs was one of Dupuit's most serious weaknesses, as Stigler has pointed out (1950, p. 314). Interest and amortization, as in the above case, cannot be easily construed as marginal with respect to the number of travelers who cross the bridge. Maintenance costs have a better claim, and in an example of the Parisian Pont des Arts bridge, which followed closely on the heels of the theoretical bridges, he indicated

that, when a *private* company could double the number of crossings by cutting its rate in half, and at the same time "still earn enough extra to cover the slight increase in maintenance expenses and the costs of collection" (Dupuit, 1849, p. 12), it should do so. This would suggest that maintenance expense is indeed marginal with respect to quantity, but the statement, taken by itself, is not convincing, particularly in view of the prior insistence that the government recover a "fixed sum" from the bridge users. Dupuit seems to have intended this fixed sum to be inclusive of fixed costs and to be *independent* of quantity, a situation not particularly evocative of an incremental cost, either constant or changing with quantity.

Other references in his writings shed some light on this important issue. Dupuit made several interesting statements concerning costs of production in the 1844 article. Juxtaposing the utility argument over the pricing principles of yet another bridge, he concluded that, with a high enough tariff, it was possible to render the bridge useless. He then queried whether this means "that there should only be very low tolls or even that there should be none at all?" (Dupuit, 1844, p. 97). The rhetorical question is answered in the negative, and the reader is directed to study tariffs "according to rational principles, in order to produce the greatest possible utility and at the same time a revenue sufficient to cover the cost of upkeep and interest on capital" (Dupuit, 1844, p. 98). If Dupuit were using a short-run marginal cost argument, he would have proposed a negligible toll or none at all. At such points, Dupuit appears to have been intuitively groping toward a long-period concept of marginal costs (implicitly assuming constant returns to scale), but the cloudy notion of the nature of costs, either short or long run, casts strong doubts on this possibility. The interest charge would be marginal if the *construction* of the bridge were the issue, since there are obviously no fixed costs at such a time. Unfortunately, Dupuit's studies are couched in terms of *alternatives* between governmental and private operation after a facility has been built and is in operation.

IV. The Issue of Subsidies

The key to understanding Dupuit's concrete recommendation that fixed costs be recouped under government operation lies in his bias against subsidies paid out of taxation. In an earlier discussion, Dupuit made reference to a statement made by Navier, an engineer, in an article appearing in the *Annales des Ponts et Chaussées* of 1832. Navier was also concerned with measuring the "utility" of public works, but he was under the spell of Say's dictum that costs of production equaled price and that this was the measure of utility. This point was, of course, criticized by Dupuit, but Navier had also indicated that in order for government "operation not to be a burden on the taxpayer, the annual economy

effected by the transport must be at least equal to the interest on the capital expended together with the costs of maintenance" (Dupuit, 1844, p. 92). Dupuit consistently took Navier's proposal as his own, although one of his statements spuriously implies the advocacy of subsidy. Considering the consequences of a tariff reduction for the state, he pointed out that

> the money which escapes the fisc stays in the pockets of the old users, together with all the profit they have made through the rate reduction, and new users have profited in their turn; the government can therefore recover its loss by levying in other forms the money it lost by lowering the toll [Dupuit, 1849*b*, p. 12].

Here Dupuit was not suggesting that the government must recover revenue for operational losses in public projects, that is, due to pricing below full costs; rather, it should recover in other forms the monopoly revenue it would lose by "lowering the toll." It is the *profit-maximizing* revenue which has "escaped the fisc." Dupuit, then, could not have been thinking in terms of marginal cost pricing under conditions of decreasing cost, and it is this application which has been the stock and trade of modern theorists in the area. He could have advocated marginal cost pricing only in constant and increasing cost industries, for, in the latter, full costs are always covered. There is no clear indication of the nature of production costs in Dupuit's writings, however, and the restriction is a limitation which would not ordinarily be placed on the tool.

The analytical details contained in Dupuit's development of several other pricing tools do not lend support to a marginal cost argument in the case of the bridge. In one of the most distinctive contributions to the early theory and application of price discrimination (Dupuit, 1865), Dupuit advocated just that amount of discrimination on the part of municipal governments which would be necessary to cover the full costs of water distribution. Although Dupuit noted the high fixed costs of supplying water to communities, he insisted that water should not be made free but that differential subscription should be so designed as to cover full costs exactly (Dupuit, 1865, pp. 13–14). The goal in this case was to make use of all the water available while seeking to indemnify the exploiter's *initial* and *recurring* expenses.

Monopoly in transportation was also one of Dupuit's major concerns, but here, as in the case of water distribution, we find a marked distaste for subsidies from tax revenue. Although governmental operation would be desirable if full costs could be covered and public utility enhanced, a subsidy would be proof positive that the enterprise was ill-founded. In a contribution to the *Dictionnaire de l'Économie Politique*, he points out that "the subsidy which it [the State] gives corresponds always to an

equivalent tax which it collects. Not only is there no wealth produced, but there is wealth lost by virtue of the subsidy" (Dupuit, 1853, pp. 15–16). Dupuit saw a diminution of wealth as stemming from the real cost of the transfer. Capital investment will be "directed naturally to the most lucrative opportunities of the moment," that is, toward those most in demand by the public. "The subsidy device," continued Dupuit, "detours them [capitals] from these practical usages and relates them to others which are far less so" (Dupuit, 1853, p. 16). Thus, in the cases of water distribution and transport monopoly, Dupuit was emphatically opposed to the subsidization of publicly owned or operated enterprises. Although Dupuit there entertained a discriminatory pricing policy, there is no evidence to indicate that he was of a different mind in the matter of toll bridges.

Objections of a non-economic character also account for Dupuit's aversion to subsidization. Dupuit, for example, assailed the granting of privilege by the state in several contributions to the *Journal des Économistes*. Postmasters, because of their establishment, demanded an "indemnity" of 25 centimes on railroad travel where railroad routes were parallel. Dupuit found that the practice led to misdirection and to poor establishment of railroad traffic, adding that the state should "let those die who cannot live with their receipts," (Dupuit, 1851, p. 151). Here and in other statements (Dupuit, 1849*a*, p. 219), he was emphatically opposed to the caprice of political influence in the granting of subsidies. His opposition was based on the belief that the political selection of projects to be subsidized would not be grounded in economic criteria.

It is noteworthy that Harold Hotelling, among those who have attributed the marginal cost principle to Dupuit, later qualified his position in a 1949 letter to Burnham P. Beckwith. Hotelling pointed out that "Dupuit mentions . . . the idea of a zero toll for which I argued in my 1938 paper" but that "he fails to endorse it explicitly" (Beckwith, 1955, p. 83).[6] Dupuit's views on subsidies, quite apart from the feckless treatment of costs in his writings, lends support to the qualification.

V. Conclusions

This paper has shown that a short-run marginal cost theory cannot be attributed to Dupuit, at least as that argument is most commonly applied. Had Dupuit been equipped with Marshallian period analysis or had he specified or indicated that his bridge studies involved a long-run market period, the fixed and maintenance expenses would have indeed been marginal. A long-run approach, moreover, would have possibly been more in keeping with contemporary practice in cost-benefit studies. But

[6] Houghton (1958, p. 50, n. 5) questions Hotelling's earlier attribution, unaware of the qualification.

the practitioner may yet hold the achievement of Dupuit in high regard. His early and original insights into welfare theory have provided the necessary backdrop against which an important and fruitful area of modern economics is being enacted. The clear enunciation and application of the utility principle and the demonstration that society's welfare could be improved by public action in a private economy when conditions of competition are not ubiquitously effective leave Dupuit unchallenged as the most important early precursor of modern doctrine and practice in the area.

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