Transport Policy xxx (2017) 1–6

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Consumer surplus and pricing of transport infrastructures: The legacy of Jules Dupuit

Alain Bonnafous *, Yves Crozet

University of Lyon, LAET, France

1. Introduction

From Jules Dupuit's article (1844) to the works of Maurice Allais, the advances made in public economics have often been inspired by poignant issues relating to the transport sector. However, their results apply to every facet of public economics, especially any area bringing together public finance and commercial revenues. Indeed, if one were to raise the question of how a university should be financed by sharing the burden between the taxpayer and its users, one finds oneself facing the same problem as that of the optimal combination between the level of a toll and the subsidy required to finance a highway or railway project. Regarding both transport economics and the more general concept of surplus, the Nobel prizewinner Maurice Allais frequently emphasized the contribution made by Jules Dupuit (Baumstark and Bonnafous, 2010). When mentioning the issue of tariff differentiation, he wrote, for example, (Allais, 1989): "*Jules Dupuit, a precursor little known for too long, demonstrated extraordinary perspicacity in his two dissertations of 1844 and 1849 on transport infrastructures, and opened a king's highway for economic thought*".

The list of Maurice Allais's citations in praise of the master is long. Perhaps this was in reaction to the lack of importance given to Jules Dupuit in French economic literature despite the fact that few around the world contest his role as the father of economic calculation. Fittingly, since 1992 the *WCTR* has awarded the Jules Dupuit prize instigated by Marc Gaudry and Antti Talvitie. The purpose of this paper is to illustrate the importance and modernity of Jules Dupuit's discoveries, especially in the works of French engineer-economists of whom Maurice Allais was the brilliant epitome in the 20th century.

Maurice Allais, Nobel Prize 1987 (1981) is particularly clear regarding the epistemological dimension of Dupuit's contribution. He underlines: "*the efforts that the meditation of Dupuit's work, thirty years ago, could have saved me, in particular by freeing me from the clutches of the marginalist school whose dogmatism has substantially slowed down the development of economic thinking*".

Jean Tirole (2014), in his acceptance speech for the Nobel Prize mentioned: "*Industrial organization has a long tradition: first theoretical, with the work of French "engineer-economists" Antoine Augustin Cournot (1838) and Jules Dupuit (1844)*".

In the following parts of this paper, we will show how Jules Dupuit addressed different kinds of utilities, anticipating the concepts of consumer surplus but also deadweight loss and finally price differentiation. We will show how these concepts can be introduced in the evaluation of transport infrastructures and their optimal pricing.

2. Absolute utility, net utility and lost utility

The entire work of Jules Dupuit is a huge response to the questions with which he was confronted in his capacity in administration and in the debate in which he was opposed to some of his colleagues of the "Ponts et Chaussées". It entails formulating tools capable of assessing the interest of public works, in particular when such interest is not covered by revenues. However, his questioning went well beyond: "*Transport routes raise a multitude of economic questions on which we are far from reaching agreement: questions of fact, questions of principles. What routes are the most advantageous? How can their utility be monitored and measured? Who must pay the capital costs? Who must build them? Who must operate them?*" (Dupuit, 1873).

In order to give an answer to these questions, Dupuit proposed to draw a marginal utility curve identified to a demand curve (named by Dupuit *courbe de consommation)*. In some graphs summarized in the Fig. 1 (see below), he was therefore able to present his key concepts of *absolute utility*, *net utility* and *utility loss*.

When the price (P) is null, the absolute utility is at its maximum as the quantity of goods consumed (N). Dupuit was here anticipating the fact that some public goods have to be offered freely. But a price equal to zero does not represent a cost equal to zero. When we multiply the average production cost (p') by the related demanded quantities (n') we can obtain the production cost but also the net utility and the lost utility.

At a time when economists did not yet use equations, no one is better

* Corresponding author.
E-mail address: alain.bonnafous@let.ish-lyon.cnrs.fr (A. Bonnafous).

https://doi.org/10.1016/j.tranpol.2017.12.008
Received 7 August 2017; Received in revised form 24 November 2017; Accepted 1 December 2017
Available online xxxx

Please cite this article in press as: Bonnafous, A., Crozet, Y., Consumer surplus and pricing of transport infrastructures: The legacy of Jules Dupuit, Transport Policy (2017), https://doi.org/10.1016/j.tranpol.2017.12.008

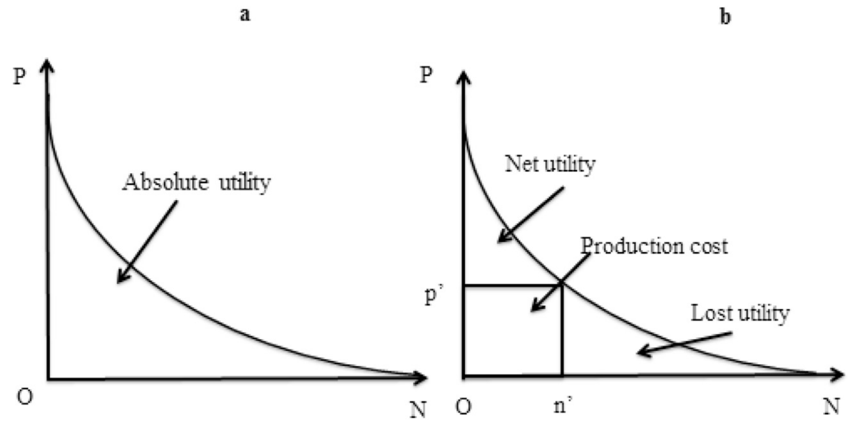

Fig. 1. From utility curve to net utility and utility loss.

qualified to summarize these results than Dupuit (1844) himself: "*The utility of a transport route is at its maximum when the toll or price is null. When the toll is non-null, the utility is shared in three parts: 1) the utility lost by those who do not consume it due to the price; 2) the utility received by the person who receives the price; 3) the utility remaining for consumers.*"

As indicated by Allais (1989), Dupuit was returning to the classical definition of the object of economics: the use of limited resources to satisfy the unlimited needs of men. This perception is subject to consensus in public economics and obviously requires the measurement of both the constraint of scarcity and the degree of satisfaction. Almost from the outset, the latter was identified as having collective utility, but the prevailing academic reserve of the 19th century asserted that it could not be measured. Jules Dupuit's notion of net utility resolves this problem. It was clear to Maurice Allais that this engineer from the elite "Ponts et Chaussées" was the founder of the notion and he devoted long passages to it in his *General Theory of Surplus*. According to Maurice Allais, the three essential contributions of Dupuit are the following:

- the concept "net utility", i.e. consumer surplus in the modern economics;
- the concept of "lost utility", i.e. deadweight loss;
- fundamental intuitions relating to price differentiation, i.e. Ramsey-Boiteux pricing.

It is therefore clear that we can turn Dupuit's reasoning and recommendations into a welfare analysis very powerful to understand what is at stake in the domain of transport infrastructures.

3. From consumer surplus to public utility

The well-known articles of Dupuit (1844, 1849), were, in the middle of the nineteenth century at the heart of a lively theoretical debate on the measure of utility. Dupuit was a strong opponent of the dominant conception of measuring utility inspired by J. B. Say based on trading prices observed on the market, and thus on production costs (Bordas, 1847). He destroyed this conception with a single sentence: will a road that costs "*half as much due to the skill of an engineer also have half as much utility*?"

As we have seen, he proposed to take into account the preference of individuals by assessing the monetary sacrifices to which they are ready to consent to satisfy their desires. It is then possible to bestow a precise expression of utility as do modern methods based on revealed preferences and willingness to pay.

The great advantage of the concept of consumer surplus is to transform private gains into a public utility and finally into a Cost-Benefit-Analysis of the welfare gains or losses. For example, if we consider a bridge, it can be assumed that the passage over it can be subjected to a toll that will be varied progressively. At each level of price, certain users will inevitably give up using it, thereby revealing its utility to them when their willingness to pay changes to refusal to pay.

By proposing such a protocol, Dupuit shed light on a very simple phenomenon. Any tax collected for the use of a public good, e.g., a bridge, results in excluding some of its users. The result is what was called by Dupuit "lost utility" because some potential users cannot cross the bridge. In modern economics, this loss of consumer surplus is designated as the "deadweight loss" that is to say this part of the surplus that is neither obtained by the potential buyers nor captured by the producer. As a consequence, since the public value of a good depends on the sum of utilities gained by the users, any exclusion of a user leads to reducing the value of the public good concerned. When there is no toll, under condition of other scenarios to which we shall return in what follows, the public utility of the bridge for the users is maximal and the deadweight loss is null. The higher this tax becomes, the higher the number of users excluded, since the utility conserved is shared between the toll revenues and the utility that remains for those willing to pay for it. The level of use falls until cancelling itself completely, as does the public utility of the infrastructure.

Dupuit did nothing less than establish what would become the fundamental Cost-Benefit-Analysis equation. Indeed, in the meaning of, and subject to, the usual assumptions of economic calculation, the variation of public utility between a reference situation denoted 0 and a situation to be evaluated denoted 1 (which can, for example, be differentiated by the absence or presence of a structure, or by two different toll prices) is written as follows:

$$\Delta U = \Delta C + \Delta R - \int_0^1 T \cdot dp \quad (1)$$

Where: ΔC is the variation of the cost of the transport system between situation 0 and situation 1.

ΔR the variation of the revenue.

and $-\int_0^1 T \cdot dp$ the variation of the consumer surplus, *T* being the quantity of transport service consumed at price *p*. Thus we find exactly what Dupuit had recommended. Besides the mathematical formalization, the only theoretical difference evident in the contemporary approach is that this result is obtained on the basis of welfare theory, the first complete demonstration linking the surplus of the user to the welfare gain being established only belatedly (Lesourne, 1972, 1975). In the field of transport the cost C is no only the price paid by the users, as in Dupuit's analysis, but the generalized cost that is to say the monetary cost plus the cost of time. The latter depends on the value of time of travelers usually introduced today in Cost-Benefit Analysis.

If we were to limit our reading of Dupuit to this result, it could be understood as a demonstration of the public utility of a zero toll. Obviously, the problem is not quite so simple. In the case of a zero toll the absolute utility of the bridge is the sum of the absolute utilities of the users. The relative utility is obtained by *"deducting the maintenance costs*