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A comment on W. Wei and M. Hansen's benefit estimation in "An aggregate demand model for air passenger traffic in the hub-and-spoke network"

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ABSTRACT

This comment analyzes the demand model and method used by W. Wei and M. Hansen for computing the benefits of an airport capacity extension. The log-linear specification and coefficients of the demand function imply that the airport extension's positive effect on demand decreases with the volume of traffic and associated congestion. If this unlikely result is accepted, the surplus method used by Wei and Hansen underestimates the users' investment benefit. The note argues that the marginal willingness to pay for a capacity extension should rather increase with congestion. If this is the case, the method used by Wei and Hansen could actually overestimates the benefit.

A better specification would rather allow for a function concave to the origin in order to account for capacity constraints, and also set a maximum finite price. Above all, a fair evaluation of the users' benefit should be based on a function which explicitly includes a variable, or function of variables, that permits an estimation of the users' cost of congestion.

1. The model specification

In their recent paper Wei and Hansen (2006) rightly insist on the need of appropriate analytical demand models for a good understanding of transport network systems and interactions between airport and airline passengers. In particular, they point out that analytical models are essential for reliable evaluation of the benefits of airports capacity expansion projects.

On the basis of data published by the US Department of Transportation (ONBOARD, O&D PLUS, and HUB data), they estimate a comprehensive log-linear demand model where the number of passengers (PAX_{SHA}), from spoke S travelling through hub H to all other spokes and flying with airline A, is a function of service frequencies, average aircraft size, number of spokes, distance, number of trips from S, total income in the metropolitan area of H, travelling fare charged by airlines ($FARE_{SHA}$), and arrival capacity at H ($CAPACITY_H$) which determines the hub's service convenience. Considering that demand is estimated as a function of income, we can accept it as an expression of a compensated demand function (Oum et al., 1992). The adjusted R-square is 0.79 and all the coefficients are significant at the 0.01 level. The signs are as expected and provide useful information.[1] In particular, the coefficient of fare, i.e. its elasticity, is equal to −0.899, and the coefficient of capacity is 0.35.

To illustrate the usefulness of this demand function, Wei and Hansen apply it to compute the direct benefits that would accrue from an increase of arrival capacity at the DFW hub of American Airlines. Since the ensuing problem can be reduced to

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[1] The precise definition of all variables and the value of other coefficients can be found in the paper.

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the relationship between PAX, FARE and CAP (for short), all other variables being kept constant, the relevant components of the estimated model, after transformation, can be presented as

$$\mathrm{PAX} = f(\mathrm{FARE}, \mathrm{CAP}) = (358,491.581) \cdot (\mathrm{FARE})^{-0.899} \cdot (\mathrm{CAP})^{0.35}. \tag{1}$$

Inversing this relation to set FARE as the dependent variable, we can then take the following derivatives:

$$\frac{\partial \mathrm{FARE}}{\partial \mathrm{CAP}} > 0 \quad \text{and} \quad \frac{\partial^2 \mathrm{FARE}}{\partial \mathrm{CAP} \cdot \partial \mathrm{PAX}} < 0. \tag{2}$$

The first derivative indicates that the service marginal value increases with the extended capacity, as it is expected. The second derivative shows that this value increment diminishes with the volume of traffic. This result follows from the function specification and the signs of the FARE and CAP coefficients. The first derivatives have the correct signs, but the negative sign for the above second-order cross derivative cannot be accepted. It means that the marginal value of capacity extension, the marginal willingness to pay for capacity, decreases as the number of passengers increases, or, equivalently, that a capacity expansion has a smaller impact on demand when the volume of traffic and congestion are higher. Inversely, common sense suggests that the impact of a capacity extension on demand should tend to zero when traffic and congestion decrease.

Furthermore, the function specification that allows an infinite fare level can be called into question in the context of a market where several travel services are competing for the same clientele. Indeed, it is unlikely that any demand for a particular travel service would subsist above a certain fare. It is another problematic feature, because it implies that the marginal value of capacity extension goes to infinity along the price increase.

Finally, we should note that the estimated function is convex to the origin, as it is illustrated by Fig. 1 reproduced from their paper. To the extent that the problem is to evaluate the extension of a congested airport terminal, one would think that the demand function for a given capacity level should rather tend to exhibit a certain degree of concavity beyond a traffic level where congestion begins to affect the demand. Note that, given the above coefficients' signs, the double-log specification again necessarily leads to that anomaly.

All these features may sometimes be of little consequence when the analysis aims at measuring the impact of small variations of fare on the number of passengers and the associated surplus, at least when the fare variation remains within the range of values of the estimation sample. Then, the estimated function may be useful enough if it is deemed reliable over the sample. It may be a very different matter if the problem is to estimate the benefit of a capacity extension, which induces a shift of the demand function as illustrated in Fig. 1.

2. The benefit computation

Wei and Hansen compute the direct benefits accruing to the passengers from an increase of arrival capacity at the DFW hub of American Airlines on the basis of the variables' relevant average values that are given in their paper (Table 2).

They compute the accruing surplus in three steps. First, they compute the number of passengers which would use the hub for a given fare of 235, if the arrival capacity is expanded from 135 to 140. Second, they compute the reduced fare (231) which would induce the same increase of passengers as the capacity expansion. Finally, they obtain a surplus by the computation of the area below the initial demand function, at capacity 135, between the two fare levels. In their Fig. 1, this measure corresponds to the area PABP′.

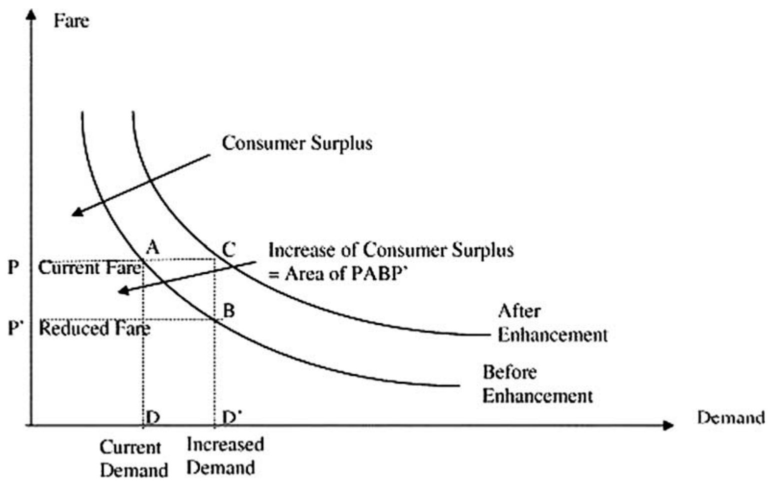

Fig. 1. Method of calculating change of consumer surplus.