Cost and time damping: Evidence from aggregate rail direct demand models

Abstract

Background

There is a significant body of evidence from both disaggregate choice modelling literature and practical transport modelling that the responsiveness to cost and possibly to time diminishes with journey duration. This has, in Britain at least, been termed ‘Cost Damping’, and has entered demand analysis and appraisal guidance issued by the Department for Transport (2013).

This study aims to investigate the evidence for cost and time damping by developing rail direct demand models using rail ticket sales data. The rail ticket sales data in Britain has, for many years, formed the basis of analysis of a wide range of impacts of rail demand. It records the number of tickets sold between station pairs, and it is generally felt to provide a reasonably accurate reflection of travel demand.

The existing results of rail direct demand models estimated by rail ticket sales data indicate that there is only slight variation in the fare elasticity with distance. This is already evidence to support the hypothesis of cost damping, because the assumption of constant cost sensitivity implies that fare elasticity should increase strongly with distance, because of the increasing impact of higher fares at longer distances. As far as the authors are aware, there is no corresponding body of evidence in rail ticket sales data relating to the sensitivity to time.

Data

The data consist of all ticket sales in Britain. The data selected relates to trips outside London and not wholly within the South East, and station pairs are limited to those separated by a distance of 20 to 300 miles. The London trips and Intra-South East trips are excluded since a wide range of tickets has historically been on offer for those journeys, while other flows tend to be on a smaller range of tickets with less competition between them. Hence the use of average revenue per trip as a measure of fare involved fewer approximations. We also excluded station pairs with distances under 20 miles where rail is often not an attractive transport mode and those over 300 miles where fewer trips are observed and air competition is a relevant issue.

The remaining data covers 3,201 station-to-station movements for the years 1990 to 2005, excluding 1994 which was seriously affected by widespread industrial action, and all sales other than season tickets. Sales were aggregated over each of the 15 complete years. Pooling data across routes and over time yields 48,015 observations for modelling purposes.

Models

The basic approach is to estimate fixed effect pooled cross-section time-series models but instead of the standard approach of estimating constant elasticities with respect to fare and time the models allow the fare and time elasticities to vary with journey length in ways suggested by disaggregate and conventional transport planning analyses. This is done by specifying continuous functions which allow increasing, diminishing or no effect with journey length, measured by distance, cost or journey time, on the elasticities. These effects are then tested empirically.

A variety of fixed effects models is estimated, but the general form is shown in the following equation:

$$\log T_{ij}^{t} = \text{constant} + \mathrm{f}\left(fare_{ij}^{t}, GJT_{ij}^{t}, dist_{ij}, Inc_{i}^{t}, \boldsymbol{\lambda}, \boldsymbol{\alpha}, \kappa\right) + \beta_1 \log Inc_{i}^{t}$$
$$+\beta_2 Hat2000^{t} + \beta_3 Hat2001^{t} + \beta_4 Hat2002^{t} + \text{fixed effects} + \text{error}$$

where, for station *i* to *j* at year *t*, *T*, *fare*, and *GJT* denote rail ticket sales, fare (revenue per trip), and generalised travel time which is a measure in time units of the timetable-related service quality and comprises the origin to destination station journey time, service headway and any need to change trains. The GJT measure is standard in the UK rail industry and was supplied in its combined form. $dist_{ij}$ represents the distance from *i* to *j*. Inc_{i}^{t} denotes income per head at year *t* in region where origin station *i* is located. Further, three dummy variables are introduced to explain effects of the Hatfield accident where $Hat2000^{t} = 1$ for $t = 2000$; 0 otherwise and $Hat2001^{t}$ and $Hat2002^{t}$ are defined similarly. ‘Fixed effects’ mean 3,200 station-to-station dummies whereby a dummy variable for each flow to indicate the basic level of demand, linked to factors such as the population around the origin and destination stations, with other variables explaining variations around this level of demand. The estimated parameters κ, **α**, **λ**, and β represent income elasticity to fare, parameters related to the damping, parameters expressing relative importance between fare and GJT, and the other parameters, respectively. κ, **α** and **λ** appear within the function f which is defined in different ways to investigate different damping functions.

Damping functions

The authors investigated functions f of fare, GJT, distance, and income, which express the cost and time damping mechanisms analysed. The damping is expressed in terms of

- multiplication by power of distance (e.g. $fare_{ij}^{t}\left(\frac{Inc_{i}^{t}}{\overline{Inc_{i}^{t}}}\right)^{-\kappa} {dist_{ij}}^{\alpha_1}$, $GJT_{ij}^{t}{dist_{ij}}^{\alpha_2}$), or

- a power function (e.g. $\left(fare_{ij}^{t}\left(\frac{Inc_i^t}{\overline{Inc_i^t}}\right)^{-\kappa}\right)^{\alpha_1}$, $\left(GJT_{ij}^{t}\right)^{\alpha_2}$), or
- a log function (e.g. $\log\left(fare_{ij}^{t}\left(\frac{Inc_i^t}{\overline{Inc_i^t}}\right)^{-\kappa}\right)$, $\log\left(GJT_{ij}^{t}\right)$).

Note that the distance term does not appear in the second and third expressions. Tests were made to determine whether damping should be considered separately for fare and GJT terms or should be considered jointly after converting these two terms into an equivalent unit. A combination of the above forms was also investigated by using a Box-Cox of transformation.

Results to date indicate that separate damping for fare and GJT is needed, confirming an expected increase in the value of time with trip length. Moreover the log function appears to give the best results, indicating a very strong damping effect. Further results will be included in the paper, as well as investigations of the impact of the income elasticity κ.

Dft (2013) TAG Unit M3 Variable Demand Modelling, Chapter 3, section 3.3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275597/webtag-tag-unit-m2-variable-demand-modelling.pdf#nameddest=chptr03