

Studies in Local Public Transport Demand

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Abstract:

This thesis consists of four papers where the overall purpose is to contribute to the understanding of how local public transport demand is affected by different factors. An underlying theme running through the thesis is the two-way relationship between public transport demand and the service level, caused by the fact that capacity and quality are joint products.

In Paper I the relationship between public transport demand and the service level (in terms of vehicle-kilometres) is investigated using panel data from Swedish counties. A Granger causality test is performed in order to test if the level of service cause public transport demand or if demand cause service level, or if they cause each other. It is found that demand and service cause each other, which is to say that there is a two-way relationship between them.

In Paper II elasticity estimates for local public transport demand from previous research are summarised and the variation in results is analysed using meta-regression. The variation is explained by model specification, type of data used and origin of data.

In Paper III a demand function for local public transport is estimated using panel data from Swedish counties. Instrument variable estimation is used in order to avoid the problem of a two-way relationship between demand and service level (vehicle-kilometres). Demand elasticities with respect to public transport fare, price of petrol, vehicle-kilometres and car ownership are found to be -0.4, 0.34, 0.55, and -1.37. After also taking the effects of income on car ownership into account, it is found that the total effect of income on public transport demand is close to zero.

In Paper IV it is found that the strong increase in public transport demand in the town of Linköping between 1946 and 1983, at least in part, can be explained by the rapid increase in female labour force participation and the expansion of the city's outer areas. After that, female labour force participation decreased slightly and the town expansion has stopped. Without these positive forces to counterbalance the rising levels of car ownership bus trips per capita has fallen by 71%. The effects of a policy change, including peak-load pricing, straighter bus routes, smaller bus size and staggered school hours, is analysed. It is found that the proposed changes would increase public transport travel by 42 % compared to present policy.

Keywords: Public transport, Demand, Elasticity, Price, Service, Time series, Panel data

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Table of contents

Introduction

- Paper I Demand and supply of public transport – The problem of cause and effect
Published in: Hencher, D. (ed), (2005), *Competition and Ownership in Land Passenger Transport - Selected Refereed Papers from the International Conference (Thredbo 8)*, Elsevier
- Paper II Meta-analysis of public transport demand
Published in: *Transportation Research: Part A: Policy and Practice*, vol. 41, pp. 1021-1035
- Paper III Local public transport demand revisited
- Paper IV Public transport in towns – Inevitably on the decline?
(co-authored with Jansson J.O. and Ljungberg A.)
Forthcoming in: *Research in Transportation Economics*

STUDIES IN LOCAL PUBLIC TRANSPORT

Introduction

The problem

Local public transport in towns has for a long time been on the decline, in Sweden as well as in most countries in the industrialised world. Is this development inevitable or due to suboptimal policy? Would a different policy break the negative trend?

Purpose and limitations

The purpose of this thesis is to contribute to the understanding of how local public transport demand is affected by different factors. Such understanding provides a basis for answering the questions mentioned above. The problem analysis in paper I and II has led to the conclusion that there are some important issues left to address in order to achieve this goal. (1) Despite the fact that transport supply and demand most likely are connected in a two-way relationship, the former is often used in empirical research in order to explain the latter without taking the opposite causal connection into account. (2) The magnitude as well as the direction of the income-effect is still uncertain, which might be due to difficulties in disentangling the effects of income and car ownership. (3) Some of the variation in the different

elasticity estimations in previous research might be due to factors left out of the analysis.

There are a number of different types of models that might be used in order to analyse these questions for which the data requirements are quite large. Suitable data for the present purpose within the means of this project are those provided by the county public transport authorities (CPTA) in Sweden who reports several key statistics including number of trips made, total vehicle-kilometres provided, total revenue and total costs. These data are, in combination with other statistics obtained from Statistics Sweden, suitable for direct demand model application. Direct demand models can be said to combine the effects of trip generation, distribution and mode choice (Ortuzar and Willumsen 2001, Balcolme et al 2004) and are often used to estimate aggregate demand elasticities.

The primary drawback of using direct demand models (as opposed to sequential or disaggregated models) is that they cannot provide specific information on the effects of policy or external factors on modal split and route choice. Such information is vital for detailed traffic planning, but for overall strategic planning the direct demand models can be useful.

The main methodological issue

The most urgent methodological issue has to do with the dual role played by the supply of vehicle-kilometres. Besides being a measure of the capacity provided, it is frequently used as a measure of service quality in empirical work. Since long it has been pointed out that most likely there is a two-way relationship between demand for public transport and vehicle-kilometres

and that ignoring this will result in biased and inconsistent estimates. In the classic “black book” Webster and Bly states that:

estimates of vehicle-kilometres elasticities centre around 0,7, in range typically from 0,2 to 1,2, these values are known to be overestimated (except perhaps in special cases when increases in service provision have been made as general policy without consideration of the actual capacity required) because of the difficulties of disentangling cause and effect.

(Webster and Bly, 1980, p. 142)

Twelve years later in another often cited study, Oum et. al. acknowledge the problem by saying:

In practice, the data observed by researchers are the result of interactions between forces of demand and supply. It is well known in econometrics that the parameter estimates will be biased if such interactions are not recognised. /...../ Unfortunately, most empirical studies of transport demand have failed to take this into consideration. Greater effort needs to be taken towards modelling the interactive forces of supply and demand in future studies.

(Oum et. al. 1992 p. 159)

Despite these authoritative observations the problem has been ignored in most studies of public transport demand. A fairly recent exception is FitzRoy and Smith (1999), and strangely enough it seems like other

attempts to address this problem in empirical work were made in the seventies, including Nelson (1972), Veatch (1973), Garbade and Soss (1976) and Frankena (1978). How to deal with this problem is an issue running through all four papers, so some preparatory points on this matter appropriate in this overall introduction.

Capacity and quality as joint products

At the heart of the matter is the fact that capacity and quality are joint products in scheduled transport. Increasing capacity by using more vehicles, either on existing or on newly established routes, will also reduce waiting and/or walking time. Therefore, the level of demand affects the level of service provided and the other way round. Consider the demand function:

$$Q = Q(F, V, X) \tag{1}$$

where Q is number of trips made by public transport, F is the public transport fare, V is vehicle-kilometres provided, and X represents other variables affecting public transport demand including income, other prices and car ownership.

Why is the jointness of capacity and quality a problem for estimation of this kind of demand function? The problem is that the most important quality variable V becomes an endogenous variable because of its dual nature of also representing the capacity requirement which is (partly) determined by the level of demand, Q :

$$V = V(Q, Z) \quad (2)$$

where Z represents other variables that might affect V . When it comes to estimating the demand function by regressing Q on F , V and X , the most common course of action is to assume that the demand function is linear in the parameters, and then use the ordinary least square (OLS) estimator to estimate it.

It can be shown that under the assumptions often summarised as the Classical Linear Regression Model (CLR),¹ the Ordinary Least Square estimator (OLS) is Best Unbiased Linear Estimator (BLUE)². If, in addition, the disturbance term is distributed normally OLS is not only BLUE but also Best Unbiased Estimator (BUE). This, in addition to computational ease, explains the popularity of the OLS estimator. However, as is pointed out by Kennedy, the OLS estimator:

is in fact too popular: it is often used, without justification, in estimating situations that are not accurately represented by the CLR model. If some of the CLR model assumptions do not hold, many of the desirable properties of the OLS estimator no longer hold. If the OLS estimator does not have the properties that are thought to be of most importance, an alternative estimator must be found.

(Kennedy, 2003: p. 52)

¹ The assumptions are: (1) the model is linear in the parameters, (2) The expected value of the disturbance term is zero, (3) The disturbance terms have constant variance and are not correlated with one another, (4) The observations can be considered fixed in repeated samples, (5) The number of observations is greater than the number of independent variables and that there is no exact linear relationship between the regressors.

² In this context best refers to minimum variance.

In the present case with supply and demand for public transport it is the assumption of fixed or nonstochastic regressors that are violated. This is not a problem as long as the disturbances are independent or uncorrelated with the regressors but in this case they most likely are.

In a case where, for some reason, there is a disturbance in demand through a jump in the disturbance term, a positive disturbance will lead to an instant (same time period) increase in the number of trips made which due to the capacity requirement also result in an increase in the supply of vehicle-kilometres. However, vehicle-kilometres is one of the explanatory variables. Hence, the disturbance term is correlated to one of the regressors (vehicle-kilometres) and under such circumstances the OLS estimator is not only biased but also inconsistent. The reason for this is that a positive disturbance (causing a direct increase in demand) is accompanied by an increase in vehicle-kilometres (which also increases demand). When using OLS to estimate the demand function, both of these increases in demand are attributed to vehicle-kilometres instead of just the latter. (See e.g. Greene, 2000 for proof)

Solutions to the problem of estimation

A general estimation technique which is applicable when one or more of the explanatory variables are not independent of the disturbance term is the instrumental variable (IV) technique. Applied correctly, the IV technique is a consistent estimator in situations when there is contemporaneous

correlation between a regressor and the error. The technique is to find what is called an instrument for each variable that is correlated with the error, and replace that variable by the instrument in the regression. The instrument is a new variable which for the procedure to work must have two properties. It must be contemporaneously uncorrelated with the error, and it has to be correlated (the higher the better) to the variable it is replacing. The hard part of the procedure is often to find one or more variables fulfilling these criteria.

If suitable variables are found, the instrument(s) is constructed by running a regression with the original variable (to be replaced) as dependent variable and the intended instrumental variables as explanatory variables. The fitted values from this regression constitute the instrument and are then used to replace the original variable in the estimation of the original function.

This procedure has also given name to the two stages least squares (2SLS) estimator, which is a special case of the IV technique. In 2SLS estimation the instrument is created in the same manner as described above, using all exogenous (or predetermined) variables as in the entire model as instrumental variables. This is very useful if one has knowledge of which (exogenous) variables are significant determinants of the endogenous variables in the system.

Summary of the papers

The thesis consists of four papers addressing different questions in order to contribute to the overall purpose of the thesis.

Paper I, *Demand and supply of public transport – The problem of cause and effect*, is published in Hencher (2005). In this paper the causal relationship between public transport demand and vehicle-kilometres is investigated using a Granger-causality test. The test is performed using a panel data set originating from Swedish counties for the period 1986 - 2001. It is concluded that while vehicle-kilometres is found to cause number of trips made, the number of trips also causes vehicle-kilometres. Hence, there is a two-way relationship between these variables.

Paper II, *Meta-analysis of public transport demand* is published in *Transportation Research Part A, Policy and Practice*. The purpose of this paper is twofold: the first is to provide a summary of previous elasticity estimates for local public transport demand, and the second is to explain the extensive variation in those results. A large amount of previous research on local public transport demand was reviewed and the different estimates obtained in those studies were combined into a data set describing the results and the method they used in getting them. For the second purpose regression analysis is used where five different local public transport demand elasticities, with respect to fare, level of service, income, price of petrol and car ownership, respectively and separately are explained using

different study characteristics such as functional form, type of data and origin of data as explanatory variables.

Paper III, *Local public transport demand revisited*, is not yet published elsewhere. The purpose of this paper is to provide estimates for local public transport demand using the same panel data as in Paper I. The potential upsides of using panel data are several, some of them that are of particular interest in the present case are: (1) Differences between counties that can not be attributed to the explanatory variables can still be accounted for by incorporating county specific effects. (2) By combining time-series and cross-section data more information is gained reducing the potential problems of multicollinearity and increasing efficiency. (3) Since a panel consists of several cross-sections it also allows the possibility of observing dynamic behaviour. The elasticities with respect to public transport fare, price of petrol, vehicle-kilometres and car ownership are found to be -0.4, 0.34, 0.55, and -1.37. After also taking into account the effects of income on car ownership it is found that the total effect on public transport demand is close to zero.

Paper IV (co-authored with Jan Owen Jansson and Anders Ljungberg), *Public transport in towns – inevitably on the decline?*, is forthcoming in *Research in Transportation Economics*. The major drawback of the panel data material used in Paper I and III is its high level of aggregation. Since the data from each county consists of data from all urban areas, both large and small, the averaging can be extensive. Therefore Paper IV takes a closer look at the town of Linköping. The time-series used in this article covers the

period of 1946 – 2006 which in addition to reducing the problems of aggregation also provides the opportunity to further study the changes in traffic in an urban area where public transport demand was on the increase in the first half of the period and has been declining after that. The number of bus trips increased much faster than total population between 1946 and 1982. From that point, trips per person has decreased by 71 % up to now. The effects of a policy change, including peak-load pricing, straighter bus routes, smaller bus size and staggered school hours, is analysed. It is found that the proposed package would increase public transport travel by 42 % compared to present policy.

References

Balcombe, R., Mackett, R., Pually, N., Preston, J., Shires, J., Titheridge, H., Wardman, M. and White, P. (2004). *The Demand for Public Transport: a Practical Guide*. TRL report, TRL593.

FitzRoy, F. Smith, I. (1999), Season Tickets and the Demand for Public Transport, *Kyklos*, 52, pp. 219-231

Frankena, M. (1978), The Demand for Urban Bus Transit in Canada, *Journal of Transport Economics and Policy*, pp. 280-303

Garbade, K. Soss, N. (1976), Fare Policies for Mass Transit Deficit Control: Analysis by Optimization, *Transportation Research*, 10, pp. 237-247

Greene, W. (2000), *Econometric Analysis*, Prentice-Hall

Kennedy, M. (2003), *A guide to econometrics*, 5 ed. MIT Press

Nelson, G. (1972), *An econometric model of urban bus transit operations*, PhD-thesis, Rice University

Ortuzar, J. and Willumsen, L. (2001). *Modelling transport*, 3rd ed. Wiley

Oum T.H., Waters, W.G. and Yong, J.S. (1992). Concepts of price elasticities of transport demand and recent empirical estimates. *Journal of Transport Economics and Policy*, 26, 139-154

Veatch, J. (1973), *Cost and demand for urban bus transit*, PhD-thesis, University of Illinois

Webster F.V. and Bly P.H. (1980). *The demand for public transport*. Report of the international collaborative study of the factors affecting public transport patronage