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Estimating multimodal public transport mode shares in Athens, Greece

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ABSTRACT

We analyze market shares for each public transport mode in total public transport ridership for the multimodal public transportation system of Athens, Greece. This analysis provides useful information for making investment decisions concerning the public transport infrastructure and for allocating subsidies. Due to the non-stationary properties of the data, cointegration techniques are applied to investigate the long run equilibrium relationships. Error Correction Models are implemented to estimate short run dynamics as well as the speed of adjustment from the short to the long run. Results suggest that fare and GDP are the main determinants of the public transport mode shares both in the short and in the long run. Findings also indicate the role of total ridership fluctuations in explaining variations in public transport mode shares.

1. Introduction

The limited availability of resources and the need to reduce operating subsidies as current economic conditions dictate, increase the complexity of efficient management of public transportation systems. Demand analysis is a necessary condition for efficient decision making in a public transport system; network expansion, pricing policies, subsidy and operational decisions are based on demand analysis. The analysis of the share of each transport mode in a multimodal urban public transport system is a key factor that explains the relative position of each mode in the system. It may also be a useful index for making investment decisions concerning the public transport infrastructure and for allocating subsidies.

Many researchers have studied the policies and the factors that influence public transport demand (Dargay and Hanly, 2002; Lane, 2010, 2012; Taylor et al., 2009; Wang and Skinner, 1984), while others have summarized relevant findings (Goodwin, 1992; Litman, 2004; Oum et al., 1992; Paulley et al., 2006; Taylor and Fink, 2004; Trace, 1999). Some of these studies have analyzed both short and long run demand elasticities, as this distinction has important policy implications. Rose (1986) examined the short and the long run effects of fares, service and gasoline prices on rail ridership using time series analysis. In a similar context, combining cross sectional and time series data, Lane (2012) estimated lagged effects of gasoline price and service on transit patronage.

There are also papers that investigate the factors influencing ridership in a multimodal public transportation system (Garcia-Ferrer et al., 2006; Gkritza et al., 2004, 2011). In a multimodal public transportation context, methodologically acknowledging the coexistence of modes allows for explicitly considering the substitution effects that competition implies. Competition between modes is measured through the use of cross elasticities, which are highly dependent on the relative market share of each mode (Balcombe et al., 2004). Gilbert and Jalilian (1991) and Glaister (2001) have developed multimodal models for estimating cross elasticities.

Mode share of public transport is also an indicator of public transport demand (Buehler and Pucher, 2012), and it is usually related to funding for public transportation (Polzin and Chu, 2005). Numerous studies worldwide have been performed to investigate the determinants of mode choice between public transport and private car using aggregate descriptive analysis as well as disaggregated mode choice models (for example, Beirão and Cabral, 2007; Buehler, 2011; Clark and McKimm, 2005; Moniruzzaman and Páez, 2012; Vovsha, 1997). Although public transport demand studies differ on the type of data collected, the estimation methods used, the country and the number of modes included in the study, it is clear that fares, income, gasoline price and service level are among the most important factors affecting ridership.

We investigate the factors that determine the share of each transport mode in total public transport ridership for the urban public transport system of the city of Athens, both in the short and in the long run. The analysis uses cointegration and error correction techniques in a time series analysis framework, since this methodology allows for treating non-stationary data and for determining short term and long term elasticities. In the public transport sector the long run responses are mainly associated with

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investment decisions, while the short run responses are associated with operational decisions. The main goal is to distinguish and quantify short and long term effects of various factors on public transport mode shares since they provide useful information in the assessment of transport policies.

2. The Athens multimodal public transport system

The Athens multimodal public transport system includes five modes: metro, urban rail, bus, electric bus and tram.[1] The network has an average daily passenger demand of 2.5 million passengers and is spread over an area of about 650 km^2. The underground metro system in Athens has 2 metro lines with a total length of 32 km and 36 stations. The frequency of the trips is 3 min during peak-hour periods and 5–10 min during non peak periods. Urban rail is the 'oldest' Public Transport Mode in the city of Athens with a length of 25.6 km. The two metro lines and the urban rail line are connected at four central stations.

The bus network includes approximately 330 bus lines covering the entire greater Athens Metropolitan Area, with a fleet of almost 2500 buses. The electric bus network consists of 22 lines that primarily serve the Athens city centre with 366 trolley (electric) buses. There are dedicated bus lanes (total length 50.53 km) for the bus and the electric bus mode in the most congested parts of the network, in the hope that this will increase speed and reduce travel times. The bus and electric bus networks are connected to the metro and the urban rail through bus/electric bus stops that are close to the metro stations. The Tram has 3 lines mainly linking the south suburbs of Athens to the city center with a limited network of approximately 26 km and 48 stops. We do not analyze the tram because sufficient data were not available and its modal share of daily public transport trips is below 3%.

The modes discussed are interconnected. The integrated ticket, which was applied during the last two years of the study, encourages the use of different modes in a single journey. However, for large parts of the network there are parallel lines of different public transport modes that serve the proximate OD pairs (particularly for bus and metro). To this extent, there is competition between PT modes because fares, although centrally regulated, differ among modes.

3. Data description

The monthly time series data used in the analysis concern the period from January 2002 to December 2010 (a total of 108 observations). The percent share of each public transport mode is measured by dividing the monthly ridership of each of the four public transport modes (metro, bus, electric bus, urban rail) by the total public transport trips of the same month.

Fares of the different public transport modes, a dummy variable for the integrated ticket, as well as macroeconomic and demographic factors were used in our models. Table 1 shows the mean and the deviation for each of the variables included in the study over the period examined.

Table 1
Summary statistics (monthly).

Variable	Mean	Standard deviation
Public transport variables		
Metro riders	14,295,245	2,544,766
Bus riders	30,338,756	3,127,397
Electric bus riders	6,573,172	7,852,62
Urban rail riders	9,661,460	1,526,618
Metro share	0.233	0.025
Bus share	0.500	0.030
Electric bus share	0.109	0.007
Urban rail share	0.158	0.015
Metro ticket price (in €)	0.922	0.074
Bus ticket price (in €)	0.695	0.205
Electric bus ticket price (in €)	0.695	0.205
Urban rail ticket price (in €)	0.879	0.095
Integrated ticket (1 if yes; 0 if no)	0.220	0.410
Macroeconomic and demographic variables		
Unemployment rate (%)	9.076	1.752
Gasoline price (in €)	0.799	0.143
Gross domestic product (in millions €)	19.768	1.657
Population of Athens	4,014,567	71,742

4. Methodology

In economics, the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980a, 1980b), based on the theory of consumer demand, has been widely used for analyzing expenditure shares in empirical demand analysis (e.g. De Mello et al., 2002; O'Hagan and Harrison, 1984; Syriopoulos and Sinclair, 1993; Chen and Veeman, 1991; Mergos and Donatos, 1989; Romero-Jordán et al., 2010).

In our analysis, share equations of public transport modes are not based on the consumer demand theory and thus the AIDS model, in its strict form, is not suitable for analyzing the market shares of a multimodal public transport system of Athens. Instead, we estimate the shares of different modes of the public transport system using cointegration and error correction techniques. This methodology allows for treating non-stationary time series data and for evaluating both short and long run responses. We note that a time series is said to be non-stationary if its mean and/or its variance and covariance between two time periods are not constant and depend on time.

The concept of cointegration and Error Correction Models was first proposed by Engle and Granger (1987) and has been widely used, particularly in modeling and forecasting macroeconomic activities. The Cointegration/Error correction Model Approach is likely to offer much more reliable information because, in cases where the stationarity assumption underlying least squares regression models is violated, standard regression techniques can lead to spurious results (Granger and Newbold, 1974). According to the Engle–Granger two step procerdure (1987), first we estimate the cointegrating regressions to derive the long run elasticities and second we estimate the Error Correction Models to derive the short run elasticities of the share of every mode.

4.1. Cointegrating regressions

We start our estimation procedure by considering the following general equation for every public transport mode share[2]

$$Mode\,share = a_0 + a_1\,\ln ticket\,price + a_2\,\ln total\,ridership + a_3\,\ln GDP + a_4\,\ln gasoline\,price + u_t \quad (1)$$

The first step in the analysis is to check the order of integration of each of the variables included in Eq. (1). A variable is said to be integrated of order D, denoted $I(D)$, when D differences are required to make the variable stationary. The order of integration of each variable is found by applying a unit root test. If the variables are stationary i.e. $I(0)$, standard time series methods

[1] We discuss here some of the essential characteristics of the system. Readers interested in more details and maps can visit www.oasa.gr and www.ametro.gr.

[2] The model developed in this study is a 'network level' model. Therefore, to use an aggregate estimation for variables such as travel speed and stop frequency would possibly lead to erroneous or spurious results. These variables should be used for 'line' demand models.