Transport Policy 58 (2017) 72–79

Contents lists available at ScienceDirect

Transport Policy

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

What led to the establishment of a rail-oriented city? Determinants of urban rail supply in Tokyo, Japan, 1950–2010

Ryosuke Abe*, Hironori Kato

Department of Civil Engineering, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

ARTICLE INFO

Keywords:
Urban rail supply
Long-run analysis
Planning process
Induced supply
Bayesian model averaging

ABSTRACT

This study analyzed the determinants of urban rail supply in Tokyo using time series data for the postwar period. It modeled urban rail supply, measured by vehicle-kilometers of the urban rail service, incorporating demand for urban rail travel, urban rail travel speed, conditions of alternative transportation modes, land use patterns, and socioeconomic conditions as explanatory variables. The model adopted a lag structure for urban rail supply in line with the planning horizon. It was then estimated using the Bayesian model averaging approach, which provided robust estimation results based on our multivariate time series data. The results showed that investments in the urban rail network in Tokyo were primarily driven by the increase in demand for urban rail travel. In effect, demand growth in the Tokyo rail network has clearly translated to supply growth through the planning process; this induced supply has worked as one of the critical components in the establishment of a rail-oriented transportation system in Tokyo. Additionally, the negative effects of bus/tram travel speed on urban rail supply were estimated.

1. Introduction

Tokyo is one of the most transit-oriented cities in the world (Cervero, 1998). The 2008 Person Trip Survey in Tokyo shows that the most frequently used transportation mode in the metropolitan area was urban rail (30%), including suburban railways and subways, followed by cars (29%). Tokyo's urban rail market has unique characteristics. For example, the rail network was developed under the guidance of the central government, private rail companies provide many of the services, and rail users suffered from chronic traffic congestion for many years (Kato, 2014).

It is widely known that historical processes have resulted in Tokyo's current rail-oriented transportation system. Fig. 1 shows the increase in route kilometers of the urban rail service in Tokyo Metropolis over time. In 1904, the National Railways started urban rail services with electric trains in Tokyo. Subsequently, many rail operators started providing services in its suburban areas. The major framework of the urban rail network, excluding the subways, was completed by the 1920s, when the first major suburbanization (1920–1935) started in the modern history of Tokyo. In the central areas of Tokyo, tram (electric streetcar) system played an important role before World War II, but the majority of its service was closed by the early 1970s and replaced by the subway network, which coincided with the second major suburbanization (1955–1970). As most subway lines started their operations during the postwar period, a direct connection system between suburban rail and subway lines was introduced during the 1960s. To date, suburban rail operators have continuously invested to increase their service capacity through measures such as upgrading from double-track to quadruple-track lines. In Japan, rapid motorization commenced in the 1960s; nevertheless, the rail network has continued to attract a significant number of travelers in Tokyo (Aoki et al., 2000; Maruyama et al., 2003; Yajima and Ieda, 2014).

In discussing issues on long-run changes in urban transportation, it would be necessary to highlight the factors influencing the supply of transportation service. For example, most people in a city would use the rail network if it offers a better level of service, on average, than other modes of transportation, as many studies have shown (e.g., Hensher, 2008; Holmgren, 2007; Wardman, 2014). This study examines what factors have strongly affected the supply of urban rail services, thus making the rail the most preferred mode of transportation over time.

Various factors could have affected urban rail supply in Tokyo over time. Fig. 2 shows the supply and demand trends of the urban rail service in Tokyo Metropolis. First, it seems that demand growth preceded supply growth, particularly when the growth rates of the urban rail market were higher. Meanwhile, the market could feature simultaneous growth in supply and demand when growth rates were relatively low. In Tokyo, as increasing rail demand seemed to promote investments in the rail

* Corresponding author.
E-mail addresses: abe-r@ip.civil.t.u-tokyo.ac.jp (R. Abe), kato@civil.t.u-tokyo.ac.jp (H. Kato).

http://dx.doi.org/10.1016/j.tranpol.2017.05.004
Received 9 March 2016; Received in revised form 4 May 2017; Accepted 12 May 2017
Available online 22 May 2017

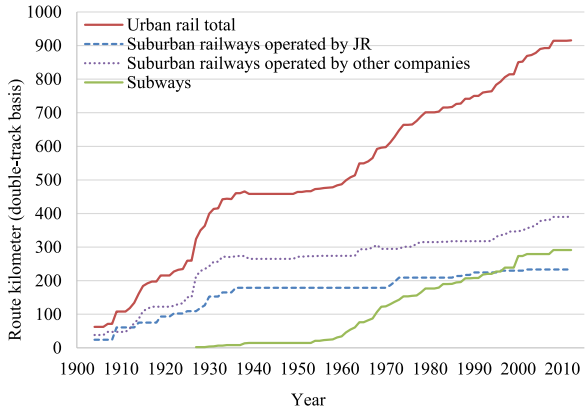

Fig. 1. Trend in route kilometers of urban rail services in Tokyo Metropolis. *Note 1*: JR represents the East Japan Railway Company or its predecessors. *Note 2*: When quadruple tracks are introduced into rail sections, the route kilometers for such sections are doubled.

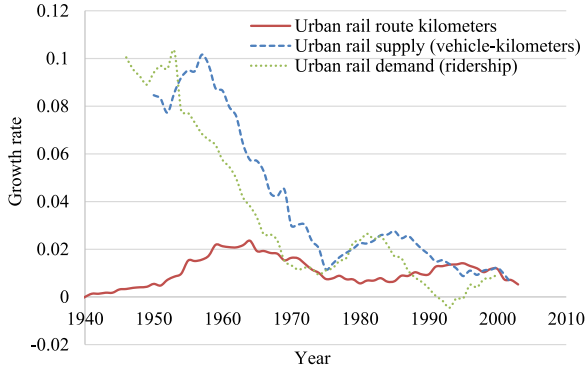

Fig. 2. Trend in growth rates of supply and demand of urban rail service in Tokyo Metropolis. *Note*: Growth rates are defined as annual average growth rates over (forward) 10-year intervals.

network, its development has been termed as “demand-driven” or “demand-following” (Yasoshima, 1986; Yoshida, 2014). This implies that growing demand for rail travel might have stimulated rail investment. Second, the degradation in the service levels of alternative transportation modes such as trams could have also promoted urban rail investment. Third, urban rail supply might have also been correlated with urban growth and the demographic changes of the city.

This study investigates the determinants of urban rail supply in Tokyo using time series data from 1950 to 2010. Potential determinants include demand for urban rail travel and its associated speed, bus/tram travel speed, car ownership, land use patterns, and socioeconomic conditions. A model framework that considers the planning process of urban rail supply is applied. Finally, the Bayesian model averaging (BMA) approach is used to deal with the multivariate time series data, allowing a robust estimation of the model.

The remainder of the paper is organized as follows. The next section reviews related studies. Sections 3 and 4 explain the model structure and data used in this study, respectively. After describing the estimation method, Section 5 presents and discusses the estimation results. The final section summarizes the findings and provides the implications for transportation policy.

2. Literature review

2.1. Long-run growth of the urban transportation market

Many studies have reviewed the historical development of urban transportation. For example, Barter (2004), Dick and Rimmer (2003), Hook and Replogle (1996), Morichi and Acharya (2012), and Rimmer (1988) analyzed the historical processes of urban transportation development primarily to inform transportation policy decisions in the developing world. Meanwhile, Nivola (1999) and Pucher, (1988, 1995) discussed the differences between the transportation markets in the automobile-dependent U.S. cities and the relatively transit-oriented/compact-structured European cities from a historical perspective. Barter (2004) pointed out that the development of urban transportation is highly path-dependent, implying that addressing its dynamics is important in analyzing the long-run growth of urban transportation.

Past studies have often used aggregate-level data in analyzing the long-run period (here, 20 years or more) of urban transportation. For example, McIntosh et al. (2014) and their colleagues have developed datasets that include cross-sectional time series data of urban transportation and land use for cities across the world for 1960, 1970, 1980, 1990, and 2000. With these datasets, statistical analyses have been applied, particularly to isolate the critical factors determining travel demand. Meanwhile, Baum-Snow and Kahn (2005) examined the effects of major urban rail infrastructure improvements on rail ridership, using cross-sectional time series data for the U.S. at the census tract level for 1970, 1980, 1990, and 2000. These studies intended to analyze travel demand robustly with cross-sectional time series data rather than the dynamics of urban transportation markets. Few studies, therefore, have analyzed the long-run growth of the urban rail market with long-period data, focusing particularly on market dynamics.

2.2. Determinants of the urban rail market

The determinants of urban rail demand have been established. For example, many studies have intensively analyzed urban rail demand as a function of fares, income, and the level of its service (e.g., for literature reviews and meta-analyses, see Hensher (2008), Holmgren (2007), and Wardman (2014)).

Although many studies have estimated the production or cost functions of urban rail firms (e.g., Graham et al., 2003; Savage, 1997; Wunsch, 1996), few studies have analyzed urban rail supply as a function of travel demand, alternative transportation modes, socioeconomic conditions, and so on. Nonetheless, exceptions do exist. For example, Albalate and Bel (2010) and Taylor et al. (2009) have estimated the supply of urban public transit services using a city-level cross-sectional dataset. Likewise, Voith (1997) has estimated the service level and price of urban rail service, incorporating demand, with a station-level cross-sectional time series dataset. They analyzed the determinants of public transit ridership, in which the model for supply, service level, or price was simultaneously estimated. However, typically, they focused on demand-side explanations.

This study explicitly highlights the determinants of urban rail supply in the long-run context. Since network- or infrastructure-related factors such as stations and route length are considered as production inputs for urban rail firms (Graham et al., 2003), a long-run analysis of urban rail supply needs to account for changes in those factors as well. For example, when infrastructure investments are relevant in explaining an additional supply of rail services, urban rail supply could have a time lag in responding to the condition of the urban transportation market and socioeconomic conditions. Although no studies of urban rail supply have incorporated time lag variables to our knowledge, some studies have considered time lags in road investment, for example, in California (Cervero, 2003) and the Twin Cities (Levinson and Karamalaputi, 2003). Kydland and Prescott (1982) also stressed the importance of time lags in the investment process or time-to-build in their macroeconomic model.

3. Model

3.1. Variables considered

Fig. 3 shows a hypothetical causal relationship among major factors related to urban rail supply. Following the framework in Cervero