Transportation Research Part A 91 (2016) 236–250

Contents lists available at ScienceDirect

Transportation Research Part A

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

Implications of the cost of public funds in public transit subsidization and regulation

Yanshuo Sun [a], Qianwen Guo [b,*], Paul Schonfeld [a], Zhongfei Li [b]

[a] Department of Civil and Environmental Engineering, University of Maryland, College Park, 1173 Glenn Martin Hall, College Park, MD 20742, United States
[b] Department of Finance and Investment, Sun Yat-Sen Business School, Sun Yat-Sen University, Bldg 388, 135 Xingangxi Rd, Guangzhou 510275, China

ARTICLE INFO

Article history:
Received 18 October 2015
Received in revised form 11 May 2016
Accepted 29 June 2016

Keywords:
Public transit
Subsidization
Cost of public funds
Social welfare

ABSTRACT

This paper identifies some implications of the cost of public funds (CF) in public transit subsidization and regulation. Regulation is considered because a monopolistic operator is assumed. A social welfare maximization model is proposed, subject to individual rationality and vehicle capacity constraints. Optimality conditions are provided and a key formula is derived about CF's role in balancing the need to cover the fixed operation cost through fares on the operator's side and the effort to maintain the user surplus on the passengers' side. Major findings from this model's formulation include: (1) CF determines the extent to which the passengers' surplus is compromised in order to cover the fixed part of the operating cost, and (2) subsidy is unjustified when CF exceeds the critical shadow price of the financial constraint. Analytical relations are illustrated through numerical examples.

1. Introduction

This study is motivated by the insufficient understanding of the implications of the cost of public funds in public transit subsidization and regulation. Although it is worldwide practice to finance public transit systems which have operating deficits through subsidy programs, debates over the justification of transit subsidies have been heated for decades. In the theoretical literature, especially in studies focusing on the Mohring effect (Mohring, 1972), which describes economies of demand density, at least two streams of studies refute each other, e.g., Van Reeven (2008) versus Savage and Small (2010) and Basso and Jara-Díaz (2010). Conflicting conclusions are also drawn with empirical evidence from various geographical regions (Nelson et al., 2007; Tscharaktschiew and Hirte, 2012). Thus, there is no consensus among researchers on what conditions, if any, justify subsidies. Such a controversy is further fueled by the consideration of costly public funds, i.e. the social welfare losses when the revenue is raised to finance the public spending through the distortive taxation (Dahlby, 2008). Hence, this paper presents an analytical model for analyzing the impacts of the cost of public funds in transit subsidization and regulation. Regulatory constraints are introduced because a monopolistic operator is considered in this study.

A bilevel program is proposed, where the government, which is aware of the cost of public funds, designs service policy constraints (fare and service frequency limits) and determines the level of subsidization, subject to the financial feasibility constraint (the sum of revenues and subsidies is no less than the total operating cost). At the lower level, the operator seeks to maximize the total profit by optimizing operational parameters, subject to the service policy constraints and the availability of subsidy. Due to the symmetric information, the bilevel structure is reduced and optimality conditions are

* Corresponding author.
E-mail addresses: yssun@umd.edu (Y. Sun), guoqw3@mail.sysu.edu.cn (Q. Guo), pschon@umd.edu (P. Schonfeld), lnslzf@mail.sysu.edu.cn (Z. Li).

http://dx.doi.org/10.1016/j.tra.2016.06.029
0965-8564/

derived analytically. Three subsidization methods, namely "Subsidies as Incentives", "Subsidies as Compensations" and "Subsidies as Benefits", are introduced and compared in Sun and Schonfeld (2015a). Only the first method is considered in the present study, but other two subsidization schemes can also be used in the future.

We contribute to the literature mainly by incorporating the cost of public funds into the transit subsidization and regulation problem and identifying its policy implications. Major findings include:

(1) The financial constraint is binding at optimality, resulting in a zero profit.
(2) The cost of public funds determines the extent to which the passengers' surplus is compromised in order to cover the fixed part of the operating cost.
(3) The optimal decision of a public operator can be reproduced, while the private operator's behavior cannot be reproduced from this model's optimality conditions, when cost parameters are specified in practical ranges.
(4) A subsidy is unjustified when CF exceeds the critical shadow price of the financial constraint.

The remainder of this paper is structured as follows. The Literature Review section summarizes both theoretical and empirical studies supporting public transit subsidization or refuting it and also reviews selected optimization methods for subsidization. The Formulation section presents the optimization model after defining important functions and the Solution section provides the analytically derived optimality conditions. The Discussion section interprets major findings of this study and the Numerical Studies section illustrates analytical results graphically. The last section concludes with major comments on this study as well as prospective research directions.

2. Literature review

2.1. Controversy about public transit subsidy

It is worldwide practice to finance public transit systems through subsidy programs when they have operating deficits. Documented case studies are available from the U.S. (Savage and Schupp, 1997), France (Gagnepain and Ivaldi, 2002), Germany (Tscharaktschiew and Hirte, 2012), Chile (Serebrisky et al., 2009), Japan (Zou and Mizokami, 2014) and China (Deng and Nelson, 2013). Parry and Small (2009) provide a summary of transit subsidies as a percentage of total operating costs for 20 U.S. transit authorities. For instance, that percentage is around 90, meaning heavily subsidized, in the Dallas Area Rapid Transit. Hess and Lombardi (2005) reveals the evolution process of transit from a potentially profitable private business to a public entity heavily supported by federal, state and local funds and examines the role of public subsidies in financing transit in the U.S. since the 1950s. Despite their ubiquitous implementation, transit subsidies have been controversial for several decades, both theoretically and empirically.

The most cited rationale for subsidizing public transit services is the so-called "Mohring effect" (Mohring, 1972), which depicts economies of scale on the user side: A rise in demand shortens the waiting times of passengers because more vehicle runs would be scheduled. Access times can also be reduced because the demand increase leads to denser transit routes and stop locations. Thus, the average users' cost decrease as demand increases. Both producer and user economies of scale are combined and generalized by Jansson (1979). Other rationales for subsidization, such as positive externalities, can be found in a review article by Elgar and Kennedy (2005).

Vickrey (1980) concludes that a subsidy is necessary if the fare is set at the marginal social cost, which is below the average cost due to the increasing returns to scale when user inputs such as waiting times, are considered. Van Reeven (2008) argues that the "Mohring effect" does not constitute a valid justification for general subsidization of public transit services and the profit-maximizing frequency is no lower than the welfare-maximizing frequency under some conditions. Savage and Small (2010) as well as Basso and Jara-Díaz (2010) refute Van Reeven's argument, although in different ways. Savage and Small (2010) find the suboptimal service frequency of a monopoly operator by modifying Van Reeven (2008)'s demand assumptions so as to incorporate users' heterogeneity in the reservation price; therefore, subsides are needed for improving the frequency to the social optimum. Basso and Jara-Díaz (2010) slightly change the modeling framework and show that "welfare losses emerge under profit-maximization" and "subsidies are required for first-best operations". Karamychev and Van Reeven (2010) counter by showing that a monopolist might oversupply frequency depending on the degree of users' heterogeneity. Gómez-Lobo (2014) concludes that all results of Van Reeven (2008), Basso and Jara-Díaz (2010), Savage and Small (2010) and Karamychev and Van Reeven (2010) are special cases of Spence (1975) and provides more discussions on the relations between subsidies and the Mohring effect.

The disagreement is not limited to the theoretical literature. Conflicting results from empirical studies are also reported. For instance, Nelson et al. (2007) estimate the benefits to transit users and congestion-reduction benefits to motorists for the Washington, DC metropolitan area and find that (1) the congestion-reduction benefits due to rail transit systems exceed the subsides to rail transit services, and (2) the combined benefits, for both bus and rail, easily exceed the total subsidies. Parry and Small (2009) also conclude that the substantial operating subsidies for three major metropolitan areas, i.e., Washington, DC, Los Angeles, CA and London, UK, are warranted for efficiency. While Nelson et al. (2007) and Parry and Small (2009) support transit subsidization with empirical evidence, Tscharaktschiew and Hirte (2012) conclude that "optimal subsidy levels are either small or even zero" with empirical data from a German metropolitan area.

Thus, there is no consensus among researchers on what conditions, if any, justify subsidies.