Research in Transportation Economics 23 (2008) 85–98

Contents lists available at ScienceDirect

Research in Transportation Economics

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

Public transit subsidies, output effect and total factor productivity

K. Obeng [a,*], R. Sakano [b,1]

[a] Department of Marketing, Transportation and Supply Chain, School of Business and Economics, North Carolina A&T State University, Greensboro, NC 27411, USA
[b] Department of Economics and Finance, School of Business and Economics, North Carolina A&T State University, Greensboro, NC 27411, USA

ARTICLE INFO

Article history:
Available online 1 March 2009

Keywords:
Subsidies
Output effect
Total factor productivity decomposition
Cost functions
Scale economies

ABSTRACT

This paper extends previous works on total factor productivity decomposition when firms receive both operating and capital subsidies. It shows that previous works considered either the lump-sum or substitution effects of these subsidies but not together. Using constrained cost minimization as the framework it offers formal proofs to show that cost increases are inevitable if the total effects of the subsidies are considered, and that total factor productivity growth results from increasing amounts of subsidies under economies of scale and in the absence of technical change. Applications of the decomposition equations derived to a sample of transit systems finds near constant returns to scale and negative contributions of these subsidies to total factor productivity growth. Technical change reverses this decline and results in total factor productivity growth. Further, it finds that the lump-sum effects of the subsidies reduce total factor productivity more than does the substitution effect.

1. Introduction

More than two decades ago Kim and Spiegel (1987) examined the effects of lump-sum subsidies on the productivity of public transit systems that operated under rate of return regulation. Through their theoretical work, they showed that lump-sum subsidies affect factor proportions, output and cost. Following their theoretical work they estimated a neoclassical cost function that included lump-sum subsidy as a variable and used it to link these subsidies to decline in total factor productivity (TFP). Since then, few studies have followed the direction of Kim and Spiegel to theoretically derive models that link subsidies to TFP in public transit systems. They include Obeng and Sakano (2000, 2002) who studied operating and capital subsidies in a constrained output maximization framework and linked them to TFP. The major difference in these models is their treatment of subsidies. Kim and Spiegel (1987) treated subsidy as a variable in their model. Obeng and Sakano (2000, 2002) showed that because capital and operating subsidies are input oriented they make managers misperceive input prices. This misperception results in implied input prices that are lower than actual input prices and optimal input combinations that increase cost just as in Kim and Spiegel (1987). The empirical work of Obeng and Sakano (2000) reinforced the conclusions of Kim and Spiegel (1987) that subsidies contribute to TFP decline though in later work (Obeng & Sakano, 2002) they did not find this decline. In other studies, Kerstens (1996, 1999) found technical efficiency was negatively related to subsidies and in Matas and Raymond (1998) average efficiency was negatively related to subsidies. Nolan (1996) found negative relationships between state subsidies and technical efficiency and positive relationships between federal subsidies and technical efficiency. In the private sector, Bergstrom (2000) studied capital subsidies and found little evidence to show that they affected productivity. He argued just as Boame and Obeng (2005) did that subsidies advance the accumulation of technology in firms and could increase productivity. This is especially so because capital subsidies add to productive capacity and replacement investment such as modernizing existing capital stock and increasing efficiency (Harris & Trainor, 2005). In addition, Bergstrom (2000) argued that capital subsidies can help firms use economies of scale.

Countering this productivity growth argument Harris and Trainor (2005) provide reasons why capital subsidies could reduce productivity. Among them are, if they are given to less productive firms, if they result in a change in input mix which leads to allocative inefficiencies, and if they lead to *x*-inefficiency. Others are if they divert resources away from productive to rent-seeking activities, and if they make firms fail to organize their activities to improve performance.

In his empirical work, Bergstrom (2000) used firms that received or did not receive capital subsidies and found that only in the first year of the subsidies did TFP increase. After that, TFP continued on a declining trend so much so that after the third year it was below that of firms that did not receive subsidies. Harris and Trainor (2005) also examined the impact of capital subsidies on TFP in various firms in Ireland by looking at firms that did or did not receive them and the sizes of the subsidies. They found that capital subsidies increased TFP in electrical engineering, drink and tobacco industries.

* Corresponding author. Tel.: +1 336 334 7231; fax: +1 336 334 7093.
E-mail address: obengk@ncat.edu (K. Obeng).
[1] Tel.: +336 334 7744; fax: +336 334 7093.

0739-8859/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.retrec.2008.10.006

The common strand in these works that provides the motivation for further study is that they recognize that subsidies affect output but fail to account for this effect in their decompositions of TFP. These works fall into three groups. The first and most common uses a two-step approach where TFP measured as the Divisia (1926) index or the translog index is calculated and then related to subsidies (Benjamin & Obeng, 1990; Bergstrom, 2000). This approach does not address the impacts of subsidies that occur when they change input levels through input substitution, and that can affect TFP calculations through the shares of inputs in cost. Further, it does not permit researchers to decompose TFP into which component is due to the input substitution effects of subsidies and which is due to lump-sum subsidy effects. And, it does not answer the question if the lump-sum effects on TFP are more dominant than the substitution effects of the subsidies on TFP.

Harris and Trainor (2005) critique this approach pointing out that it gives inefficient and biased estimates because it suffers from omitted variables problem. Their favored approach is the second in which other determinants of output including subsidy and time are included in the production function. Then, following a similar approach as in Caves, Christensen, and Swanson (1980) and Oum, Tretheway, and Waters (1992) and taking the first order partial derivative of this function with respect to time and solving, they obtain TFP in terms of the variables in the production function. This second approach is also favored in the works of Bergstrom (2000) and Kim and Spiegel (1987) though the latter author uses a cost function. The third method is limited to Obeng and Sakano (2000, 2002). Here, the impacts of operating and capital subsidies on TFP are traced through their input substitution effects that result when the subsidies change the shares of inputs in cost. This third approach does not consider the lump-sum effects of subsidies on output.

While these approaches provide some understanding of subsidy impacts on TFP, to our knowledge there is no literature that considers the lump-sum and the input substitution effects of subsidies together to show how they affect TFP. To fill this void this paper examines the impacts of operating and capital subsidies on inputs and output and develops a decomposition approach to show how these impacts affect TFP. In doing so, it contributes to the productivity literature by considering the total effects of these subsidies on TFP. It uses an unbalanced panel data of 463 observations for 25 transit systems to calculate TFP. Because the data are limited and are not a representative sample of all U.S. transit systems the results of the decomposition are considered preliminary.

In the following sections, theoretical considerations are presented where the basic model, substitution effects of subsidies and TFP, and total effect of subsidies on TFP are found. After this section are the neoclassical cost models estimated, data, estimation and results. Finally, the results of the decomposition are presented followed by the conclusion.

2. Theoretical considerations

2.1. The basic model

Consider a firm that is currently producing the level of output Q using labor (L^*), fuel (G^*) and capital (K^*). The government gives the firm operating subsidy (A_o) and capital subsidy (A_k). After the firm receives the subsidies its output and input levels increase. It is these increases and their impacts on productivity that we model. Since operating and capital subsidies target specific inputs, let their functions be given as below, where for convenience and ease of exposition we include all the inputs in each subsidy function.[1]

$$A_o = A_o\left(K^*, L^*, G^*\right) \tag{1}$$

$$A_K = A_K\left(K^*, L^*, G^*\right) \tag{2}$$

Each subsidy type is fully allocated among the inputs such that the sum of subsidy elasticity with respect to the inputs is one. Thus, for each subsidy type the following restriction applies $\partial \ln A/\partial \ln K^* + \partial \ln A/\partial \ln L^* + \partial \ln A/\partial \ln G^* = 1$ where these terms are the elasticities of subsidies with respect to capital, labor and fuel, respectively. Following Obeng (1994) and using Kim and Spiegel's (1987) constraint, Eq. (3) gives the transit firm's after-subsidy cost.[2]

$$C^* = w_G G^* + w_K K^* + w_L L^* - A_o\left(K^*, L^*, G^*\right) - A_K\left(K^*, L^*, G^*\right) \tag{3}$$

where w_K, w_L, w_G are the respective market prices of capital, labor and fuel and an asterisk shows observable inputs and output. If transit systems minimize their after-subsidy costs given by Eq. (3) subject to output constraint[3] the Lagrangian for this constrained maximization is,

$$\begin{aligned}\ell = {} & w_G G^* + w_K K^* + w_L L^* - A_o\left(K^*, L^*, G^*\right) - A_K\left(K^*, L^*, G^*\right) \\ & + \lambda\left[Q - Q\left(K^*, L^*, G^*\right)\right]\end{aligned} \tag{4}$$

The last term on the right-hand-side is the production function and Q is output. From the first order conditions of Eq. (4), it can be shown that for any pair of inputs such as labor and capital the ratio of their marginal products can be written as,

$$\begin{aligned}&\frac{\partial Q/\partial G^*}{\partial Q/\partial K^*} = \frac{w_G}{w_K}\left[\frac{(1 - A_{oG}\varepsilon_{oG} - A_{KG}\varepsilon_{KG})}{(1 - A_{oK}\varepsilon_{oK} - A_{KK}\varepsilon_{KK})}\right] = \frac{\hat{w}_G}{\hat{w}_K} \\ &\text{where } 0 \le (\varepsilon_{oG}, \varepsilon_{KG}, \varepsilon_{oK}, \varepsilon_{KK}) \le 1, \\ &A_{oG} = A_o/w_G X_G^*, A_{KG} = A_K/w_G X_G^*, \varepsilon_{oK} = \partial \ln A_0/\partial \ln X_K, \varepsilon_{KK} \\ &\quad = \partial \ln A_K/\partial \ln X_K \; A_{oK} = A_o/w_K X_K^*, A_{KK} = A_K/w_K X_K^*, \varepsilon_{oG} \\ &\quad = \partial \ln A_0/\partial \ln X_G, \varepsilon_{KG} = \partial \ln A_K/\partial \ln X_G\end{aligned} \tag{5}$$

In Eq. (5), A_{oG}, A_{oK} are the shares of operating subsidies in fuel and capital costs, respectively, and $\varepsilon_{oG}, \varepsilon_{oK}$ are the respective elasticities of operating cost with respect to fuel and capital. Similarly, A_{KG}, A_{KK} are the shares of capital subsidies in fuel and capital costs and $\varepsilon_{KG}, \varepsilon_{KK}$ are the elasticities of capital subsidies with respect to fuel and capital.

The right-hand-side is the ratio of the implied input price of fuel to that of capital. Because these prices are lower than market prices, they induce firms to buy more inputs. Also, the term in the brackets shows relative price distortion because firms perceive input prices different from their market prices. If this term is greater than one the implied price of fuel is more than the implied price of capital, thus inducing firms to substitute capital for fuel. If it is less than one, fuel is relatively cheap compared to capital and firms substitute fuel for capital. Finally, if it is equal to one, relative prices remain unchanged and the subsidies do not lead to price distortion.

Fig. 1 shows input price distortions from subsidies. If a firm does not receive subsidies it produces Q units by using G units of fuel and K units of capital, given input prices w_G for fuel and w_K for capital.

[1] Capital subsidy is made a function of all input to simplify the derivation. It is recognized that this subsidy targets capital inputs and labor assigned purposely to capital such as overseeing construction projects.

[2] Kim and Spiegel (1987) used the constraint $p(y) + h - rK - wL \le sK$ where h is lump-sum subsidy, s is rate of return, r is capital's user price and $p(y)$ is total revenue. Eq. (3) is this constraint minus total revenue and the return on capital.

[3] The dual problem which is the maximization of output subject to an after-subsidy cost constraint gives the same results.