COST AND FARE ESTIMATION FOR THE URBAN BUS TRANSIT SYSTEM OF SANTIAGO

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ABSTRACT

In this paper, we estimate the cost function of bus operators of Transantiago and the budget balance fare to contribute technically to the discussion on the level of subsidies needed for transit system of Santiago. We estimate the cost function and an aggregate demand model. Our results show that there are economies of density and the budget-balance fare (type Ramsey price) is higher than the actual bus fare, suggesting that subsidies are justified. Nevertheless, we estimate that for the current (December 2011) fare the subsidy should be 40% lower than the one determined by the Government. On the other hand, we estimate that for such level of subsidy the optimal fare should be only 50% of the current fare.

Keywords: cost estimation, subsidy, fare estimation, urban bus transit system, Transantiago

1 INTRODUCTION

In 2007 the city of Santiago, Chile implemented a public transportation plan (Transantiago) that included a new urban bus transit system and fare integration with the Metro (Muñoz and Gschwender, 2008). For the new bus operation, the system was designed as a network of feeder and trunk services. The city was divided into nine feeder areas and five trunk services; each feeder feeding the trunk lines and the Metro. Each feeder area and trunk service was tendered and awarded to the highest bidder that fulfilled the requirements. Because of the new feeder-trunk structure, passengers would have to transfer more often between routes, compared to the bus system before Transantiago was implemented.

Also, another important change was the implementation of a smart card (Bip! card) as the only means for paying the fare of the trip. Additionally, this smart card permitted fare integration over the entire trip (among buses and Metro). The administration of the fare transactions generated by the system was also tendered to a financial and technological manager, called the AFT. We should note that its planners envisioned Transantiago as a subsidy-free system, which was an economic restriction for its initial design.

Transantiago had a very complicated and traumatic start (Muñoz and Gschwender, 2008), the Government recognized that the system was running a financial deficit of 35%, and the system became a main political issue. Because subsidies were not part of the original plan of Transantiago, yearly the Congress has a huge debate between politicians, public agencies, and operators about if there should be a subsidy for Transantiago and the amount.

In this paper, we estimate the cost function of the operators and the optimal fare of the system, in order to contribute technically to this discussion. Our database is from several sources and includes public data from the bus operators. We also estimate an aggregate demand model. Once the cost function is estimated, we compute a budget-balanced fare using Ramsey pricing.

2 MARKET DESCRIPTION AND DATA

In this section we explain Transantiago's bus system by describing the bus services in terms of the number of firms operating the system, how they operated at the beginning of Transantiago, what measures were taken by the public agency in charge of the operation of Transantiago in order to enhance the quality of the service, the means of payment, and the level of evasion. Also, we describe the data available to carry out this research and present a brief analysis of the main variables considered.

2.1 Market Description

The operation of the system consists of five trunk services and nine feeder services. The trunk services have exclusive operation in main roads in the city, and their routes connect the edges of the city with the Central Business District (CBD) or goes across the city from one extent to another. The feeder services operate in exclusive zones and connect to the trunk services. At the beginning of the period of analysis, there were four firms operating only trunks, six firms operating only feeder services (one of them operated two zones) and one firm operating two feeder zones and one trunk service. By the end of 2008, the latter firm was unable to operate the trunk and one of the feeder services; therefore two new firms entered the market at the beginning of 2009. In December 2009, the same firm became insolvent and exited the market; its zone was awarded to an incumbent firm operating another feeder zone. Thus, in the period of analysis there were thirteen firms operating in the market. We have data from ten of these thirteen firms for our estimation of the cost function. Since some trunk and feeder concessions have merged into larger firms, operating a mix of both types of services, once we estimate the operator's cost function our results should show the existence of economies of scale or spatial scope (Basso et al., 2011).

When Transantiago started in February 2007, each operator signed a contract where they guaranteed to fulfill the operational program established by Coordinación Transantiago, the Government agency in charge of supervising the operators. Although this plan established an operational fleet of 5,600 buses, the actual number observed was 4,600 buses (Beltrán el al. 2012). The contracts only established a commitment on terms of following the operational program, but no punishment in case of failing to follow this program by mid-2007 Coordinación Transantiago implemented a program of compliance measures and fines to enforce the fulfillment of the contracts. Such program increased the operating fleet from 4,600 to 5,800 buses in only five months (Beltrán el al. 2012). This implies that the actual total kilometers driven differs from the one established in the contract. Nevertheless, we will use the total kilometers driven in the operational program as a proxy of the actual total kilometers driven.

In the original design the supplied frequency and the bus lines were insufficient to cope with the demand. Therefore, the authority increased the supply in these aspects through the operational program. Table 1 displays the kilometers driven, the fleet size, and the number of bus lines from 2007 to 2011. It should be noted that after 2010 Coordinación Transantiago started reducing the total kilometers offered as a way to reduce the subsidy for the system.

Table 1: Evolution of public transport commercial kms, fleet and bus lines

Year	Driven km (million)	Fleet	Bus lines
2007*	371.1	4,489	223
2008	481.4	6,399	322
2009	487.2	6,572	334
2010	512.4	6,564	357
2011	483.0	6,165	370

(Source: Coordinación Transantiago)
* Figures correspond to February 2007 when Transantiago was inaugurated

There is a significant fare evasion in bus services in several parts of the city. By the end of 2011, the fraction of passengers evading the bus fare attained 23% (Coordinación de Transportes de Santiago, 2012). There are many reasons for this evasion. One of them could be that fares have increased by 50% in the last two years and for a significant fraction of users paying the fares twice on every workday represents around 15% of their income (MDS, 2009). Thus, the high fares might increase the propensity to evade.

Transantiago was designed to operate without subsidies. However, the new conditions on the firms along with the new operation scheme and the fare integration led to a higher cost than the estimated one based on the previous public transport system. For instance, formal contracts for drivers increased labor costs, and the integrated fare implied additional collection and management costs. In addition, fare integration reduced the revenues of the system. In consequence, the total subsidies have reached around US$50 million per month, around 40% of the total costs (Coordinación de Transportes de Santiago, 2012).

Users tap in to enter each bus of the network. During two hours, passengers may make up to two transfers paying a single fare as long as they do not repeat the same bus line. Thus, the total ridership in the system is estimated as the number of passengers entering the system paying their fare (even if they make more than one trip). However, the ridership of each firm is estimated as the number of taps registered in the buses of the firm.

2.2 Data

To estimate the cost function, we use data from several sources because there are many different types of information involved in our estimation. We need costs, input prices, transport demand, operation variables and fare information.

We obtained data on firms' cost from the Chilean Securities and Insurance Superintendence (Superintendencia de Valores y Seguros - SVS). The transport firms operating in Santiago must deliver financial reports quarterly, which include information operation cost, financial cost, and total cost. This information is public and available through Internet (Superintendencia de Valores y Seguros, 2012). The financial reports were submitted quarterly until March 2010, after that the regulation for this information changed to annual reports. Thus, we have quarterly information from the second quarter of 2007 to the first one of 2010. However, some firms continued reporting financial information quarterly until December 2010. Some firms exited the industry during this period (firm 5 exits in the third quarter of 2010) or few months after (firms 2 and 4 exit in the third quarter of 2011), and another firm enters (firm 10 enter in fourth quarter of 2009). Hence, we have an unbalanced panel of firms, where some firms have around 15 observations whereas others only have 2-3 observations (Table 2).

Table 2: Number of Observations for Each Firm in the Sample

Firm	Data		No. Obs.
	From (year-quarter)	To (year-quarter)	
1	2007-2	2010-1	12
2	2007-2	2010-1	12
3	2008-1	2010-1	9
4	2007-2	2010-1	12
5	2009-1	2009-3	3
6	2007-2	2010-1	12
7	2007-2	2010-4	15
8	2007-2	2010-4	15
9	2007-2	2010-4	15
10	2009-4	2010-1	2

As inputs for our cost model, we use labor, diesel, and capital. In all cases, we assume that the firms have no monopsony power in the input markets and that those markets are competitive. Thus, all firms face the same prices for labor, diesel and capital. Usually, the labor price is calculated as the ratio between the total expenses in labor and the number of workers in the firm. However, we do not have information on such variables. Therefore, as labor price we adopt the quarterly average of the Real Cost Labor Index from Banco Central de Chile (2012).

The diesel price is obtained from the statistics collected by Banco Central de Chile (2012). We use as diesel price the quarterly average CIF price per barrel of imported diesel in US dollars. This way, the diesel price is independent of the dollar exchange rate.

The price of capital is mainly the price of rolling stock and parts required for its maintenance. To take into account the effects of this input on the cost we consider several factors: national interest rate, international interest rate, and dollar exchange rate. All this variables should have an effect in the amortization and depreciation of rolling stock. However, after a number of preliminary estimations, the only relevant variable was the dollar exchange rate. We obtained all information on these variables from statistics from Banco Central de Chile (2012).

We obtained the operation information from Coordinación Transantiago. This is the government agency that controls the contracts with the bus service providers. The agency also defines the operation plans for the bus lines. We use the information on operation to characterize the product of the firms, because the number of passengers is not enough to describe the output of a transportation firm (Spady and Friedlaender, 1978). Therefore, we introduce the total kilometers contracted in the quarter and the average number bus lines operated by each firm.

For the number of transported passenger we use the total of taps of Transantiago’s smartcard recorded by the system. Also, we acknowledge the fraction of passengers that do not pay, considering this evasion as part of the operation cost. Indeed, if the evasion is constant in the period we analyze, it is taken into account by increasing the marginal cost.

Table 3 shows the averages of the main variables used in estimation for each firm in the period for which we have data. There are differences among the firms’ averages because the data used correspond to different length periods.

To estimate the demand model, we have monthly data of total taps in the bus system. Notice that the total taps are different from the total number of passengers because of the evasion. In addition, the propensity to pay has a price elasticity that could not equal the demand price elasticity.

Table 3: Average of main variables used in the estimation

Firm	Cost (millions $)	Taps (millions)	Bus lines	Driven kms	Labor Index	Diesel price	Dollar Ex. Rate
1	7.2	12.3	42.6	10,000	102.5	81.0	533.0
2	14.9	24.4	74.9	19,277	102.5	81.0	533.0
3	6.1	11.3	36.1	8,350	103.0	82.3	538.6
4	37.4	40.2	102.5	44,185	102.5	81.0	533.0
5	11.8	8.0	36.3	8,054	104.5	55.7	573.4
6	29.1	32.0	48.3	20,812	102.5	81.0	533.0
7	44.7	45.8	81.8	36,773	103.8	81.0	527.9
8	41.8	50.3	63.0	33,194	103.8	81.0	527.9
9	23.7	31.1	36.8	20,701	103.8	81.0	527.9
10	8.2	5.2	46.0	2,385	106.8	78.7	518.6
Total	26.4	31.3	60.5	24,256	103.2	80.4	532.2

3 COST AND DEMAND MODELS

In this section we present the functional form adopted for the cost model and discuss some useful indexes to study the industrial structure of the urban bus transit of Santiago. We also present the demand model used in the estimations.

3.1 Cost Model

To specify the cost function, it should be considered that transport output is multidimensional. Indeed, it is recognized that transport output is defined by a flow vector with components identified by origin, destination, period and commodity type (Jara-Díaz, 1982). In the case of Transantiago, such description of the product is unfeasible because it implies an output vector of dimension $X(X\text{-}1)/2$ for each line, where X is the number of the stops in the route. For instance, a trunk service can have around 70 stops along its route, thus the multi-output vector should have 1,190 components. Hence, the output in the cost function must be specified as an aggregated measure. In this case, the aggregated product is defined as the total passenger flow.

In addition, to take into account some characteristics of the multi-product nature of the problem, we adopt a hedonic output approach (Spady and Friedlaender, 1978). We define the output as a vector of aggregates with components describing different characteristics and technological factors of the output. These components are useful to calculate economies of scale unambiguously (Jara-Díaz and Cortés, 1996). On this respect, as the aggregated output is the total passenger flow, the calculation of economies of scale is straightforward. Indeed, the degree of multiproduct economies of scale (S) is equal to the inverse of the cost elasticity to aggregated output (Jara-Díaz and Cortés, 1996). Therefore, the additional variables used to describe the output are the kilometers contracted during the period and the average fleet size of the firms.

To model cost structure we assume a Cobb-Douglas function. This is a common functional form in productivity analyses with known properties, as discussed in Varian (1982) and Viton (1981). In particular, the index of economies of scale is given by the inverse of a parameter, thus it is straightforward to test the hypothesis of constant returns to scale. It is not necessary to evaluate some nonlinear function of the estimated parameters and variables as in the case of linear or quadratic cost function. By the contrast, the marginal cost is a function of all the variables in the cost function. The functional form used is

$$C_i = K_i q_{1i}^{\alpha_1} q_{2i}^{\alpha_2} q_{3i}^{\alpha_3} w_1^{\beta_1} w_2^{\beta_2} w_3^{\beta_3} \quad , \tag{1}$$

where C_i is the firm i's total cost , q_{1i} is the number of passengers, q_{2i} is kilometers contracted during the period, q_{3i} is the average bus lines operated by the firm i, w_1 is the price of capital, w_2 is the price of diesel, and w_3 is the price of labor. We include two variables related to the output, q_2 and q_3, to capture the heterogeneity of the product.

The parameters to estimate are K_i, α_1, α_2, α_3, β_1, β_2, and β_3. The technology is represented by K_i and should be specific for each firm. This parameter also includes differences related to the geographical area where each firm operates. According to the production theory shown in Varian (1982), Viton (1981), Mattson and Ripplinger (2012), and Gagnepain and Ivaldi (2002), the cost function should be homogeneous of degree one in the input prices, therefore we impose the following restriction:

$$\beta_1 + \beta_2 + \beta_3 = 1 \tag{2}$$

For estimation, we write the cost function in logarithm and assume an additive error term (e_i). Thus, the equation we estimate is

$$\ln C_i = k_i + \alpha_1 \ln q_{1i} + \alpha_2 \ln q_{2i} + \alpha_3 \ln q_{3i} + \beta_1 \ln w_{1i} + \beta_2 \ln w_{2i} + \beta_3 \ln w_{3i} + e_i \quad , \tag{3}$$

where $k_i = \ln K_i$ and e_i is the firm i's random error term.

We use the degree of economies of density (or economies of scale with fixed network size) to analyze the industrial structure of the urban bus transit in Santiago. In our case, such index is equal to the inverse of the cost elasticity to the number of passengers. According to equation (1), the degree of economies of density is:

$$S = \frac{1}{\alpha_1} \tag{4}$$

To study the effect of network expansion on costs, we should use the concept of economies of spatial scope, which is unambiguous in contrast with the economies of scale with variable network size (Basso and Jara-Díaz, 2005).

3.2 Demand model

As others authors have done in the past (De Borger et al., 1996; Gagnepain and Ivaldi, 2002; Dargay and Pekkarinen, 1997), we define an aggregate demand model where the only variable is the fare of the bus. However, we take into account the effect of the natural demand growth and the monthly seasonality. The functional form we adopt is an exponential demand as follows:

$$q_t = t^{\mu} \exp\left[\eta p_t + \delta_0 + \sum_{m=1}^{11} \delta_m d_m \right], \tag{5}$$

where q_t is the total demand for bus transit in Santiago in the period t, p_t is the fare in period t, and d_m is a dummy variable that is 1 if the period t corresponds to the month m and 0 otherwise. The parameters to estimate are μ, η, and δ_m, $m = 1,...,11$ (from January to November). Notice that the demand model is a simple linear-elasticity model including some variables to take into account the effects of time and seasonality. Indeed, without such variables the demand will be given by $q_t = exp(n\, p_t + \delta_0)$, which is a standard demand functional form.

The adopted functional form implies a non-constant trend growth rate of the demand. However, such rate converges to zero. Indeed, the monthly growth rate is $(t+1)^{\mu} / t^{\mu} - 1$. Also, the functional form implies that the demand price elasticity (ε_t) is proportional to the fare. Indeed,

$$\varepsilon_t = \frac{dq_t}{dp_t} \frac{p_t}{q_t} = \eta p_t \ . \tag{6}$$

4 RESULTS

In this section, we present and analyze the results of the cost function and demand estimation. Table 4 shows the cost function parameters estimated with equation (3). Because of the homogeneity constraint explained in section 3.1, the parameter associated to labor is not estimated, but it is defined by the equation $\beta_3 = 1 - \beta_1 - \beta_2$. Since R^2 equals 0.97 the model fits the data very well.

We also estimated a model with passengers as the only measure of the output (Model 2). The estimation results for both models are shown in Table 4. The models are statistically significantly different, the likelihood ratio test is 13.55 (p-value = 0.001). This is explained because the number of served passengers is not the only variable describing the output. As explained before, it defines the number of bus lines and operation kilometers run by the firm capture the heterogeneity of the multiproduct nature of the transport firms.

Our estimation implies the industry exhibits significant economies of density. Indeed, the degree of economies of density, *S*, is 1.60 and 1.36 according to Model 1 and Model 2, respectively. These results agree with previous research (Viton, 1981; Williams, 1979) that estimated cost functions for urban bus operators of large cities. Also, these results explain the mergers of firms observed in the market, which were thirteen in 2007 and became seven in 2012.

Table 4: Estimated Parameters of the Cost Function

		Model 1		Model 2	
Parameter	Variable	Estimate	t-test	Estimate	t-test
α_1	Passengers (million)	0.625	7.828	0.736	9.551
α_2	Kilometers (thousands)	0.087	3.204	-	-
α_3	Number of bus lines	0.073	0.878	-	-
β_1	Fuel	0.133	2.377	0.162	2.793
β_2	Dollar exchange rate	0.513	2.857	0.509	2.688
β_3	Labor	0.353	-	0.329	-
k_1	Firm 1's fixed effect	0.128	0.297	0.928	2.785
k_2	Firm 2's fixed effect	0.322	0.691	1.145	3.194
k_3	Firm 3's fixed effect	0.042	0.098	0.835	2.514
k_4	Firm 4's fixed effect	0.857	1.755	1.712	4.502
k_5	Firm 5's fixed effect	0.902	2.088	1.740	5.270
k_6	Firm 6's fixed effect	0.835	1.852	1.604	4.330
k_7	Firm 7's fixed effect	0.979	2.037	1.798	4.684
k_8	Firm 8's fixed effect	0.865	1.840	1.645	4.234
k_9	Firm 9's fixed effect	0.683	1.565	1.437	3.930
k_{10}	Firm 10's fixed effect	1.003	2.325	1.805	5.872
R^2		0.97		0.96	
Likelihood ratio test		13.552			

(-) = Not estimated

In Model 1, the fixed effects (k_i) indicate the degree of technical efficiency of the firms. If we assume that the operation of trunk and feeder services use a different technology, it is possible to rank the firms according to technical efficiency. Since firms 1, 2, 3, 5 and 10 operate only feeder services, firm 10 is the less efficient feeder service. This is consistent with what was observed in Santiago, because that firm became insolvent in the third quarter of 2009 and exited the market. As firm 10 entered the market at the end of 2009, we assume that it was in a learning process in the period of analysis. Firms 6 to 9 operate only trunk services; therefore, firm 7 is the more inefficient one. As firm 4 operated two feeder and one trunk services, its technology is a mix of both types. As a feeder service, firm 4 is very inefficient, and as trunk service is in middle rank of efficiency. The inefficiency of this firm is confirmed because it resigned its contracts of service provision in 2011. Since our research is limited by the lack of firm-specific data for the factor prices of inputs (labor, fuel, and capital) it is possible that the estimated fixed effects are capturing differences in the actual factor prices that the firms are paying. Nevertheless, we could think about this as a problem of asymmetric information, where these differences in prices can be interpreted as differences in managers' effort to reduce cost, which induce inefficiency as Gagnepain and Ivaldi (2002) show.

The estimated parameters of the demand model presented in equation (5) are shown in Table 5. We transform the model applying logarithm and then we estimate the parameters with linear regression. The estimated model fits the data reasonably well; the adjusted-R^2 is 0.75.

Table 5: Estimated Parameters of the Demand Function

Parameter	Variable	Estimate	t-test
η	Fare	-0.001	-6.432
μ	Trend	0.083	6.414
δ_0	Constant	4.766	106.980
δ_1	January	-0.107	-4.552
δ_2	February	-0.247	-9.471
δ_3	March	-0.171	-6.545
δ_7	July	-0.070	-2.929

The demand exhibits high elasticity. For a fare of Ch$560 the elasticity is (in absolute value) 0.56. Such value is consistent with elasticities reported by Oum and Waters (2000), where they summarize estimated demand elasticities for passenger transport from several studies and report demand elasticities for bus trips in the range of (in absolute value) 0.01-0.96.

5 BUDGET-BALANCE FARE AND SUBSIDY

In this section we analyze three alternatives for financing the bus system in Santiago. In the first case, we determinate the balance-budget fare assuming no subsidy. In the second case, we take the fare as given at the level in December 2011 and compute the subsidy needed to keep such fare. Finally, we assume the amount of available subsidy is the amount approved by the Chilean Government in April 2012 and we calculate the according budget-balance fare.

Since the industry exhibits decreasing returns to scale, a marginal-cost pricing policy makes the operation unprofitable. Thus, we apply Ramsey pricing, which boils down to average-cost pricing.

To design the pricing policy, we need to consider that the system operates with integrated fares; so, the total revenue is not the fare times the number of taps. To estimate the fare by trip, we need to know the average number of taps per trip in the system. Using data on trips and taps for year 2011, we estimate that the average taps per trip is 1.605. Therefore, the fare will be 1.605 times the optimal payment per tap.

We make all computation assuming that factor prices (for labor, diesel and dollar exchange rate) are the values in December 2011. Also, the total kilometers driven and the number of services are set and keep constant on the value in December 2011. This assumption implies the actual frequencies and routes are enough to capture any demand increment. Likewise, we distribute the total demand among the firms according to the share of the demand in their corresponding served area in December 2011. The total cost of the system is, consequently, the sum of the costs of each firm.

We include the cost of the payment system as a fixed cost. This amounts to 8% of total cost of the system approximately. We assume the monthly cost of the payment system in December 2011 (Coordinación de Transportes de Santiago, 2012). In addition, there is another cost related to the user information system and an intermodal station that we consider as fixed cost. All these fixed costs sum 6,204 millions of CLP. Thus, the total cost of the system is the sum of the fixed cost (6,204 millions of CLP) plus the sum of costs of each firm (which depends on the demand at certain fare).

In our first case (budget-balance fare without subsidy), we estimate the value of the fare equal to the average cost of the system. Please note that in order to obtain these values; we need to solve an equilibrium problem, since firm's costs depend on the demand, which depends on the value of the fare. The value of the budget-balance fare and the demand are on Table 6.

In the second case (budget-balance fare with fixed subsidy), the Chilean Government decided in April 2012 to give an annual subsidy of 370,000 millions of CLP for the operation of Transantiago. But 190.000 millions CLP of this subsidy is used for subsidizing the student fare, which is one third of the normal fare. Therefore, only 180.000 millions of CLP can be used as subsidy for the operation of the bus system. Considering this, the fixed cost of the system is reduced by the corresponding subsidy; the average cost of the system is also reduced. Thus, the new equilibrium shows a budget-balance fare of 275 CLP (Table 6), which is almost half than the actual fare of the bus system.

In the third case (Government-fixed fare), we take the fare as given and we estimate the subsidy needed to satisfy the budget constraint. We use a fare of 560 CLP, which was the value of the fare in December 2011. The subsidy estimated (Table 6) is only 60% of the actual subsidy given for the operation of 2012.

Table 6: Fare, demand and subsidy estimation for three cases

Case	Fare (CLP)	Monthly Subsidy (millions of CLP)	Monthly Demand (millions of trips)
Budget-balance fare without subsidy	692	0	53
Budget-balance fare with fixed subsidy	275	15,000	79
Government-fixed fare	560	9,056	60

6 CONCLUSIONS AND POLICY IMPLICATIONS

Our results indicate that the bus transit system of Santiago exhibits significant economies of density. This means that for a given route structure, the expansion of the number of passengers reduce the average cost and it is convenient for the firms to increase the patronage. This may explain, at least in part, the reduction in the number of firms operating the system. Indeed, the firms try to reduce costs by increasing the patronage. Nevertheless, the merger of two firms operating in different areas implies an increase in the network covered by each firm and the effect on cost of such increase should be analyzed by means of the concept of economies of spatial scope (Basso and Jara-Díaz, 2005).

The existence of increasing returns to scale in the industry prevents applying a first-best (marginal-cost) pricing policy, because the average cost is higher than the marginal cost. The second best (Ramsey) pricing policy, which imposes a breakeven constraint, results in a fare around 15% higher than the current fare. It seems to be hard to implement in practice because the demand would be strongly reduced. This implies a high political cost in a city where the 60% of the trips are made by bus. Thus, according to our results a subsidy given by the Government is justified.

However, as far we know, such subsidy has been determined as the amount necessary to make profitable the operation of the system using accounting information delivered by the operators. There is no econometric study to determine the optimal level of subsidies. On the one hand, we show that for the current (December 2011) fare the subsidy should be 40% lower than the one determined by the Government. On the other hand, we show that for such level of subsidy the optimal fare should be only 50% of the current fare. It is remarkable that the existence of increasing returns to scale in the industry induces such a significant reduction in the fare.

Our results do not consider the different levels of efficiency in the industry. Thus, it seems possible to reduce furthermore the subsidies or the fare if we consider that only the more efficient firms operate. We leave this additional analysis for future research.

Also, we should mention that we use taps instead of real demand of passengers in our models. The main problem of this approach is the payment evasion. In the case of the cost function, this should not be a problem because the estimated parameters include the evasion as part of the cost. If the evasion is a constant fraction of the total demand, the marginal cost increases. If the evasion is a constant number of passengers, the fixed cost increases.

In the case of the demand model, our estimate of the price elasticity represents the elasticity to payment, which could be different from demand elasticity. However, for pricing policy design, the former should be the relevant elasticity, at least for small changes of the fare, because the main interest is the firms' revenue more than the total effective demand. This could be a problem if the cost was a function of the real demand, but in this case is a function of the taps.

Finally, in this calculations we do not take into account the externalities generated by private car and public transport trips such as accidents, pollution, congestion, and noise. Further research should include them, in order to have a broader picture for the decision-makers.

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