Technical Efficiency and Contractual Incentives: the Case of Urban Public Transport in France

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Abstract: This paper studies the relative performances of contractual arrangements used in the French local public transport industry. Levels of inefficiency are estimated with a production frontier approach. The results confirm the theoretical properties of incentive contracts that lead to better technical efficiency.

1. INTRODUCTION

In each French city, a local authority regulates the public transport industry. Most of these "Organising Authorities" do not choose a direct administration (*régie*), and the coexistence of several operators in the same area is uncommon. Usually, a single operator provides the urban transport service. In that case, a formal contract between the authority and an operating company defines the service specifications and the financing rules (pricing and subsidies). This paper aims to explore the different types of contract and their impact on the efficiency of public transit systems. Attention will be focused on the operational side (as opposed to the commercial side) and especially on the operators' level of efficiency. Our objective is to investigate the incentive clauses that may influence technical efficiency.

In order to obtain an econometric measure of inefficiency levels, we use a production frontier approach. The idea of best-practice frontier is to compare efficiency over time, across space, or both. Among the methods, which have been developed, we choose a parametric and stochastic specification. We run a database that gathers the large results of an annual survey. A production frontier is estimated for an eight-year panel of 136 French bus networks (989 observations) using the methodology proposed by Battese and Coelli [1995].

A recent survey (Murillo-Zamorano 2004) of the literature on frontier methods highlights the raid growth of this field. Due to the development of frontier methods for the study of efficiency, there is a large literature on the efficiency of bus (De Borger, Kerstens and Costa 2002) or rail (Oum, Waters and Yu 1999) transportation. Urban transit systems have specificities from one country to another. A lot of recent papers study the operators' production conditions, for instance in the U.S. (Sakano, Obeng and Azam 1997), Spain (Matas and Raymond 1998), Japan (Mizutani and Urakami 2003), or Norway (Jorgensen and Preston 2003).
But, this communication complements that kind of estimation by testing some of the institutional determinants summarised in De Borger and Kerstens

[2000]. Two recent contributions are close from our field (Gagnepain and Ivaldi 2002) or our methodology (Dalen and Gomez-Lobo 2003). Gagnepain and Ivaldi [2002] applied a structural approach[1] to the French sector. We did not choose this methodology, which introduce unnecessary biases that are avoided by the reduced form approach adopted here. Ivaldi and Gagnepain concluded that cost-plus contract are dominated by any type of second-best contract. On the other hand, Dalen and Gomez-Lobo [2003] used the methodology we will use, proposed by Battese and Coelli [1995], to investigate to what extend the different Norwegian regulatory contracts affect bus companies efficiency. They confirmed the dynamic benefits of yardstick competition.

The crucial question is which urban transit regulatory policy is best suited to stimulate technical efficiency. By testing the theory of incentives, we would like to participate in this debate. Our first contribution lie in the methodology implemented in order to determine the contractual determinants of efficiency. The second contribution concerns the database: this study is the first econometric use of the current best French panel on urban transportation.

The structure of this communication is therefore as follows: In section 2, we comment on the regulatory chances in France. Section 3 describes our data. In section 4, we present and discuss our model. Section 5 discusses our empirical findings. Finally, in section 6, the main conclusions from our work will be summarised.

2. REGULATORY SPECIFICITIES OF FRENCH URBAN TRANSPORT

The Domestic Transport Orientation Law (LOTI 1982) sets out the framework in which public urban passenger transport networks can be operated. The regulatory schemes have to take into account the fact that budgets are never balanced without subsidies. Indeed, operating costs are twice as high as commercial revenues in average. Prices are maintained at a low level in order to ensure affordable access to all consumers. As a consequence, the local communities, represented legally by an Organising Authority (OA), manage the market well before the consumers.

Each OA has the responsibility to choose a regulatory policy in order to organise the bus services in its area of responsibility. Direct operation by an administration is rare. Moreover, when operation is delegated by contract, the OA must issue a tendering procedure in order to choose the operator. Then a contract determines the relationships between the OA and its partner.

The contractual arrangements are multiple and various, but one of the most important dimensions concerns the industrial risk distribution. A usual typology defines the sharing of responsibilities and risks between the two partners (Certu 2003). On the one hand, the Organising Authority takes on both the commercial - the revenue - and industrial - the costs - risks in a “management contract” (*Gérance*). On the other hand, the operator takes on the industrial risk and the commercial risk in a "net cost contract". The OA provides an additional contribution to compensate the fare restrictions and the obligations related to the framework. In a "gross cost contract" (*Gestion à Prix Forfaitaire*), the operator takes on the industrial risk alone. The OA pays its operator a fixed annual sum determined as a function of forecast operating cost. This typology is modelled in table 1, according to Caillaud and Quinet [1993].

Table 1: Risks and types of contract

		Risk on cost borne by	
		Organising Authority	**Operator**
Risk on revenue borne by	**Organising Authority**	Management contract : $\tilde{\pi} = \pi^0$ $\tilde{s} = s^0 + (r^0 - \tilde{r}) - (c^0 - \tilde{c})$	Gross Cost Contract : $\tilde{\pi} = \pi^0 - (c^0 - \tilde{c})$ $\tilde{s} = s^0 + (r^0 - \tilde{r})$
	Operator		Net Cost Contract : $\tilde{\pi} = \pi^0 + (r^0 - \tilde{r}) - (c^0 - \tilde{c})$ $\tilde{s} = s^0$

π is the operator profit, *s* is the amount of subsidies, *r* correspond to the receipts and *c* represent the operating costs. π^0, s^0, r^0, c^0 are ex ante variables. $\tilde{\pi}, \tilde{s}, \tilde{r}, \tilde{c}$ are ex post variables.

In fact the contractual clauses are more various than suggested by the previous model. The risk distribution often depends on the negotiations and the local conditions. The share-out is rarely binary, and instead resembles a compromise. Moreover, the contracts do not systematically correspond to their name (from the usual typology). For instance, a net cost contract could have become a management contract since the last tendering, but its name remains the same. The contract is also a political signal. Aware of this complexity, we will consider that contracts have statistically the same meaning that suggested by their type name. This choice is more problematic for the most general and the most used contract: the net cost contract.

3. DATA

The database used here is provided by the CERTU (ministerial agency). The CERTU collects the results of an annual survey to all the French networks except in Paris area. The data are available between 1995 and 2002. We excluded the networks with at least one mass transit system (subway and tramway) which have obviously a different production function. We also reduced our sample by excluding the small network (under 30,000 inhabitants) that we assume to also have a different production function. In addition, several observations (network-year) are not full. Hence, an unbalanced panel (99 observation are not in the panel) has been run. This study is based on 989 yearly observations from 136 networks between 1995 and 2002.

3.1. Output and inputs

First consider the explicated variable, we opt for the number of vehicle-kilometres. In the literature, a "pure" supply indicator of output (e.g. vehicle-km or seat km) or demand-related output measures (e.g. passenger-km or the number of passengers) has been used. The main argument explaining our choice is that inputs do not necessarily vary systematically with demand-related measures, and therefore do not allow a reliable description of the underlying technology.

We used the traditional inputs in transport described in table 2: capital (number of vehicles), labour (including temporary work and subcontracting personnel), and energy (equivalent diesel m^3). The decomposition between driving and non-driving labour does not introduce additional elements and weigh down unnecessarily the model estimated.

Two types of issues complicate the network comparison. First, urban areas are characterised by different exogenous contexts: city sizes, types of housing, natural barriers. Several endogenous choices should also not be ignored: extensions into the suburbs, demand level (since we just consider the operation side) and public obligations. These two types of variables need to be controlled statistically. The estimation of a production function has a better meaning if we take the network differences into account. However, controlling for network structures and spatial characteristics is always a problem.

We used two control variables: the networks' length and the total amount of journey. The number of journey is important if we want to concentrate on the production side. Moreover, the demand impact on efficiency needs to be controlled. The networks' length is also an important control variable because an operator will be more productive in terms of vehicle-km if the network stretches far away. For instance a bus is able to go faster outside of the city than inside. We know that network length is a weak approximation of the speed differences but it is the only variable available.

Table 2: descriptive statistics

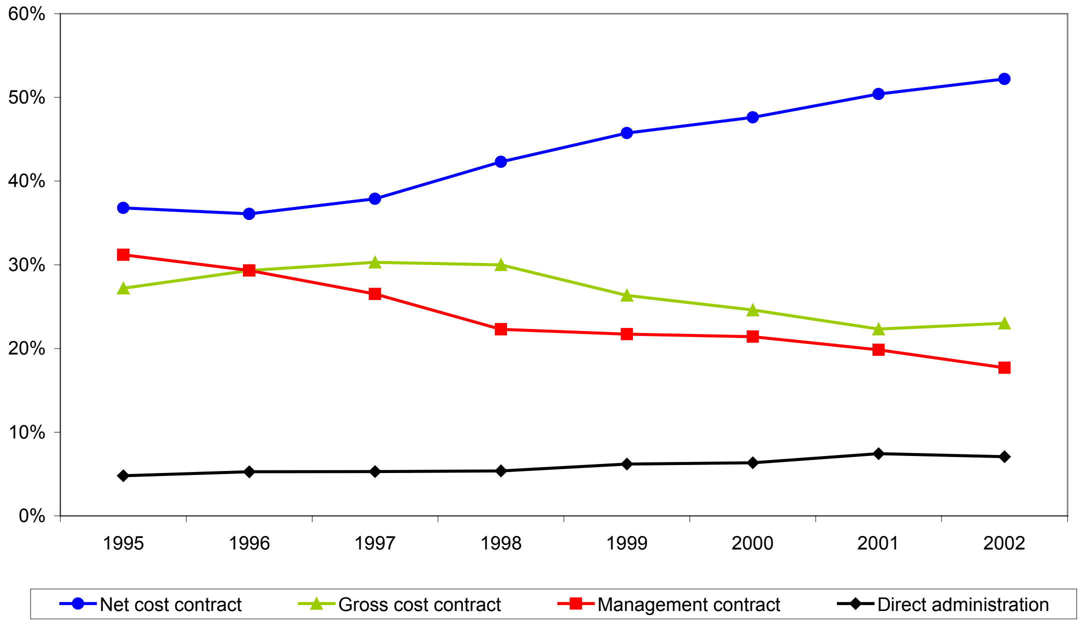
	Mean	Median	Standard deviation	Min	Max
Vehicle-km	2 468 941	1 266 089	2 535 040	178 106	11 380 524
Driving labour	108	56	120	7	691
Non-driving labour	38	18	46	1	280
Energy	1 113	533	1 257	63	6 006
Vehicle	64	37	64	5	365
Network length	158	110	127	14	645
Journey	6 901	3 266	8 395	173	38 295
Subcontracting	10,0%	4,6%	13,0%	0,0%	68,4%

3.2. The institutional determinants tested

We kept nine institutional variables that may influence efficiency. They deal with direct administration, contractual type, company partner, call for tenders and subcontracting.

Direct administration is not very common, especially in the larger networks. The percentage of direct administration is less than 6% of the networks and fewer than 3% of the vehicle-km provided (table 3). This scheme appears difficult to implement in the cities with more than 100,000 inhabitants. However, Troyes and La Rochelle are the only example[2].

Figure 1: Regulatory schemes from 1995 to 2002 (% of networks)



Two thirds of the regulatory schemes and 75% of the contracts are made up of incentive clauses. The net cost contract represents 45% of the contract on average and has an increased position during the period studied (figure 1). The other ones have a share close to 25% on average. Gross cost contract is the only one proportionally less used in the small networks.

The three major companies of the French urban transport sector, Connex, Keolis and Transdev, represent up to 70% of the vehicle-km offered. They are more involved in the big networks. Keolis has the biggest market share at 31% of the networks and 35% of the vehicle-km. This company is as big as Connex and Transdev together.

Table 3: Shares of the major companies and shares of each regulatory scheme

	Keolis	Connex	Transdev	Total affiliation	Net Cost	Gross cost	Manag-ment	Direct Adm.
% of networks	31.0% 49.4%	17.4% 27.8%	14.4% 23.0	62.7%	41.4% 45.8%	25.6% 28.3%	23.4% 25.9%	5.6%
% of vehicle-km	35.2% 50.6%	18.2% 26.2%	16.1% 23.2%	69.5%	46.0% 47.3%	21.8% 22.4%	29.4% 30.2%	2.8%

The second lines of small figures represent the percentages among the three major companies or between the contracts only.

Table 4 displays the contingencies between the companies and the regulation schemes. There are several key points. The first one is obvious since it concerns the incompatibility between a direct administration and a private company. The second situation concerns management contracts: Transdev do not really use this type of contract (0.6% of the observations), even though the networks without affiliation are using the management contracts more than the others (11.6%). In the opposite, net cost contracts are particularly used by Keolis (16%). This case is at least twice as common as the others. Finally, Connex do not often use gross cost contracts (3.8%).

Table 4: Number of each type of contracts for each affiliation

	Net Cost	Gross Cost	Management	Direct Adm.	Observations
KEOLIS	51.4%	27.1%	21.5%	0	317
CONNEX	49.7%	21.2%	29.1%	0	179
TRANSDEV	57.4%	38.5%	4.1%	0	148
Without affiliation	25.8% (31%)	24.1% (40%)	33.3% (39%)	16.68%	345
Observations	426	264	241	58	989

The variable *Subcontracting*, which represents the percentage of vehicle-km subcontracted, is described in the last line of table 2. And the last variable we tested was about one year before the end of the next call for tender. We suspected modifications of behaviour had lead to an increase in efficiency on the previous year.

4. THE MODEL

Farrell [1957] introduced the idea of best-practice frontiers and provided the first measurement scheme for efficiency. Several typologies of efficiency concepts had been introduced since this seminal paper. We will focus on technical efficiency, which appears to be the major source of poor performance in this sector (Kerstens 1999). Technical efficiency (TE) is defined as production on the boundary of the production possibility set. An operator is technically inefficient if its production occurs in the interior of the possibility set. By including a TE parameter, the production function becomes:

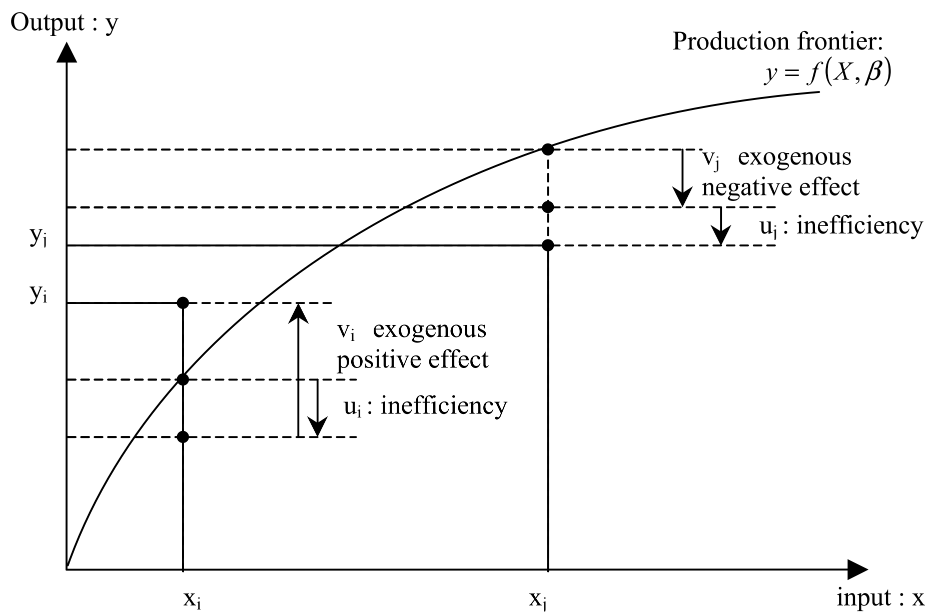
$$Y = f(X, \beta).TE$$

where Y is the output, X the vector of input and β a vector of technological parameters. The technical inefficiency is defined by the ratio between the real production with a fixed set of input and the best production with the same quantity of input,

$$TE = \frac{Y}{f(X,\beta)} \quad \text{which imply} \quad 0 \le TE \le 1$$

Deterministic methods take all observations as given and implicitly assume that these observations are exactly measured. We opt for a stochastic frontier analysis (SFA). Stochastic methods make explicit assumptions with respect to the stochastic nature of the data by allowing for measurement error. This approach is especially fruitful with panel data.

Figure 2: Decomposing the error term of a one input stochastic production frontier



The panel model proposed by Battese and Coelli [1993, 1995] allows for year/company specific efficiency measures to be estimated. The error structure adopted below follows their specification.

Consider the stochastic production frontier for panel data:

$$Y_{it} = f(X_{it}, \beta).\exp(v_{it} - u_{it})$$

where Y_{it} denotes the production at the t-th date (t = 1, 2, …, T) for the i-th firme (i = 1, 2, …, I);

X_{it} is a vector of values of known functions of inputs of production and other explanatory variables associated with the i-th firm at the t-th date; β is a vector of unknown parameter to be estimated.

The v_{it}s are assumed to be iid N(0, σ_v^2) random errors, independently distributed of the u_{it}s. The u_{it}s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be distributed independently, such that u_{it} is obtained by truncation at zero of the normal distribution with mean $z_{it}\delta$ and variance σ_u^2.

The technical inefficiency effects, u_{it}s, are assumed to be a function of a set of explanatory variables z_{it}, and δ a vector of unknown coefficient. The technical inefficiency effect in the stochastic frontier model could be specified as,

$$u_{it} = z_{it}\delta + w_{it}$$

where the random variable w_{it} is defined by the truncation of the normal distribution with zero mean and variance σ_u^2 (the point of truncation is $-z_{it}\delta$). w_{it} and v_{it} are assumed to be independent.
The technical efficiency of production for the i-th firm at the t-th date is defined by

$$TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - w_{it})$$

The errors terms are assumed to be independent from each other and form the inputs, Battese and Coelli propose the method of maximum likelihood[3] for simultaneous estimation for the parameters β and δ. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right)$.

We consider this simultaneous estimation preferable compared to the two-stage method. This older method consists of estimating a production frontier first, deriving the inefficiency measures for each firm. At the second stage, the inefficiency effects are regressed on some other variables, which explain efficiency variations across firms by an OLS or a Tobit model. The two-stage method is somewhat inconsistent since the inefficiency error terms are assumed to be identically distributed for each firm in the first stage. This assumption is contradicted clearly in the second stage when these error terms are assumed to depend on some other variables, except if every coefficient is nil.

5. RESULTS

The stochastic translog[4] frontier to be estimated is:

$$\ln Y_{it} = \beta_0 + \sum_{k \in \{P,E,V,L,J\}} \beta_k \ln X_{it}^k + \sum_{\substack{(l,m) \in \{P,E,V,L,J\} \\ j \geq k}} \beta_{lm} \ln X_{it}^l \ln X_{it}^m + v_{it} - u_{it}$$

Y is the total quantity of vehicle-km.
X^P is the total number of personnel
X^E denotes the quantity of energy
X^V corresponds to the total number of buses
X^L is the network length
X^J is the total number of journeys

where the technical inefficiency effects are assumed to be defined by:

$$u_{it} = \delta_0 + \delta_1 (NetCost_{it}) + \delta_2 (GrossCost_{it}) + \delta_3 (Management_{it}) + \delta_4 (Keolis_{it}) +$$
$$\delta_5 (Connex_{it}) + \delta_5 (Transdev_{it}) + \delta_5 (Tendering_{it}) + \delta_5 (Subcontracting_{it}) + w_{it}$$

There are four variables in the vector z that influence efficiency. Firstly, the regulatory scheme in a particular year is represented by three dummy variables (*NetCost*, *GrossCost* and *Management*). Secondly, three dummy variables represent the three main companies of the sector (*Keolis*, *Connex* and *Transdev*). Thirdly, a dummy variable notes if the network is in the year before the results of the competitive tendering (*tendering*). Finally, a variable stores the percentage of *subcontracting*.

Model 1 estimates the previous functions. Model 2 estimates the regulatory scheme alone in order the test multicolinearity between the regulatory schemes ant the operating company. Model 3 is a linearised version of the logarithm of the Cobb-Douglas production function.
All models were estimated using the software FRONTIER 4.1 (Coelli 1996).

According to table 5, the estimate for the variance parameter, γ, is close to 0.5 in the model 1 and close to 0.67 in the models 2 and 3. It indicates a significant level of technical inefficiency.

The three major companies of the sector contribute to efficiency whatever the regulatory scheme (except a Direct Administration, which excludes a partnership). Transdev, which has a very small number of management contracts, looks to be statistically in the best position.

The proximity of the next competitive tender procedure and the level of subcontracting do not appear to have a significant influence on operators' level of efficiency.

Table 5: Production frontier estimation results

Variables	Explicated variable: vehicle-km ; 989 observations					
	Model 1		Model 2		Model 3	
	Coefficient	t	Coefficient	t	Coefficient	t
Constant	9.54	21.1	9.42	21.48	8.84	188.2
Personnel (ln P)	0.545	0.664	0.518	6.778	0.038	6.138
Energy (ln E)	-0.764	-2.325	-0.583	-1.799	0.761	41.08
Vehicle (ln V)	0.051	0.209	-0.034	-0.140	0.170	11.07
Lines length (ln L)	0.148	1.238	0.137	1.198	0.021	3.245
Journey (ln J)	0.510	3.326	0.468	3.113	-0.061	-6.096
ln P x ln P	0.037	8.158	0.035	7.863		
ln E x ln E	0.380	4.620	0.344	4.182		
ln V x ln V	-0.080	-1.599	-0.083	-1.642		
ln L x ln L	-0.021	-2.119	-0.019	-2.078		
ln J x ln J	0.019	1.076	0.023	1.309		
ln P x ln E	-0.230	-6.024	-0.212	-5.533		
ln P x ln V	0.092	3.150	0.080	2.847		
ln P x ln L	0.022	1.330	0.020	1.302		
ln P x ln J	0.034	1.716	0.031	1.621		
ln E x ln V	-0.156	-1.336	-0.110	-0.953		
ln E x ln L	0.071	1.831	0.073	1.883		
ln E x ln J	-0.189	-3.106	-0.190	-3.069		
ln V x ln L	0.014	0.404	0.006	0.170		
ln V x ln J	0.123	2.142	0.116	2.014		
ln L x ln J	-0.073	-3.092	-0.070	-2.964		
Constant	-0.184	-2.871	-0.368	-5.667	-0.218	-1.224
NetCost	0.079	2.087	0.051	2.018	0.054	1.003
GrossCost	-0.219	-3.627	-0.487	-5.489	-0.442	-1.570
Management	0.166	3.887	0.230	5.985	0.045	1.140
KEOLIS	-0.075	-3.208			-0.242	-1.715
CONNEX	-0.104	-3.187			-0.022	-1.088
TRANSDEV	-0.204	-3.879			-0.241	-1.797
Tendering	-0,0069	0.634				
Subcontracting (%)	0,0004	3.202				
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.011	6.47	0.016	11.03	0.0186	3.332
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.496	4.41	0.670	17.12	0.6718	6.370
Log likelihood function	1114.37		1110.41		1042.41	
LR test of the one-sided error	42.11		34.18		26.18	

The estimated coefficient (in the inefficiency model) of each contractual arrangement creates particular interest within this study. The *Management* coefficient is positive, which indicates that a regulation with a management contract is more inefficient than a direct administration. The negative estimates for *GrossCost* implies that networks with that type of contract, tend to be less inefficient compared to direct management. In relation to net cost contracts, the relationship is very weak because the coefficient is very small and not very significant.

According to this estimation, the management contract, without incentives, is the worth regulatory scheme in term of technical efficiency. This result was expected since the private company has automatically a subsidy which exactly compensate its cost whatever its effort. Furthermore, contrary to a direct administration, Organising Authorities are unable to observe the lacks in its operator effort. The managers benefit from this informational asymmetry.

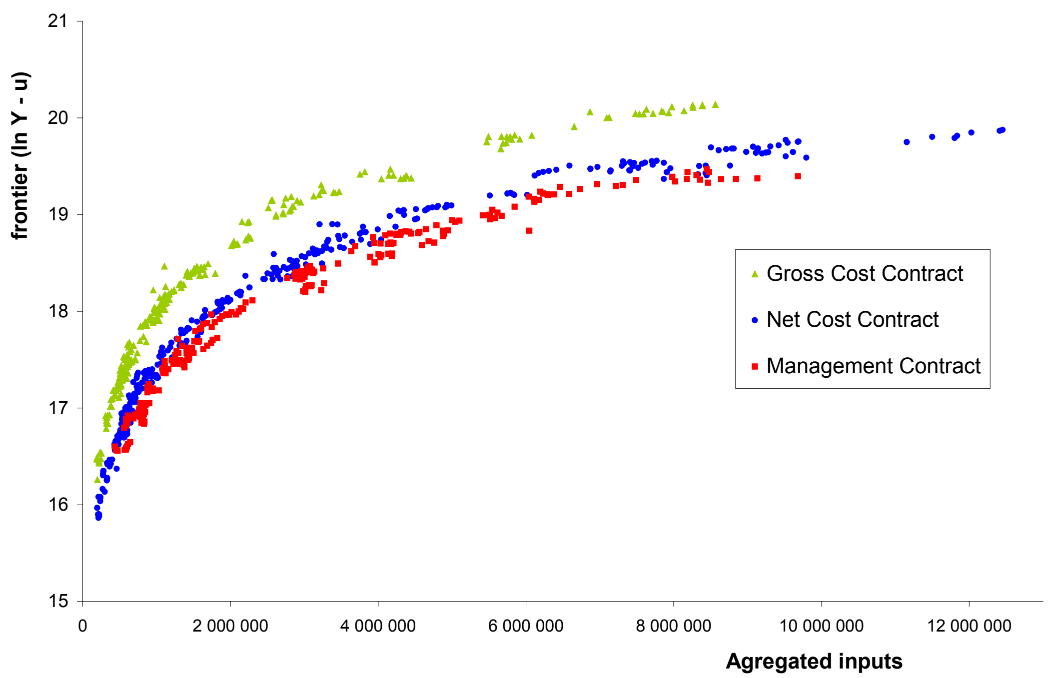
In a gross cost contract, the operator receives subsidies to finance the expected operating deficit. As a consequence, the operator has a financial interest in the productivity gains. Our estimation confirms that a gross cost contract promotes efficiency.

Theoretically, the net cost contracts have the same type of effect, but the coefficient is close to zero. The net cost contract is the most common contract. The nature of net contracts can vary and thereby could conceal the overall effect. Typically, this type of contract is used by some OA to do away with public transportation. The term "net cost contract" is also used in some contracts, including its clauses, which are relevant to a management contract. For instance, over a certain level of losses, the OA will compensate the deficit. Whatever, the coefficient is still significantly smaller than the *management* one, which is relevant to the traditional theoretical proposition about incentives.

Technical efficiency is correlated with incentives. Figure 3 represents the three frontiers. The management contract frontier is under the others. The possibilities of production with an incentive contract are higher. An incentive contract reduces inefficiency. Moreover, the choice of a partnership between the OA and one of the three major companies is statistically a source of efficiency.

Figure 3: Frontier estimates for each type of contract (model 2)

The vertical dimension represents real production diminished by inefficiency due to the contractual form.



6. CONCUSION

In this communication the Battese and Coelli model is used for this French urban transport panel data. We measured simultaneously the technical efficiency with a stochastic production frontier and the contractual effects on efficiency. According to this approach, we observed the expected positive effect of incentive contracts on technical efficiency.
This could be a strong argument in order to explain the decreasing number of management contracts compared to the incentives ones.

As underlined by Johansen, Larsen and Norheim [2001], technical efficiency is only part of the problem and tendering leaves the responsibility for market efficiency to public authorities that very often have limited capability and expertise. Once technical efficiency is maximised by incentive clauses, the next stage for local public transportation is to internalise the benefits of an increased level of service.

NOTES

[1] They start to recover operator's cost efficiency in order to model the effects of the introduction of an optimal regulatory contract.
[2] Marseille is not in our sample since it has light rail transits.
[3] See Schmidt and Sickles [1984] for a survey on stochastic frontier estimation methods with panel data.
[4] For a detailed perspective of translog functional form see Christensen, Jorgenson and Lau [1973]

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