# Incentive Regulatory Policies: The Case of Public Transit Systems in France

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*This paper is aimed at assessing the empirical relevance of the new theory of regulation. It relies on a principal-agent framework for studying the regulatory schemes used in the French urban transport industry. Taking the current regulatory schemes as given, the model of supply and demand provides estimates for the firms' inefficiency, the effort of managers, and the cost of public funds. It allows deriving the first-best and second-best regulatory policies for each network and comparing them with the actual situation in terms of welfare loss or gain. Fixed-price policies are lying between fully informed and uninformed second best schemes. Cost-plus contracts are dominated by any type of second-best contract. From these results, we may conjecture that fixed prices contracts call for better informed regulators.*

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## 1. Introduction

For more than ten years the new theory of regulation has been inspired by the theory of incentives and cast in terms of the principal-agent model. (See Loeb and Magat, 1979, Baron and Myerson, 1982, Laffont and Tirole, 1986.) The empirical adequacy of this framework is clearly on the research agenda for scientific and policy reasons. Providing evidence on the magnitude of informational asymmetries, on the relevance of adverse selection models or on the role of moral hazard is important scientifically. Moreover, as the design of more efficient incentive regulatory schemes has a social value, empirical studies could be helpful in implementing solutions derived from the new theory of regulation.

As a contribution to this new research in applied industrial organization, this paper studies the schemes used by the local political authorities in French cities to regulate their urban transport operators. Two main objectives drive the study. The first is to develop a methodology aimed at identifying and measuring informational asymmetries from observed behaviors and constraints. The second is to evaluate the discrepancy between actual regulatory practices and the optimal solution proposed by economic theory. In the process of achieving these goals, interesting measures of labor inefficiency, managerial effort, and the cost of public funds are obtained as by-products.

Testing the principal-agent framework raises several technical difficulties that are linked to the presence of latent variables not observable to the econometrician. In the recent years, advances in econometrics have offered ways to circumscribe these problems and have thus given birth to an empirical literature on asymmetric information. In a pioneer paper, Wolak (1994) estimates the production function of a regulated firm and is able to measure the effects of private information possessed by a Californian water utility in the regulatory process. He shows that estimation of an asymmetric information model may provide a different view on the technology from one that could be obtained by estimating a standard cost function. Wunsch (1994) calibrates menus of linear contracts as proposed by Laffont and Tirole (1986) for the regulation of mass transit firms in Europe. From the unexplained variance of previous cost function estimation, he measures the regulator's prior beliefs about the distribution of efficiency across firms. This approach is similar to that proposed by Dalen and Gomez-Lobo (1996) who recover the distribution of efficiency measures for transit operators in Norway from the residuals of a previous cost estimation. Finally, Gasmi, Laffont and Sharkey (1997) use prices of capital and labor to simulate the technological uncertainty and the effect of managerial effort on costs in local exchange telecommunications networks.

Here, unlike these earlier papers, we do not assume that actual regulatory mechanisms are optimal which remains in a sense to be made precise. Instead, we take their characteristics as given for estimating the model parameters, and then we measure the welfare differential between actual and optimal schemes. We recognize that doing so implicitly assumes that the choice of regulation is exogenous, and that relaxing this assumption would require a dynamic setting. However, given that only a few cases of change in the regulatory environment are provided by our sample, the dynamics of regulation cannot be addressed in a relevant way.

Nevertheless, the application of the theory of regulation under asymmetric information to the analysis of the urban transport industry in France turns out to be adequate and fruitful. In each city, we assume that the urban transport service is regulated by a local authority and is provided by a single operator. These two parties are tied together by a regulatory mechanism that is, in practice, either a fixed-price contract or a cost-plus contract. We assume that the principal (the regulator) does not observe the technological efficiency or the cost reduction activity of the agent (the operator). In this context, the regulator chooses prices in response to demand according to some observed or known parameters: costs, demand elasticities, the local cost of public funds and an engineering relation between demand and capacity. Moreover, the regulatory rule affects the operator's behavior and associated operating costs in one way or another. The econometric task consists in recovering the parameters of a static model of supply and demand, testing the relevance of the asymmetric information hypothesis, and evaluating the optimal regulatory schemes that can be designed using the estimates. Note that the whole model is set up as a sequential system of equations. This explains why we discuss the estimation of the supply model and the econometric analysis of the demand model independently.

Section 2 describes the regulation of urban transportation in France in more details and presents our database. Section 3 discusses the assumptions that are maintained throughout the paper. Section 4 introduces a theoretical modeling of the main features of urban transportation and the environment in which network operators make their decisions. Section 5 then presents a formal specification of the cost function and the effect of regulatory constraints. Section 6 is devoted to the discussion of the estimation method and results on the supply side. Dealing with the demand side, section 7 yields an evaluation of the cost of public funds for each urban area covered by the data set, derives the first-best and second-best optimal regulatory arrangements and compares them to the actual arrangements in terms of welfare changes. Section 8 provides a summary and some concluding remarks.

## 2. Overview and data

As in most countries, urban transportation in France is a regulated activity. Local transport networks cover each urban area of significant size; a local authority (a city, a group of cities or a district) regulates each network whereas a single operator provides the service. Regulatory rules prevent the presence of several suppliers of transport services on the same urban network. A distinguishing feature of France compared to most other OECD countries is that about eighty percent of local operators are private and are owned by three large companies, two of them being private while the third one is semi-public.[1, 2]

In 1982, a law on the organization of transport within France was promulgated whose main objectives are to decentralize urban transportation and to provide a guide for regulation. As a result, each local authority organizes its own urban transportation system by setting the route structure, the level of capacity and quality of service, the fare level and structure, the conditions for subsidizing the service, the level of investment and the nature of ownership. It may operate the network directly or it may concede service to an operator. In this case, a formal contract defines the regulatory rules that the operator must support as well as the payment and cost-reimbursement rule between the principal and the agent. In 1995, 62% of systems were operated under fixed-price contracts and 25% were operated under cost-plus contracts. Local authorities owned and directly operated only 6% of the networks.[3]

In most urban areas, operating costs are twice as high as commercial revenues on average. Budgets are rarely balanced without subsidies. One reason is that operators face universal service obligations. Prices are maintained at a low level in order to ensure affordable access to all consumers of public transportation. Moreover, special fares are provided to special groups like pensioners and students. The subsidies come from the State budget, the budget of the local authority, and a special tax paid by any local firm (having more than nine workers). They are not necessarily paid to the operator. Under fixed-price contracts, operators receive subsidies to finance the expected operating deficits; under cost-plus regulation, subsidies are paid to local authorities to finance ex-post deficits. In addition to the price distortions causing deficits, informational asymmetries that affect the cost side and lead to inefficiencies make it more difficult to resume these deficits. This is discussed in more details in what follows.

Performing a welfare analysis of regulatory schemes in a one-authority-one-operator setting requires a database that encompasses both the performance and the organization of the French urban transport industry. The basic idea is to consider each system in an urban area during a time period as a realization of a regulatory contract. Such a database has been created in the early 1980s. It assembles the results of an annual survey conducted by the Centre d'Etude et de Recherche du Transport Urbain (CERTU, Lyon) with the support of the Groupement des Autorités Responsables du Transport (GART, Paris), a nationwide trade organization that gathers most of the local authorities in charge of a urban transport network.[4] This rich source is probably unique in France as a tool of comparing regulatory systems to each other and over time. For our study, we have selected all urban areas of more than 100,000 inhabitants for a purpose of homogeneity. However, the sample does not include the largest networks of France, i.e., Paris, Lyon and Marseilles, as they are not covered by the survey. The result is that the panel data set covers fifty-nine different urban transport networks over the period 1985-1993.

## 3. Delineating the scope of the study

The organization of the urban transportation industry in France motivates the following assumptions.

*Assumption 1*: The network operator has private information about its technology and its cost reducing effort is unobserved by the authority.

Since French local authorities exercise their new powers on transportation policy since the 1982 law only, and since they usually face serious financial difficulties, they probably have limited auditing capacities. A good audit system needs effort, time and money. French experts on urban transport blame local authorities for their laxness in assessing operating costs, mainly because of a lack of knowledge of the technology. The number of buses required for a specific network, the costs incurred on each route, the fuel consumption of buses (which is highly dependent on driver skill), driver behavior toward customers, the effect of traffic congestion on costs, are all issues for which operators have much more data and better understanding than their principals. This suggests the presence of adverse selection. Given the technical complexity of these issues, it should be even harder for the local authority to assess the effort of its agent (operator) to provide appropriate and efficient solutions. It is then straightforward to assume the presence of moral hazard.

Below we estimate a cost function derived from an economic model that describes the relationship between a local authority and a public transit operator according to a principal-agent setting under asymmetric information. To test for the presence and the relevance of informational asymmetries in the urban transport industry, we compare our asymmetric information model and a standard cost function model with no inefficiency parameter or effort choice using a nonnested test. The test favors the alternative we propose.

Informational asymmetries play a crucial role in the setting of contractual arrangements and the design of financial objectives. We turn now to the second assumption.

*Assumption 2:* Regulatory schemes and operators' efficiency levels are exogenous.

According to the new theory of regulation, when contractual relationships are characterized by informational asymmetries, a welfare-maximizing regulator applies the revelation principle for providing the operator with incentives to reveal the true efficiency level. This mechanism can be decentralized through a menu of linear contracts and avoids excessive rent leavings. (See Laffont and Tirole, 1993 for a model of optimal regulation under adverse selection and moral hazard.) Each operator facing such a menu chooses the contract that corresponds to its own efficiency level. In this context, the most efficient firm chooses the highest-powered incentive scheme, i.e., a fixed price contract while the most inefficient firm chooses the lowest-powered incentive scheme, i.e., a cost-plus contract. Between these two extremes are incentive schemes (according to the terminology used by Laffont and Tirole, 1993) chosen by firms with intermediate efficiency levels.

Does this framework apply to the French urban transport industry? If it did, fixed-price and cost-plus contracts would be extreme cases of a menu and would be chosen by the most efficient and the most inefficient firms, respectively. Since current rules apply to any companies (even the ones with intermediate efficiency levels) and since the real world cannot be confined to fully efficient or inefficient firms, one must conclude *a priori* that observed contracts do not allow for any self selection mechanism, and cost-plus and fixed-price schemes are equally proposed to operators without paying any attention to their efficiency level. In other words, current regulatory schemes are not optimal in this sense.

However, as shown for instance by Wilson (1993), and Lewis and Sappington (1989), a regulator can get close to optimality with a properly designed two-items menu. Therefore, the fact that we observe only two types of contracts in the industry may not be sufficient to conclude that the regulatory system is totally inefficient. The assumption that the types of regulatory contracts are exogenously chosen should rather be based on a close look at the regulatory history of the industry.

Documentary investigation of the organization of the urban transport industry and of the regulatory practices over the last 30 years suggests that the presence of a particular operator on a specific area and the choice of one particular regulatory regime are better explained by historical reasons than as the result of a well-defined economic game. First, note that usually operators belong to even larger corporations, which provide cities or municipalities with other services like water distribution, waste collection or car parking. It is not rare to find the same corporation operating the transport and water networks for instance. In this case the situation could be more rigid in the sense that it is more difficult for a municipality (which has limited resources) to get rid of its operator. Second, each of these firms is involved in different types of contractual arrangements with different local entities.[5] Third, there was no explicit competition between these firms before 1993. Contracts were renewed automatically.[6] Thus, no replacement of operator has been observed over the period; likewise, in nine years and among sixty networks, only 1.1% of arrangements switched from one contractual form to the other (cost-plus to fixed-price or fixed-price to cost-plus). Since 1993, beauty contests are lawfully required to allocate the building and management of new infrastructures of urban transportation and the automatic renewal of contracts came to an end. Finally, note that, in the seventies, cost-plus contracts were employed in almost 100% of the cases; in the eighties, these contracts represented 60% of the arrangements; in 1995, as mentioned before, the cost-plus share goes down to 25%. French experts have argued that local governments were strongly committed to the financing of the public transit system during the seventies, because the notion of universal service was extremely important for them during the period. This is why cost-plus contracts were popular until the beginning of the eighties. Afterwards, due to the uncontrollable increase of operating and investment costs in the whole industry, these local authorities decided to decrease their financial responsibilities and switched to fixed-price contracts. This phenomenon turned out to be more pronounced after 1982 when local governments became fully responsible for the public transit system, and after 1993 when some operating licenses started to be awarded through competitive tendering.[7] As already mentioned, the situation remained stable between these two periods, i.e., the periods of interest for our study.

Therefore, it is realistic to assume that regulatory schemes are independently selected. In particular, the choice of regulatory schemes is not driven by the intrinsic characteristics and efficiency levels of large service companies and of network operators. An empirical test is proposed later to support this assumption. We show that the empirical distributions of operators' inefficiency parameters associated with the two types of contract are not significantly different. This suggests that cost-plus (fixed-price, respectively) arrangements do not attract inefficient (efficient, resp.) operators.

As already noticed, assumption 2 implies that current regulatory regimes are not optimal; i.e., local governments are not maximizing social welfare. Taking current schemes as given, our objective is now to estimate the main ingredients, i.e., efficiency, cost of public funds, technology, demand characteristics; that are needed to simulate optimal contracts. We show that significant social improvements can be obtained if asymmetries of information are properly taken into account when designing the regulatory contracts. Our results moreover suggest that the degrees of asymmetry of information are quite large and differ from one network to the other.

## 4. Theory and reality

To derive a structural model of the urban transport industry requires a detailed account of the technological, informational, and regulatory constraints. Here, we consider a urban transport network which mainly relies on transport vehicles that can be affected by traffic congestion, i.e., which can marginally benefit from a limited set of specific infrastructures, like bus lane, tramway or subway.

*Technology*

In order to provide the required level of services, denoted by $Y$, the transit firm needs to combine four input factors: Labor ($L$), materials and energy ($M$), *soft* capital ($I$) and *hard* capital ($K$). $L$ includes all types of workers; $M$ corresponds to various inputs which are regularly renewed, at least within a year; $K$ refers to transport vehicles (rolling stock and infrastructure) and $I$ includes all materials used for performing management activities like computer services for instance. The production process is then represented as

$$Y = f\left(L, M, I, K \middle| b\right), \tag{1}$$

where $b$ is a vector of parameters characterizing the technology in the production process.[8] Note that $L$ is the efficient amount of labor, which is observable by the operator only. Later on, when we construct the cost function, we distinguish between this efficient quantity and the quantity observed by the regulator.

At this point, it is useful to recall recent discussions on the definition of outputs in a transit industry. This question applies to all network industries like telecom or electricity as well. In the short run, each operator faces a fixed network size. When providing the service, the transit firm offers a specific capacity determined by the total number of seats available in the transport vehicles, and the total mileage performed by these vehicles. Based on this supply and regulated prices, consumers make optimizing travel decisions that consist of a particular number of trips. Hence, as already suggested by numerous authors, passenger-trips are not as much under the control of operators as would be the number of cars constructed by an auto manufacturer, for example. Indeed, in a way, the consumer also produces trips since he or she contributes time. For this reason, it is common to distinguish between intermediate and final outputs in transit systems. (See Small, 1990.) Actually, transit firms are concerned by the intermediate output as measured with the number of seat-kilometers, i.e., by the capacity to produce a potential for trips. "The (...) outputs, such as vehicle-kilometers, are produced by the transit firm and, in turn, are used as inputs by passengers in their production of final outputs such as passenger-kilometers or total passenger-trips. This characterization of transit output is quite useful if we construct a general equilibrium model of transit, in which transit firms supply intermediate-type outputs while passengers, who demand them, generate final-type outputs." (See Berechman, 1993.)

In other words, costs and revenues are driven by two different output variables that are closely related. For the purpose of deriving the optimal contract, it is crucial to disentangle supply side effects from demand side effects, hence to distinguish between the capacity supplied, ($Y$), and the level of transport services requested by the customers ($y$). However they are technically related through an engineering function that we specify as follows:

$$Y = f(y). \tag{2}$$

Equation (2) provides a reduced form of a dynamic and technical adjustment process between capacity and demand.

The econometric model below comprises three equations in a block-recursive structure which is detailed in an appendix. The lower level provides the demand of transport that explains the demand (usage) of transport in terms of average regulated prices and some variables assumed to be exogenous like the quality of service. Note that the average price of transport services in each network is regulated according to a form of price cap imposed by the government, and so can be assumed exogenous. The middle level is constituted by Equation (2) that provides a relationship between demand and capacity (or supply). This equation just says that, at each period, one can identify the engineering function that has been used to set up the network structure in terms of size. The upper level is made of the cost function that relates cost to capacity and to other elements like the level of capital, the inputs prices and the effect of regulatory schemes.

*Informational asymmetries*

The case of information incompleteness on the demand side is ruled out. That the managers of the transit firm could have better information than regulators on the price elasticity associated with different routes of the network at different periods for different types of fare, is a conjecture that would be worthwhile to follow and to test. However, we are concerned here by the elasticity of the aggregate demand of urban transport and it is realistic to assume that it is common knowledge. Indeed, as time series or cross sectional studies estimating demand elasticity of urban transport are now widely available, regulators and operators of the urban transport industry are equally well informed.

Our focus is on informational assumptions on the supply side. As the labor input represents roughly sixty percent of total operating costs, this potential candidate as a source of informational asymmetries is unavoidable. Our assumption is that the network operator is better informed on labor efficiency than the regulator. This is based on the view that bus drivers play a decisive and acute role in operating the network, especially with respect to the flexibility and punctuality of operations in peak periods. First, bus drivers permanently meet the end users. Their behavior vis-à-vis the customers may perceptibly affect the quality of service during high peak periods. Indeed, the driver has to perform several tasks at the same time, selling tickets, monitoring the passengers' up-and-down movements, managing the use of bus seats and space. Clearly, these tasks are much harder to accomplish in periods of traffic congestion. Moreover, drivers have to deal with social and security problems, particularly in areas where the underprivileged population is large.

Second, driving ability sways the quality of capital (i.e., rolling stock) given the need to maintain engines or repair buses after a road accident. In addition, the network structure may affect the driving conditions. On a same network, each bus route has its own specificity of traffic lanes, route length, road access that complicates the evaluation of drivers' skills.[9]

These remarks have two implications. First, it is not possible to appraise the labor efficiency by just looking at the observed quantity of hired workers. Second, labor inefficiencies affect the choice of other inputs. As a result, we distinguish between observed and efficient labor forces. Let $\hat{L}$ be the physical amount of labor forces that is the source of cost distortions and is observable by the authority. Then $L$ is the efficient level of labor associated to the output level $Y$. Assume that the ratio of observed to efficient input quantities is a direct measure of informational discrepancies between the regulator and the network operator. In other words, $L$ and $\hat{L}$ are linked according to the relation

$$\hat{L} = L \exp(q - e). \tag{3}$$

Parameter $q$, the so-called labor inefficiency parameter, refers to variables that are not under the control of the operator. Actions that can be taken by managers to counterbalance the effect of labor inefficiency are summarized by the variable $e$, which defines the effort level of managers. Note that $\hat{L}$ converges to $L$ as $q - e$ goes to zero. (For a purpose of normalization, it is assumed that $q$ is always larger than or equal to $e$.[10]) Since the behavior of drivers is the source of cost distortions, we assume that managers spend time and effort in monitoring drivers, providing them with training programs, solving potential conflicts, etc. Both labor inefficiency and cost reducing activity are unobservable to the regulator and to the econometrician.

Note too that the cost function is directly influenced by informational constraints. Assuming that the operator is a price-taker in the market for input factors and has a cost-minimizing behavior for each level of effort, an operating cost function can represent the technological process. Operating costs faced by the operator are

$$C = w_L \hat{L} + w_M M + w_I I, \tag{4}$$

where $w_L$, $w_M$ and $w_I$ are the prices of labor, materials and soft capital respectively. Note that hard capital does not involve costs for the operator, who is allowed to freely use the rolling stock owned by the regulator.[11] From duality theory, the conditional operating cost function is defined by

$$C(Y, K, w, e, q \mid b) = \min_{L,M,I} w_L L \exp(q - e) + w_M \mathrm{M} + w_I \mathrm{I} \quad \text{subject to} (1), \tag{5}$$

where $w$ is a vector of input prices. This means that total costs faced by the operator not only entail operating costs, but also unobservable internal costs that are defined below. Equation (5) defines a conditional cost function in the sense that it contains a fixed factor (hard capital) and a level of effort.

Now the regulatory constraints can be cast in terms of the operating cost function.

*Regulation*

The local public authority is responsible for the organization of service in its territory. In particular, it imposes on the operator an average level of transport price, $p$, and therefore, a level of transport capacity, $Y$. Indeed, given that the selected price is a point on the inverse demand function, $p(y)$, when the authority has set the price, the associated demand is implicitly determined, i.e., the customers adjust their demand at this price. Doing so, the authority has also defined a level of capacity through the technical relation defined by Equation (2).

An important aspect of the regulation of urban transport in France is that the authority owns the rolling stock and the infrastructure, which are placed at the operator's disposal. This means that the authority should have good knowledge of the state of capital stock, in particular the age of transport vehicles.[12]

The authority also chooses the regulatory scheme that defines cost reimbursement rules and the final owner of commercial revenue at the end of the reference period, usually a year. Two types of contract are observed in practice. The first type corresponds to the so-called cost-plus contracts.[13] In this case, the public authority receives the commercial revenue $R(y)$, and pays the firm's total ex-post operational costs $C$ and a net monetary transfer $t_0^{cp}$. The remuneration of the firm is then given by

$$t = t_0^{cp} + C(Y, K, w, e, q | b). \tag{6}$$

Hence, the firm is not residual claimant for effort. For this reason, this contract is a very low powered incentive scheme, as firms under this regime have no incentives to produce efficiently. Note that the firm's utility level can be defined as

$$U = t_0^{cp} - y(e), \tag{7}$$

where the increasing and convex function $y(e)$ represents the internal cost of effort.

With the second type of contract, the so-called fixed-price contract, the operator is residual claimant for effort. This time it obtains a transfer equal to the expected balanced budget, which is the difference between expected costs and expected revenue. The remuneration of the firm is just

$$t = t_0^{fp}. \tag{8}$$

This contract is a very high-powered incentive scheme as the operator is now responsible for insufficient revenues and cost overruns.[14] The utility of the firm is given by

$$U = t_0^{fp} + p(y)y - C(Y, K, w, e, q | b) - y(e). \tag{9}$$

Finally, we define the variable $r$ that takes the value $r = 1$ for a fixed-price contract and $r = 0$ for a cost-plus contract. The payment and remuneration of the firm under the two types of contract can then be restated as

$$\begin{gathered} t = r\, t_0^{fp} + (1 - r) t_0^{cp} + (1 - r) C(Y, K, w, e, q | b), \\ U = r\, t_0^{fp} + (1 - r) t_0^{cp} + r\left[p(y)y - C(Y, K, w, e, q | b)\right] - y(e). \end{gathered} \tag{10}$$

This ends the presentation of the environment in which the operator takes its decisions, i.e., determines the level of its cost-minimizing effort and input factor quantities required for running the network system.

## 5. Cost structure and regulation

Over the contracting period, taking technological, informational and regulatory constraints as given, the operator has only to choose the optimal input and effort allocation. Our objective here is to recover the parameters of the production function, the level of inefficiency and the cost-reducing activity. This is achieved through a structural estimation of present operating costs. It is a structural estimation in the sense that the method accounts for the effects of regulatory constraints. Doing so should reduce the sources of misspecification, which, in turn, should avoid bias in the estimates of technological parameters. This will allow us to assess the potential discrepancy between current and optimal regulatory schemes in terms of global efficiency, industrial costs and welfare.

For ease of exposition and interpretation, the decision process has been decomposed into two steps. The first is defined by program (5): Whatever the contractual arrangement, the operator chooses the cost-minimizing input allocation. At this point, only the technological constraints are taken into account. This leads to a cost function conditional to a certain level of effort. Note that, for any functional form, the associated cost function depends on the distorted labor price. Indeed, just inserting Equation (3) into Equation (4) enables us to define

$$\hat{w}_L = w_L \exp(q - e). \tag{11}$$

In other words, since $\exp(q - e)$ is greater than one, the operator minimizes costs by taking into account a higher labor price. That is, the marginal rate of substitution of any pair of inputs containing labor is higher than the observed price ratio of inputs, which may lead to inefficiencies.

Now, consider the second step in resolving the operator's optimization program. First, we show that the effort level depends on the type of incentives provided by the system of regulatory constraints. Second, we describe how the contractual environment affects the cost function and input allocation, i.e., how operating costs are distorted upward or downward.

As price and output levels are set by contractual rules, the firm manager has only to determine the level of its cost reducing activity. Hence, he solves the program defined as

$$\underset{e}{Max}\, U = \rho\, \tau_0^{fp} + (1-\rho)\tau_0^{cp} + \rho\left[p(y)y - C(Y, K, w, e, \theta \,|\, \beta)\right] - \psi(e), \quad \rho \in \{0,1\} \tag{12}$$

Under a fixed-price regime, the optimal effort satisfies the relationship

$$\psi'(e) = -\partial C / \partial e, \tag{13}$$

which implies that the marginal disutility of effort $\psi'(e)$ equals marginal cost savings $-\partial C/\partial e$. Under a cost-plus regime, the optimal effort level is zero.

*Cobb-Douglas technology*

For interpretability and tractability, we choose a simple Cobb-Douglas function to represent the technology. Computations of the optimal regulatory scheme become cumbersome when one uses more elaborate cost functions like the so-called translog. The Cobb-Douglas function is easy to handle while providing a description of the technology sufficiently precise for our purpose. It may be not the best choice for achieving a good approximation of the true cost function but it allows us to derive closed form solutions. In particular, because of the choice of a Cobb-Douglas function, the two-step procedure we adopt above for solving the operator's program provides the same solution as if we have solved both steps at once, i.e., the choice of optimal levels of variable inputs conditional to a given level of effort according to Equation (5) and then, the choice of effort according to Equation (12). Under a Cobb-Douglas technology, the dual cost function is given by

$$C = \beta_0 \exp\left[\beta_L(\theta - e)\right] w_L^{\beta_L} w_M^{\beta_M} w_I^{\beta_I} Y^{\beta_Y} K^{\beta_K} . \tag{14}$$

We assume homogeneity of degree one in input prices, i.e., $\beta_L + \beta_M + \beta_I = 1$. Note however, that no constraint is imposed on the returns to scale effects.

First-order condition (13) can be restated as

$$\psi'(e) = -\partial C/\partial e = \beta_L C . \tag{15}$$

So, under fixed-price regimes, marginal cost savings are proportional to the cost level and are increasing with $\beta_L$, which can be interpreted as the marginal cost saving ratio. In other words, when the labor cost share gets larger, an increase in the cost-reducing activities leads to higher cost savings. Note that under a cost-plus regime this is not relevant.

*Current costs*

Assume that the cost of effort is specified by

$$y(e) = \exp(a e) - 1 \text{ with } a > 0 . \tag{16}$$

Combining Equations (14)-(16), the optimal effort level is

$$e^* = \left[ \ln(b_L b_0) + b_L q + b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K - \ln a \right] / (a + b_L) . \tag{17}$$

The amount of effort is an increasing function of the inefficiency parameter $q$, the output level $Y$, and the input prices $w_L$, $w_M$, and $w_I$. Moreover, $e^*$ is a decreasing function of $a$, the technological parameter of the internal cost function.

For the two types of regulatory regimes, inserting the appropriate optimal effort in the cost function defined by Equation (14) yields the final cost function to be estimated. Since a firm regulated under a cost-plus regime exerts no effort, its cost function, in logarithmic form, is given by:

$$\ln C = \ln b_0 + b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K + b_L q . \tag{18}$$

Alternatively, a firm regulated under a fixed-price scheme has the following cost function:

$$\ln C = b_0' + x\left(b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K + b_L q\right), \tag{19}$$

with $x = a/(a + b_L)$ and $b_0' = \ln b_0 + b_L(\ln a - \ln b_L - \ln b_0)/(a + b_L)$. Note that, as $a$ increases, the parameter $x$ approaches 1 and the fixed-price cost function converges to the cost-plus cost function.

It is useful to express the cost differential between a cost-plus (*CP*) and a fixed-price (*FP*) contract as

$$\ln C_{|FP} - \ln C_{|CP} = \frac{b_L}{a + b_L}\left[\ln\left(\frac{a}{b_0 b_L}\right) - \ln \tilde{C}\right], \tag{20}$$

where

$$\ln \tilde{C} = b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K + b_L q . \tag{21}$$

We expect the difference given by Equation (20) to be always non-positive.

Summing up, the operating cost function to be estimated can be written as

$$\begin{aligned} c = {} & r\left[b_0' + x\left(b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K + b_L q\right)\right] + \\ & (1 - r)\left[\ln b_0 + b_L \ln w_L + b_M \ln w_M + b_I \ln w_I + b_Y \ln Y + b_K \ln K + b_L q\right] \\ \equiv {} & c(Y, K, w, q, r \mid b). \end{aligned} \tag{22}$$

Note that the cost function to be estimated, ln$C$, is now denoted $c$ in order to avoid confusion with the functional forms presented in Equations (18), (19), and (26).

## 6. Measurement of technology, efficiency and effort parameters

The original feature here lies in the way the stochastic part is built into a classical Cobb-Douglas cost function through the efficiency parameter. Indeed, assuming that parameter $q$ has a density function $f(q)$ defined over an interval $[\underline{q}, \bar{q}]$ where $\underline{q}$ ($\bar{q}$ respectively) corresponds to the most (least) efficient firm, provides us directly with the stochastic element required to perform the estimation. Not only the technological parameters but also the distribution of the efficiency parameter can be estimated.

*Data and variables*

Estimating the Cobb-Douglas cost function requires measures on the level of operating costs, the quantity of output and the input prices. Summary statistics are given in Table 1.

Total costs $C$ are defined as the sum of labor, materials and soft capital costs. Output $Y$ is measured by the number of seat-kilometers, i.e., the number of seats available in all components of rolling stock times the total number of kilometers traveled on all routes. In other words, this measure accounts for the length of the network, the frequency of the service and the size of the fleet. Note that the network capacity is also a measure of the quality of service.

Capital $K$, which plays the role of a fixed input in our short-run cost function includes rolling stock and infrastructure. Since the authority owns capital, the operators do not incur capital costs.

The average wage rate $w_L$ is obtained by dividing total labor costs by the annual number of employees. Materials include fuel, spares and repairs. As the number of buses actually used mainly determines these expenditures, one derives an average price of materials $w_M$ by dividing material expenditures by the number of vehicles. Soft capital includes commercial vehicles, computer service and office supplies. These charges are induced by the activity of network management. By dividing investment charges by the number of customer trips per year, one obtains the price $w_I$ of managing single consumer travel.[15]

*Stochastic assumptions and estimation method*

For a network $i$ at period $t$, the stochastic cost function can be stated from Equation (22) as

$$c_{it} = c\left(Y_{it}, K_{it}, w_{it}, q_i, r_{it} \middle| b\right) + e^{c}_{it}, \tag{23}$$

where an error term is added to account for potential measurement errors. It is assumed to have a normal density function with mean 0 and variance $s^2_c$. Moreover, the efficiency index $q$ has a beta density with scale parameters $m$ and $n$. The choice of this distribution is dictated by two considerations. First, in view of the relationship between the efficient and actual levels of the work force defined by Equation (3), the labor inefficiency parameter is conveniently defined as a percentage.[16] This is readily obtained since the beta density is defined over the interval $[0, 1]$. In this case, given Equation (3), the level of effort is also defined over the unit interval since $(q - e)$ must be non-negative. In fact, choosing a beta density is an adequate normalization that does not impose strong restrictions.[17] Second, we need a density function defined on a compact support for at least two reasons: To have a well defined log-likelihood function and to have a well defined optimization program when we turn to the derivation of optimal contracts.

The likelihood of a data point conditional to $q_i$ is

$$L_{it}(q_i) = L\left(c_{it} \middle| Y_{it}, K_{it}, w_{it}, q_i, r_{it}, b, s_c, m, n\right) = \frac{1}{s_c} g\left[\frac{e^{c}_{it}}{s_c}\middle| q_i\right], \tag{24}$$

where $g(.)$ denotes the normal density function. However, since the variable $q_i$ is unobservable, only the unconditional likelihood can be computed, i.e.,

$$L_{it} = \int_0^1 L_{it}(u_i) \; u_i^{n-1} (1 - u_i)^{m-1} \frac{\Gamma(n + m)}{\Gamma(n)\Gamma(m)} du_i, \tag{25}$$

where $\Gamma(.)$ is the gamma function. Assuming that observations are independent, then the log-likelihood function for our sample is just the sum of all individual log-likelihood functions obtained from Equation (25).

The preceding specification is based on three implicit assumptions. First, the efficiency parameter is independent of time, which is debatable. This implies that contracts are renewed each year independently of what the state of nature was in the past. In a dynamic setting, inefficiency could evolve, and its evolution could be approximated by a trend. (See Cornwell, Schmidt and Sickles, 1990, for such a model.) Our attempts in this direction have not been successful. Second, the distribution of $q$ is independent of the type of contracts. In section 3 we already suggested that the choice of contract is mostly dictated by the political history of the network and the political agenda of the local authorities rather than the real efficiency $q$ of the network. Third, the inefficiency level does not depend on the identity of the company managing the network. We believe that the characteristics of each network differ from one city to the other. The managers' ability to use efficient amounts of labor, material and even fuel may differ from one network to the other, even if the workers have similar skills ex-ante. In addition, conflicts with worker unions, social and security problems, externalities like traffic congestion are clearly idiosyncratic phenomena. Hence the efficiency level $q_i$ pertains to the network itself, more than to the effect of the manager's "culture". Below we keep the temporal independence of $q_i$ as a maintained assumption, but we test the two other assumptions of independence.

*Estimation results*

Estimates are gathered in Table 2. There, we also report estimates of a Cobb-Douglas cost function without taking into account regulatory and informational constraints. This model is referred as the standard case, while the above cost function is called the asymmetric information case in Table 2. The standard case, namely,

$$\ln C_{it} = b_{0i} + b_L \ln w_{L,it} + b_M \ln w_{M,it} + b_I \ln w_{I,it} + b_Y \ln Y_{it} + b_K \ln K_{it} + e_{it}^{c}, \qquad (26)$$

includes a firm effect $b_{0i}$ to allow for a fixed-effect estimation procedure.[18]

All parameters are highly significant (except $b_Y$ in the standard case). In particular it is true for the scale parameters $m$ and $n$ characterizing the density of the inefficiency level as well as the parameter $a$ entering the cost function of effort in the asymmetric information case. Moreover, from estimations of both models performed for each year separately (which are not reported but are available upon requests), one concludes that these results are stable over time, and all parameters (except $m$ in three cases) remain significant in all experiments.

Comparing estimates from both specifications in Table 2, we note that the estimated value of $s_e$ is lower in the asymmetric information model, which indicates an improved specification with respect to the first model. Although (significant) coefficient estimates of both models are very similar, it is of interest to test which of the two specifications is the most appropriate. Since the two models are not nested, we use a test proposed by Vuong (1989). The null hypothesis is that both models are equally far from the true data generating process in terms of Kullback-Liebler distances. The alternative hypothesis is that one of the two models is closer to the true data generating process. When the Vuong statistic is less than two in absolute value, the test does not favor one model above the other. Here, the statistic of the asymmetric information model versus the standard model is 15. This strongly supports the structural approach presented in this paper.

Now, we can test the assumption that the distribution of the efficiency parameter $q$ is independent of the type of contracts. We write the likelihood (25) allowing the scale parameters of the distribution of $q$ to depend on the type of contracts. They are now four scale parameters. The results are presented in Table

3. Note that the parameters describing technology do not differ significantly from the parameters of the asymmetric information model presented in Table 2. The likelihood ratio of the four-scale-parameters model to the two-scale-parameters model is equal to .993, which indicates that we cannot reject at a 5% significance level the null hypothesis that the two models are identical. Hence the technical efficiency of a network is not associated to a particular type of contracts.

From now on, we focus on the results from the asymmetric information model presented in Table 2. First we assess the effects of regulatory policies on technology and second, we provide measures of efficiency and effort levels.

*Effects of regulatory schemes on the technology*

Consider the measure of elasticities of scale, which are usually computed as $es = \partial \ln C / \partial \ln Y$. From Equation (20), the difference of returns of scale under the two types of regulatory schemes is equal to

$$es_{|FP} - es_{|CP} = -\frac{b_L}{a + b_L} b_Y ,$$

where *FP* (*CP*) stands for fixed-price (cost-plus, respectively). In our case, given that the value of $a$ is much larger than $b_L$, this difference is very small, implying that the type of contract does not significantly affect technology.

However, the marginal and average cost differentials are significant. Table 4 provides estimates for the average revenue, marginal and average costs for a firm operating at an average level of production, facing average input prices (over our sample), and would be regulated either under cost-plus or fixed-price regimes. Note that marginal and average costs are slightly lower under fixed-price regimes, which is consistent with the theory. This result is in contrast to what the values of empirical means of average costs over the sample tell us. The ratio of observed average cost under fixed-price to observed average cost under cost-plus contracts is equal to 1.30 when one considers the sample means. This counterintuitive result is due to an effect of scale that we remove by considering estimates of the econometric cost function. From Table 4, the equivalent ratio of estimated average costs under the two types of contract is .96.

Table 4 also illustrates the financial deficit that characterizes the French urban transport industry: Prices, i.e., average revenues (over the sample), are greater than estimated marginal costs but they are set below estimated average costs. This discrepancy is emphasized when one considers values for prices and estimated marginal and average costs (which are reported here) at each point of our sample. This allows us to observe that average revenue and costs decrease with the level of passenger-trips supplied. Higher production levels lessen the gap between average cost and average revenue. This result confirms the presence of significant economies of scale in this industry. It suggests that monopoly is the relevant organization in these medium size networks.

*Efficiency and effort levels*

From the estimation, it turns out that the density function has an exponential shape. On average, most operators are relatively efficient as most of the surface under the density function corresponds to values of $q$ lower than .5.

Estimates of individual efficiency parameter can also be recovered. From Equations (22) and (23), the error term on the cost function has two unobservable, random and independent components, $q_i$ and $e_{it}^{c}$. Namely, under cost-plus regimes, the error term can be written

$$u_{it} = e_{it}^{c} + b_L q_i \, , \tag{27}$$

while, under fixed-price regimes, it is

$$u_{it} = e_{it}^{c} + x b_L q_i \, , \tag{28}$$

where $x = a \big/ \left( a + b_L \right)$ is the parameter defined in Equation (19). From a procedure initiated by Jondrow *et al.* (1982), one may recover an estimate for each $\hat{q}_i$ from the values of residuals $\hat{u}_{it}$ by considering the conditional distribution of $q_i$ given $u_{it}$, i.e., by computing $\hat{q}_i = E\left(q_i \middle| u_{it}\right)$. For all networks of our data set in the year 1993, the estimated values of efficiency levels are available from the authors. Nine operators have an inefficiency parameter larger than .5, with the highest inefficiency parameter reaching the value .904. On the other hand, thirty-six operators (over fifty-seven) are more efficient with inefficiency values less than .2.

Another important output of our study is a measurement of the manager's effort level, which appears here as an unobservable and supplementary input. Recall that, from the first order condition (13), operators under cost-plus regimes exert an optimal amount of effort equal to zero. Thus, they do not reduce technical inefficiency at all. Now, consider the case of a network like Toulouse for instance. Here the firm is managed under a fixed-price regime; the technical level of inefficiency equals .158 and the cost reducing level of effort is .125. In this case, the manager's effort almost exactly counterbalances the inefficiency of the firm.

The reader might remember that our technical inefficiency parameter should not be interpreted as a global cost distortion that measures the discrepancy between the theoretical frontier and the observed cost (See Gagnepain and Ivaldi, 1998, for more details). Cost distortion is given by

$$\exp\left[b_L(q-e)\right], \tag{29}$$

according to the cost function given by Equation (14). The maximum cost distortion is achieved for a zero level of effort and an inefficiency level equal to 1. For instance, the cost distortion for Toulouse is 1.5 percent, while it is 3.9 percent for Bordeaux.

Consider Figure 1 where we present our set of fifty-nine networks ranked according to their cost distortions defined by Equation (29). In addition, Figure 1 provides for each network, the level of the inefficiency parameter and indicates the type of contract used to regulate it, with a circle (diamond) representing a cost-plus (fixed-price, respectively) contract. Note that three groups of networks are easily detected. The first group with the lowest levels of cost distortion gathers sixteen networks, all of which are managed under a fixed-price contract. The next twenty-one can be collected in a second group as all of them (but four networks) are regulated through a cost-plus contract. Finally the last twenty networks are assembled in a third group, almost equally shared between the two types of contract.

Our estimation results provide a good approximation of the data generating process. While the average values of $q_i$ are almost equal for the first two groups (these values being .096 and .116), the average cost distortion is not significantly different from zero for the first group,[19] and it is around four percent for the second group. Concerning the third group, one just concludes that technical inefficiency is so high that even a high-powered incentive scheme, such as a fixed-price contract, cannot cure the problem. These results show that, because we account explicitly for the effect of each type of contract on the cost function and that our sample covers a large spectrum of existing networks, we are able to fully recover the distribution of the efficiency parameter.

At this point one can test the assumption that the efficiency $q_i$ is independent of the identity of the operator's owner. Recall that rejecting this assumption would imply rejection of the fundamental assumption stochastic independence that motivates the expression of the likelihood function. Given that eighty percent of networks are subsidiaries of three firms as indicated in Section 2, testing this assumption is then crucial for the robustness of our estimates. When the estimated values of the inefficiency parameter are regressed against a constant and a set of dummy variables characterizing the ownership of networks (VIA-GTI, CGEA, Transdev, AGIR and others), the parameters of these dummies are never significant. This confirms our conjecture that the efficiency $q_i$ pertains to the network itself and is not related to the manager's "culture".

## 7. Optimal incentive schemes versus actual regimes

The objective is now to perform a comparison of current and optimal regulatory policies among networks. To do so, a measure of urban transport demand is needed in order to compute the consumer surplus and to evaluate demand elasticities that usually enter optimal pricing rules. The model of demand and the estimation results are discussed in the appendix. Then, given the knowledge of demand and supply functions, and assuming that each local authority maximizes the consumer welfare, we first provide an evaluation of monetary distortions, i.e., an estimate of cost of public funds, in each system. This estimate then serves as a benchmark for comparing observed and optimal regulatory schemes.

*Current regulation and cost of public funds associated with the public transit system*

All ingredients are available in order to derive a measure of the cost of public funds in each local area. Indeed, we know the cost structure, the demand elasticity, the inefficiency level, the effort function, and the price level. However the behavior of the regulator must be specified. Assume that the local authority maximizes social welfare by choosing the optimal output level and the associated price of the transport service under some specific financial constraints.

In both regulatory cases, fixed-price or cost-plus regulation, the regulator's program is

$$\max_{y} W(y) = S(y) - R(y) - (1+l)(y(e) - R(y) + C(Y,e,q)) \quad \text{st} \quad Y = f(y), \tag{30}$$

where the constraint corresponds to the adjustment capacity function given by Equation (2). In urban areas where cost-plus regimes are employed, consumer surplus is defined as

$$V(y) = S(y) - R(y) + (1+l)R(y), \tag{31}$$

where the gross surplus $S(y)$ is derived from the demand function and the revenue function $R(y)$ is obtained as the product of the average price and the demand level. Parameter $l$ measures the tax distortion, the so-called cost of public funds. This monetary distortion is due to the collection of local taxes, required to provide subsidies to the local public transportation system in order to balance its budget.[20] The whole social monetary cost is equal to $(1+l)$ times the amount collected and $(1+l)R(y)$ is the tax reduction.[21] In urban areas where fixed-price regimes are employed, consumers' surplus is

$$V(y) = S(y) - R(y). \tag{32}$$

Operators are given a transfer that enables them to balance the budget and provides them with a monetary payment as an incentive for cost reducing activities. The expected utility of firms is then zero.

From the first-order conditions associated with program (30), the optimal pricing corresponds to a Ramsey rule, namely,

$$\frac{p(y)-f'(y)\,C_Y}{p(y)}=-\frac{\lambda}{1+\lambda}\frac{\partial\,p(y)}{\partial\,y}\frac{y}{p(y)}\,. \tag{33}$$

The left-hand side (the Lerner index) is inversely proportional to the public transport demand elasticity and the cost of public funds. This pricing rule is partial in the sense that it takes into account only the local transportation system. It excludes other policies in the realm of the local authority. In some sense, it should be weighted to account for the true cost of road transport including safety, pollution, and modal split.

Since we know everything in Equation (33) except the cost of public funds, we can solve it to provide an estimate of $\lambda$ for each network. Given the remarks of last paragraph, these estimates are probably biased however, because of the omissions and assumptions we have made so far. In particular, the estimate is conditional on the hypothesis of welfare maximization. However it should be independent of the informational availability. Indeed, the particular structure we use to incorporate asymmetric information parameters allows the incentive-pricing dichotomy principle to hold. (See Laffont and Tirole, 1993) It means that the Ramsey formula applies whether we assume complete or incomplete information. Then our estimate of the cost of public fund depends only on the observed levels of prices and the estimated values of marginal costs and demand elasticity.

Our estimates of the cost of public funds for each network in our sample are available upon request. The mean of the distribution is equal to .40, with a standard deviation of .10 and a range between .17 and .73. They are reasonable in the sense that they are in the range of values obtained by others and published in the economic literature. For instance, Ballard, Shoven and Whalley (1985) provides estimates (namely, 17 to 56% per dollar) of the welfare loss due to a one-percent increase in all distortionary tax rates. In the case of Canadian commodity taxes, Campbell (1975) finds that this distortion is equal to 24%. More generally, it seems that the shadow cost of public funds falls in the range of 15 to 50% in countries with a developed efficient tax collection system. Given that the values we obtain are realistic, we conclude that the assumption of welfare maximizing social planner is not irrelevant or that it provides a solution close to reality.

The results illustrate the Ramsey pricing relationship: When taxation involves less distortion, i.e., when $\lambda$ is close to zero, the gap between prices and weighted marginal costs is reduced, i.e., the markup decreases. Hence, the budgetary deficit is easily covered by taxation. On the other hand, when the local cost of public funds becomes high, price tends to the monopoly price since subsidies become costly for society. The firm deficit is then partially covered by commercial revenue.

Now, we derive the optimal allocations which are then used as a benchmark for the evaluation of actual regulatory schemes.

*Second-best allocations*

The regulator is imperfectly informed on the inefficiency level of the network operator. In other terms, the regulator has only some beliefs on the distribution of inefficiency, which takes the form of a distribution function $F(q)$ on a specific interval $\left[\underline{q},\bar{q}\right]$. In these conditions the optimal contract corresponds to a second best allocation.

Assume that the regulator receives the commercial revenues $R(.)$ and pays *ex-post* operating costs $C(.)$. Hence, the utility of the operator is

$$U = t_0 - y\left(e\right), \tag{34}$$

where $t_0$ is a net transfer paid to the firm.[22]

In what follows, the regulator takes the cost of public funds as given. In order to perform comparisons of optimal and current contracts on an equivalent basis, assume that the regulator uses the estimates of cost of public funds obtained previously

A second-best contract is defined by a price level $p\left(y^s\right)$ and a transfer. However given the monopoly situation, selecting a price corresponds to choosing an output level. Given Equation (34), a transfer level defines an effort level $e^s$. Hence the optimal allocation is obtained by maximizing the expected social welfare defined over the interval $\left[\underline{q},\bar{q}\right]$,

$$\underset{q}{E}W = \underset{q}{E}\left\{S\left(y\right) + l\,R\left(y\right) - \left(1 + l\right)\left(y\left(e\right) + C\left(Y,e,q\right)\right) - lU\right\}, \tag{35}$$

with respect to $y$ and $e$ under three constraints: i) A capacity constraint $Y = f\left(y\right)$; ii) an individual rationality constraint $U \geq 0$, meaning that the operator is endowed with a utility level at least as high as he/she could get outside; iii) an incentive compatibility constraint written as

$$U'(q) = -y'\left(e^s\right), \tag{36}$$

i.e., which means that, to have the incentive to tell the truth, the operator must be provided with the same gain than the one he would obtain if the announces a lower efficiency level.

Here also the first-order conditions associated with this program include a Ramsey formula as in Equation (33) defined on $y^S$ and $e^S$. In addition, at the optimal solution, the marginal cost reduction is equal to the marginal disutility of effort from which a downward distortion is subtracted in order to limit rent leavings. In our notations,

$$\frac{\partial C\left(f\left(y^{s}\right), e^{s}, q\right)}{\partial e} = -y'\left(e^{s}\right) - \frac{l}{1+l}\frac{F(q)}{f(q)}y''\left(e^{s}\right). \tag{37}$$

Moreover, an informational rent

$$U(q) = \int_{q}^{\bar{q}} y'\left[e^{s}(u)\right]du\ , \tag{38}$$

is provided by the authority to the operator. Note that $U(q)$ is now the indirect utility function derived from the original expression (34) and the first order condition (36) that ensures the maximization of the operator's utility.

*Two polar cases*

Among the class of second-best contracts, two polar contracts can be defined, according to the level of information available to the regulator. When the regulator is “fully informed”, the interval $\left[\underline{q}, \bar{q}\right]$ shrinks to one point, $q$ , that is exactly the inefficiency level of the network. In this case *the fully informed second-best contract*, defined by Equations (36)-(38) where the interval $\left[\underline{q}, \bar{q}\right]$ is replaced by $q$ , coincides with (what it is usually called) the first best contract, referenced by the letter *f* in what follows. To transform a second-best scheme into a first best scheme, two actions are needed. First, the informational rent given by Equation (38) is eliminated, as it can be easily observed. Second, the second-best effort $e^{s}$ is increased, so that the first best effort level is higher that any second best effort level. Indeed one can show that

$$e^{f} = e^{s} + \left(a + b_{L}\right)^{-1}\ln\left[1 + a\frac{l}{1+l}\frac{F(q)}{f(q)}\right]. \tag{39}$$

where the term $\left(a + b_{L}\right)^{-1}$ takes a positive value as well as the logarithm since $a$ and $l$ are positive.

At this point, two remarks shed light on the role of information incompleteness here: First, the effort distortion $\left(e^{f} - e^{s}\right)$ decreases with $\underline{q}$, $q$ being held constant. Second, the informational rent $U(q)$ increases with $\bar{q}$ , $q$ being held constant. Hence, both the rent and distortion levels depend on the beliefs of the regulator.

The other polar case happens when the regulator has no information at all. More precisely, one says that the regulator is "fully uninformed" when it only knows the largest and lowest values of the inefficiency parameter $q$, as obtained by an econometrician who could fit a cost function on a sample of networks. Here, the lowest and highest inefficiency levels estimated in Section 6 are equal to .035 and .904 respectively. The (*totally*) *uninformed second-best contract*, referenced by the letter $u$, entails the highest downward effort distortion (compared to the first best contract) and the highest rent. It provides the worse level of social welfare among all the second-best contracts.

*Second-best versus current policies*

Using our estimates of the Cobb-Douglas cost function, the demand function, the parameters of the distribution of $q$, we can compute, for each network of our sample and for the two polar contracts, the values for the total welfares, $W^u$ and $W^f$.[23,24] Given that we know the terms of contract implemented in each network, one can also compute the current level of welfare $W^a$ as

$$W^a = S(y^a) + l R(y^a) - (1 + l)(y(e^a) + C(f(y^a), e^a, q) + U), \tag{40}$$

where the letter $a$ refers to the *current contract*. Note that $U$ now measures the current net gain or loss, while, in Equation (35), it designates the informational rent left to the operator. It is equal to zero under cost-plus schemes, but could be either positive or negative under fixed-price regimes depending on whether current subsidies are either too high or too small, respectively.

The discrepancy between the fully informed (first-best) and current welfare levels is given by

$$\Delta W^f = W\left(y^f, f\left(y^f\right), e^f, q\right) - W^a, \tag{41}$$

while the discrepancy between the uninformed-second-best and current welfare levels is

$$\Delta W^u = W\left(y^u, f\left(y^u\right), e^u, q\right) - W^a. \tag{42}$$

Given that $W^s$ is the second best welfare level, conditional on the regulator's information, we necessarily have $W^u \leq W^s \leq W^f$, i.e., $\Delta W^u \leq \Delta W^s = W^s - W^a \leq \Delta W^f$. The econometrician, who does not know anything about the level of information available to the regulator, is only able to provide a lower bound, $\Delta W^u$, and an upper bound, $\Delta W^f$, to any change in welfare due to the introduction of a second-best contract in place of a fixed-price or a cost-plus contract.

At this point, several comments should be made. First, we expect $\Delta W^u$ to be positive if the current regime is cost-plus. On the other hand, $W^a$ may be greater than $W^u$, i.e., $\Delta W^u$ to be negative if *(i)* the current contract is fixed-price, and *(ii)* the regulator is better informed than in the worst case setting *u*, implying that his beliefs fall in an interval smaller than $[0.035,0.904]$, that is to say, the interval estimated by the econometrician. Note that $\Delta W^u$ to be negative does not contradict the assumption that current contracts are chosen independently of inefficiency levels $q$ : Since regulators are better informed in reality than in the worst case setting *u*, the level of rent they manage to extract under fixed-price regimes makes any uninformed second-best contract damageable for society's welfare.

Second, we expect $W^f$ to be greater than $W^a$, i.e., $\Delta W^f$ to be positive if *(i)* the current regulatory scheme is cost-plus, or *(ii)* the current scheme is fixed-price and the operator enjoys positive profits (in which case the information obtained by the regulator is not perfect.) On the other hand, we may obtain that $W^f$ and $W^a$ are equal, i.e., that $\Delta W^f$ is equal to zero if *(i)* the current contract is a fixed-price, and *(ii)* the regulator has perfect information.

We turn now to the results presented in Table 5. Note that $\Delta W^u$ is negative (positive, resp.) when the actual contract is fixed-price (cost-plus, resp.) Second, the values for $\Delta W^f$ show large potential welfare gains when actual contracts are cost-plus and almost no gains when they are fixed-price. Therefore, we conclude that, in networks where fixed-price schemes are currently employed, regulators are better informed than in the worst case setting *u*. Even they can be almost perfectly informed as in some cases like Caen, Grenoble and Nantes for instance. On the other hand, a cost-plus contract is always dominated by any type of second-best contract. This suggests that cost-plus contracts are so weakly incentive powered that even a totally uninformed regulator with a properly designed regulatory scheme would improve welfare.

Hence, we may conjecture that fixed prices contracts may call for better-informed regulators. Intuitively, a fixed price contract, which involves a higher level of incentives, needs more information to be implemented.

## 8. Conclusion

The first aspect of this paper is methodological. Due to the presence of an adverse selection parameter, the econometric model coincides with the theoretical model. In particular, the stochastic part is already built-in, even if one may add to the theoretical model a disturbance term to account for potential measurement errors. Doing so, this inference based on asymmetric information models contributes to an improved econometric specification. For instance, it is visible in the way the regulatory constraints affect the structure of the cost function. This should provide a better estimate of the effects of regulatory constraints than what is usually performed. (See Mathios and Rogers, 1989, among many others.) In addition, this approach also proposes a way to measure unobservable variables from a set of economic data, in particular, to estimate the distribution of the adverse selection parameter (here, the inefficiency level of firms) and to evaluate the effort level for each manager of our sample.

A second methodological aspect has also been proved fruitful. Contrary to what most contributors to the econometrics of asymmetric information models have hypothesized, we do not consider that the actual regulatory schemes are optimal. Our method is to use a two-step analysis in order to measure the potential discrepancy between current and optimal policies. First, we estimate all parameters of interest, taking the institutional constraints as given; second, we simulate the optimal allocations based on our parameter estimates and compare them with the actual situation. This approach has produced several interesting results. We obtain an estimate of the local cost of public funds; we observe whether the hypothesis of welfare maximization works; in some cases, we detect when actual management contracts of urban transport network may provide higher welfare levels to consumers; finally we show that the implementation of fixed price contracts requires the regulator to be at least partially informed. Hence, this method should help clarify the choice of regulation type in the urban transport industry.

In particular, our counterfactual experiments suggest that cost-plus contracts damage society's welfare. Due to the presence of asymmetric information, operators are providing no effort under these regimes. During the last two decades, several local authorities have experimented fixed-price mechanisms in order to control for the inflation of operating costs. The experience seems conclusive. In networks that are still regulated under cost-plus mechanisms, a very simple menu of cost-plus and fixed-price regimes would always improve social welfare: An efficient firm would prefer a fixed-price contract, while an inefficient firm would choose a cost-plus contract. With such a scheme, on the one side, the efficient firm provide the optimal effort level, and on the other side, the inefficient firm by satisfying its individual rationality constraint would avoid bankruptcy.

We have warned the reader several times in the text that all dynamic aspects are wiped out. We recall here that the inefficiency level is independent of time, which is clearly a restrictive assumption as it means that a firm cannot improve. We also do not address the question of the renewal of contracts, while we justify this choice by the state of our data set. Finally, and most importantly in our opinion, we do not model the short run dynamics of the relationship between the regulator and the operator, which ends up with the determination of an annual average price probably linked to the most recent values of average income.

Moreover, as Laffont (1996) suggests, considering simultaneously the inefficiency of local political systems and the informational incompleteness of regulators should be relevant. Under incomplete information the political inefficiencies of a majority system may affect the cost reimbursement rules and the incentives of the regulatory schemes. To test this proposition, it would be better to envision a more dynamic approach. Hence, the research agenda is completed.

## Appendix: A model of urban transport demand

The relation between supply and demand of urban transport results from two effects. On one hand, since the capacity supplied must at least meet the highest peaks of traffic, demand never saturates the network capacity on average. On the other hand, the capacity must be adjusted to the level of demand, so the former is endogenous to the latter. Here we do not present a complete model of optimal provision of transport services. Instead, we simply introduce a reduced form of a dynamic and technical adjustment process between capacity and demand according to the relation given in Equation (2), that we specify as follows:

$$\ln Y = \ln f\left(y\right) = g_0 + g_1 \ln y + g_2 t \,, \tag{A1}$$

where $t$ is a trend and $g = \left(g_0, g_1, g_2\right)'$ a vector of parameters to be estimated. De Borger *et al* (1995) uses this approach in the case of the Belgian urban transport industry. This equation just approximates how engineers adjust the network size and structure to the demand level on annual basis.

For the specification of the demand function, we follow the classical guidelines. Assume that consumer *n*'s indirect utility associated with the consumption of urban transport is a function of the transit fare, $p$, his/her individual characteristics denoted by a vector $h_n$ and other variables like service attributes denoted by $Z$ and the level of supply $Y$. (See Berechman, 1993.) From this indirect utility function, we can derive the individual demand functions and then aggregate them according to the distribution of individual characteristics in the population of a urban area. The associated aggregate demand function is interpreted as a short-run demand since it takes the capacity (i.e., $Y$ ) as given. By replacing $Y$ in this aggregate demand function by its expression in (A1), we obtain a reduced form interpreted as the long-run demand function. Choosing the usual logarithmic specification, the long-run demand function is defined as

$$\ln y = d_0 + d_1 h \ln p + d_2 Z + d_3 t \,, \tag{A2}$$

where $d = \left(d_0, d_1, d_2, d_3\right)'$ is the final vector of parameters to be estimated, $t$ is a trend and the variables $h$ and $Z$ are defined below. The price elasticity associated with this reduced-form demand corresponds to an estimate of the long-run elasticity, when capacity has been fully adjusted. Estimating Equations (A1) and (A2) avoids the simultaneity problem that exists between $y$ and $Y$ (without the need of specifying rigorously the dynamic adjustment process between $y$ and $Y$ ).

The whole model we are estimating is sequential. First the average price of transport services is set by French central authorities in a form of price cap regulation. More precisely the government puts a cap on the annual increase of the average price of transport services. The price cap is revised each year. As far as this price increase is satisfied, the operator and the local authority are able to fix prices for different types of services and for different customers. Uniform pricing over time and distances is the most common way to cross-subsidize the service. We assume that these pricing policies are exogenous. Once the price is known, the demand level is determined according to Equation (A2). The capacity is accommodated to that demand level according to the engineering function defined by Equation (A1). Finally, the cost of running the network is obtained through the cost model given by Equation (22). This gives rise to a block-recursive structure. So each equation can be estimated separately.

We now complete the specification of these functions by measuring the different variables.

*Data and variables*

We now discuss how product and consumer characteristics enter the demand function. First, remark that we did not introduce income in the aggregate demand function. A rise in income may increase the rate of private car ownership and the value of time that consumers perceive, thus depressing the demand for transit. Unfortunately, data on income at the level of each urban network are not easy to obtain. However, socio-demographic characteristics, mainly age and gender, which are highly correlated with income, are available and can be used as proxies. In addition, these variables are well known determinants of the demand for public transit. Finally, they can be used to address the problem of aggregation.

Let $a$ define age, that takes four values corresponding to centers of four classes of age, $a_k$, $k = 1,\ldots,4$. Let $s$ denote gender that takes two values, namely $s_l$, $l = 1,2$. For each network $i$, we can compute an index of heterogeneity

$$h_i = \sum_{k=1}^{4}\sum_{l=1}^{2} a_k s_l p_i[a_k, s_l], \tag{A3}$$

where $p_i[a_k, s_l]$ is the percent of the population with age $a_k$ and sex $s_l$. Obviously, the distribution by age and gender varies among urban areas, which accounts for some heterogeneity and which permits demand elasticity to vary across networks.

Service attributes are measured by the average commercial speed $(Z_1)$ and the activity density $(Z_2)$ in each network. Average commercial speed of public transit can be considered as one of the most important criterion of modal choice. Improving the commercial speed of transit systems by providing specific infrastructure improvements, like lanes dedicated to buses, tramways or even subways, increasingly concerns local authorities. Service density is obtained by dividing the total network (infrastructure) length by the urban population size. This index provides a fair measure of the attraction power of transit systems on consumers.

The total number of passenger trips measures the demand in a year. Prices are obtained using a two step procedure. In each area, the operator and the local authority must meet a percent price change that must be accepted by the representative of the French government. So, using year 1993 as the reference year, and by dividing commercial revenue by the number of total trips, we obtain an average price for each year in 1993 units.

*Estimation procedure and results*

With respect to our static approach, we assume that prices are predetermined, i.e., are set at the beginning of each period according to some exogenous rule. We add an error term $e^y$ to the demand given by Equation (A2) and we assume that this error term is decomposed into two components, a random effect specific to each network $i$, and a white-noise process. These components are independently distributed and have zero-mean homoscedastic normal distributions. Estimation is performed using the Maximum Likelihood method according to a procedure developed by Magnus (1982) for panel data. A similar stochastic specification is followed to estimate the capacity Equation (A1).

Empirical results are presented in Table A1 below. All parameters are highly significant though the overall fit (measured by the pseudo-$R^2$, i.e., one minus the ratio of the constrained to the unconstrained log-likelihood values) is fair given the simplicity of the chosen specifications.

Note that the parameters have the expected signs. In particular, improving quality, i.e., increasing the commercial speed and/or the network density has a strong effect on transit demand. The average elasticities for these two variables are .17 and .11, respectively.

The price elasticity of urban transit demand is also obtained and is given for each city of our sample in Appendix 1. For an average network it is equal to .441. Note that, from surveys by Oum *et al* (1992) and Goodwin (1992) of the major empirical studies on public transport demand since 1992, estimates of elasticity range between .01 and .78, which clearly indicates that the demand for urban transit is inelastic.

Table A1: Estimation of the demand and adjustment capacity equations

| Parameter | Estimate | Standard-error | Parameter | Estimate | Standard-error |
|---|---|---|---|---|---|
| $d_0$ | 9.511 | .11 | $g_0$ | 8.761 | 1.22 |
| $d_1$ | -.008 | .00 | $g_1$ | 1.134 | .13 |
| $d_{21}$ | .104 | .02 | $g_2$ | .033 | .00 |

| | | | | |
|---|---|---|---|---|
| $d_{22}$ | .091 | .04 | | |
| $d_3$ | .025 | .01 | | |
| Nbre of obs. | 531 | | Nbre of obs. | 531 |
| Pseudo-$R^2$ | .18 | | Pseudo-$R^2$ | .41 |

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## Footnotes

1. For an overview of the regulation of urban transit systems in the different countries of the European Union, in the United States and Japan, see IDEI (1999).

2. These companies, with their respective type of ownership and market share (in terms of supply) are: VIA-GTI (private, 29%), TRANSDEV (semi-public, 15%), CGEA (private, 14%). In addition there are two small private groups, AGIR and VERNEY, and a few firms under local government control. Market shares refer to the whole market including Paris, Lyon and Marseilles, the biggest cities of France.

3. Note that the remaining 7% are small urban transport systems, which are not included in the database.

4. CERTU is a research center mainly financed by the French government. The researchers are civil servants. GART is a non-for-profit organization aimed at promoting urban public transportation systems in France.

5. According to our data, 66% of contracts in which VIA-GTI is involved are fixed-price contracts, the others being cost-plus contracts. For TRANSDEV, the corresponding percent is 78.

6. As already mentioned, contracts are usually granted to operators for five-years periods and are often reconfirmed at the end of the term. In 1993, a new French law, aimed at preventing collusion and corruption, provided more explicit and detailed rules governing the process of awarding concessions by competitive tendering. The dynamic structure of contracts becomes crucial.

7. The cost-revenue deficit has increased continuously: In 1975, 80% of the operating costs were covered by commercial revenues, and only 55% in 1992. Note that local authorities own the rolling stock and the infrastructure and are therefore responsible for the costs due to their renewal.

8. Thereafter, we use $b$ to specify the cost technology. The parameter $b$ is a function of parameter $b$ which describes the production function.

9. These remarks on the role of drivers are drawn from discussions with or reports of experts or firm managers.

10. This assumption is meaningful in the sense that the managers' effort is aimed at reducing the inefficiency level, which cannot be larger than $q$.

11. This feature of the regulatory system of urban transport in France is again discussed later. See footnote 10.

12. The operator can argue that the quality of the capital stock is not high enough, and that in turn, the quality of service, as a function of the state of capital, is below a level that would permit to satisfy the objectives of transport supply. This situation could result in an over-accumulation of new equipment, which would lead to welfare losses. It is not addressed here, but a study on investment decisions in this industry would be certainly fruitful. The key question would be to measure the quality of service. In urban transport, it entails three dimensions: Transport capacity, commercial speed, and comfort. Note that here we only deal with the first dimension. Concerning commercial speed, it is an exogenous variable, partly determined by the level of traffic congestion. However, it can be adjusted when new transport infrastructures are added to the existing network. Hence commercial speed and obviously, comfort are two categories of capital management. Clearly these questions call for additional data.

13. These contracts are called "contrat de gérance", which could be translated as "contract of management".

14. Specifically, Equations (8) and (9) refer to the so-called "contrat de gestion à compensation financière" (i.e., "management contract with lump-sum payment"). Actually, the class of fixed-price contracts also includes another type of contract, called "contrat de gestion à prix forfaitaire", which could be translated as "management contract with lump sum price". Under this variant, the authority receives expected commercial revenue and pays the firm's expected ex-ante costs. In practice, it is similar to the first variant of fixed-price contracts.

15. A urban transport operator is vertically integrated. For this reason, it is difficult to provide an economic representation of the technology. We can think of the network technology involving two steps. In a first step, a network is established using basic inputs like labor, capital and materials. The network here is a fleet of buses and a set of routes. In a second step, this network structure together with other inputs is used to produce network capacity. Because of this technological structure it is hard to separate the different measures of inputs and outputs as in all network industries. Only very disintegrated data would allow us to deal with this question.

16. As suggested by Cornwell and Schmidt (1996), parameter $q$ is a direct approximation of inefficiency when it is small. Indeed, in this case, it approximates 1 - exp(-$q$), which is the usual measure in the literature on efficiency measurement.

17. Given the ranges for the labor inefficiency parameter and the effort level, $L^*$ cannot be greater than exp(1) $L$=2.718 $L$. We did not hit this bound at the estimation stage.

18. We also estimate a random effect model that provides similar results. In view of performing a specification test (see below), we only report results of the fixed-effect model.

19. The estimated cost distortion is slightly negative for the first seven networks. It is due to estimation errors, as we do not impose the constraint $q < e$ during the course of estimation.

20. Obviously this cost of public funds is related to the financing of the urban transportation system exclusively. It is probably different from the cost of public funds associated with the provision of all public services by the local authorities.

21. Note that, though parameter $l$, the social planer can introduce distributional considerations in the welfare function. This alternative interpretation of placing some weight on the preferences of operators is discussed in Caillaud *et al.* (1988) for instance.

22. This transfer is equivalent to the one defined in Equation (6) in the sense that it does not include any cost reimbursement.

23. The full expressions and the values for each network are available upon requests.

24. The distribution function, $F(q)$, is obtained from the estimation of the parameters of the density function $f(q)$ presented in Section 6.

Table 1: Descriptive statistics on the cost structure

| Variable | Mean | Standard deviation |
|---|---|---|
| Total cost ($10^3$ FF) | 117500.000 | 137731.000 |
| Wage ($10^3$ FF) | 174.940 | 28.384 |
| Material price ($10^3$ FF) | 26.311 | 31.386 |
| Soft capital price ($10^3$ FF) | 8.000 | 5.918 |
| Capital (# vehicles) | 143 | 134 |
| Production ($10^3$seat-kilometers) | 151302.680 | 367805.920 |
| Labor share | 0.573 | 0.128 |
| Material share | 0.296 | 0.117 |
| Soft capital share | 0.129 | 0.078 |

Table 2: Parameter estimates of the cost function

| Type of Model | Standard case | | Asymmetric information case | |
|---|---|---|---|---|
| Parameter | Estimate | Standard error | Estimate | Standard error |
| $b_0$ | | | .3068 | .150 |
| $b_L$ | .4285 | .0411 | .4491 | .048 |
| $b_I$ | .1027 | .0114 | .0824 | .006 |
| $b_Y$ | .0400 | .0373 | .1825 | .022 |
| $b_K$ | .7063 | .0920 | .7010 | .048 |
| $\ln a$ | | | 4.2827 | .257 |
| $n$ | | | .5931 | .035 |
| $m$ | | | 1.8007 | .287 |
| $s_e$ | .1300 | .0120 | .0834 | .007 |
| Mean log-likelihood | .549 | | .594 | |
| Number of observations | 531 | | 531 | |

*Note*: Since we imposed homogeneity of degree one in input prices during the estimation, $b_M$ does not appear in Table 2 or Table 3.

Table 3: Parameter estimates of the cost function using four scale parameters

| Parameter | Estimate | Standard error |
|---|---|---|
| $b_0$ | .3008 | .140 |
| $b_L$ | .4491 | .026 |
| $b_I$ | .0823 | .006 |
| $b_y$ | .1841 | .022 |
| $b_K$ | .7005 | .046 |
| $\ln a$ | 3.8440 | .229 |
| $n_1$ | .5865 | .073 |
| $m_1$ | 2.1501 | .349 |
| $n_2$ | .0111 | .102 |
| $m_2$ | -.7635 | .354 |
| $s_e$ | .0823 | .057 |
| Mean log-likelihood | | .601 |
| Number of observations | | 531 |

*Note*: Scale parameters for cost-plus contracts are $n_{CP} = n_1$ and $m_{CP} = m_1$. Scale parameters for fixed-price contracts are $n_{FP} = n_1 + n_2$ and $m_{FP} = m_1 + m_2$

Table 4: Observed average revenue, estimated marginal and average costs

| | Fixed-Price | Cost-Plus |
|---|---|---|
| Observed average revenue | 2.619 | 2.151 |
| Estimated marginal cost | .719 | .752 |
| Estimated average cost | 3.968 | 4.125 |

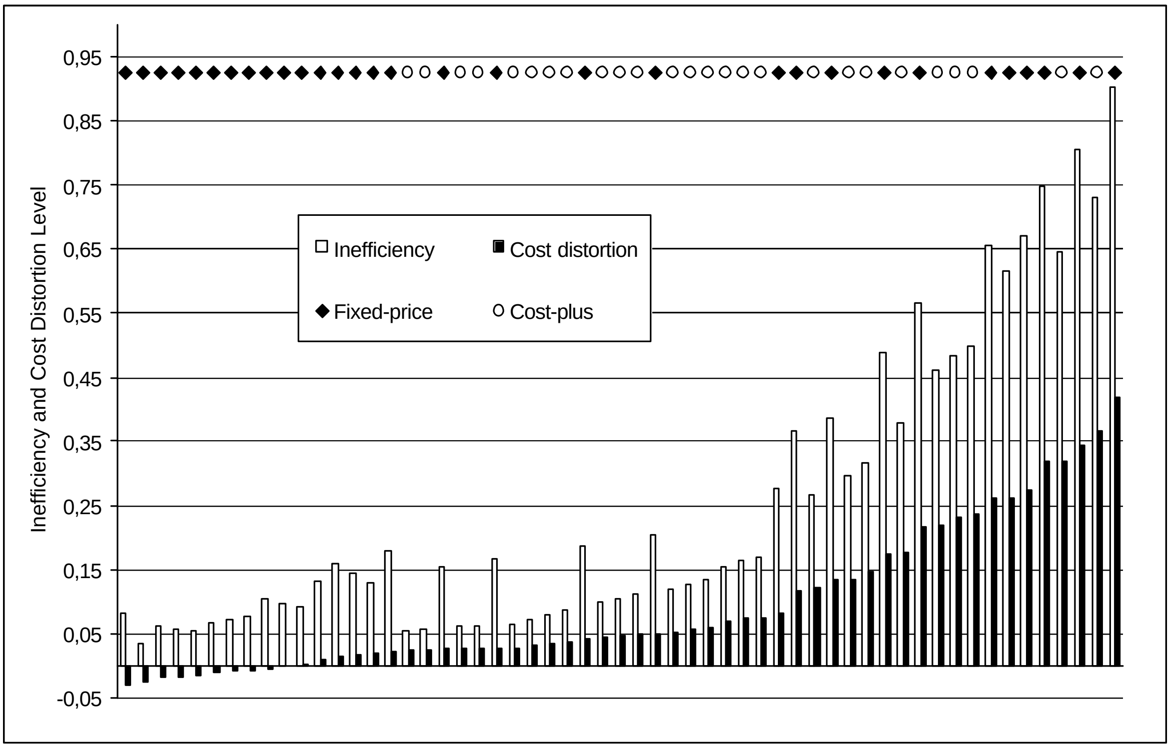
*Note:* Values are given in French Francs.

Table 5: Welfare differential between current and second-best contracts

| Network | Type of current contract | Welfare differential between uninformed and current policies (in $10^3$ Francs) $\Delta W^u = W^u - W^a$ | Welfare differential between fully informed and current policies (in $10^3$ Francs) $\Delta W^f = W^f - W^a$ |
|---|---|---|---|
| Besançon | CP | 3,965 | 6,288 |
| Bordeaux | CP | 24,766 | 32,919 |
| Caen | FP | -3,604 | 0 |
| Cannes | CP | 609 | 1,922 |
| Dijon | CP | 6,917 | 10,046 |
| Grenoble | FP | -4,509 | 1 |
| Le Havre | CP | 4,260 | 6,694 |
| Lille | FP | -11,454 | 2 |
| Metz | FP | -787 | 1,108 |
| Montpellier | FP | -2,520 | 506 |
| Nantes | FP | -6,155 | 1 |
| Rennes | CP | 7,354 | 11,248 |
| Toulon | CP | 5,864 | 8,844 |
| Toulouse | FP | -3,178 | 6,167 |

*Note: CP* and *FP* denotes cost-plus and fixed-price contracts.

Figure 1: Inefficiency and regulatory schemes




*Note*: To each network are associated three data: The inefficiency level (white bar), the cost distortion (black bar) and the type of contracts (a black diamond refers to a fixed-price contract and an empty circle indicates a cost-plus contract.