Measuring Inefficiencies in Transport Systems: Between Technology and Incentives

Philippe Gagnepain
Departamento de Economía, Universidad Carlos III, Madrid, Spain

Marc Ivaldi
University of Toulouse (IDEI) and EHESS, Toulouse, France
CEPR, London, UK

In modern microeconomics, a firm associates various inputs and a specific technology to reach a particular level of production. The theory of frontiers has defined the notion of a maximum level of production that can be reached given the inputs and the technology available. Such a frontier becomes a reference for the producers in the sense that all firms are affected during the production process by productive inefficiencies.

These inefficiencies have been studied by the econometricians interested in estimating frontiers of cost. Originally proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), a frontier model consists of a function of the usual regression type with an error term comprising various parts. The first part corresponds to the usual white noise process while the second part represents inefficiency. As it is well established in the literature, global inefficiency of individual sample firms can be predicted on the basis of cross-sections or panel data sets on these firms. The method based on cross-sectional data suffers from one serious difficulty: The estimation procedure must assume that inefficiency is independent of regressors. This might be incorrect since input and output quantities are together determined at the equilibrium and since firms may know something about their level of inefficiency when they choose inputs quantities.

Now consider the incentives for cost reduction faced by a producer during the production process. This article provides two examples to show that the cost frontier of this producer involves a global inefficiency term that comprises two terms. The first component is a purely exogenous random term; the second one is endogenous in the sense that it depends on the producer's actions and hence on observable variables in an indirect and imbricated way. This decomposition of global inefficiency resembles the specification commonly used in the literature on stochastic frontiers. However, it is here endogenously derived while, in the tradition of stochastic frontiers, it is imposed in ad hoc way.

This resemblance finds its source in the economic literature. On one side, a tradition initiated by Leibenstein (1966) motivates the specification of stochastic frontiers. Without referring explicitly to the notion of frontier, Leibenstein clearly mentions the existence of a global inefficiency that depends on the will of managers and workers in a production process. A low powered incentive environment due to a lack of productivity of working agents induces the inefficiency, while appropriate incentives can lead to significant operating cost reductions.

On the other side, since the emergence of the new theory of regulation, economists admit that, in industries where a producer is regulated by an authority, the principal-agent relationship is at the core of the question of assessing the performance of a firm. (See Loeb and Magat, 1979, Baron and Myerson 1982 and Laffont and Tirole 1986.) Hence, technical inefficiency and effort are two unobservable parameters, which characterize the incentives faced by a firm to reduce costs and define the source of global inefficiency.

Likewise, in industries where several producers enjoy a local monopoly power, a sudden opening of the market to perfect competition may create a new pressure in terms of incentives for carriers to reduce costs and improve efficiency.

In this perspective, incentive models provide a relevant framework for the analysis of cost frontiers. In addition, because such models are able to elicit the structural relationship between the observable variables and the inefficiency term, they directly provide a way to deal with the endogeneity of the inefficiency term, i.e., with the stumbling block of the econometrics of stochastic frontiers.

The analysis presented below is based on two examples of cost reduction incentives. The first one focuses on the regulatory structure drawn from the French urban transport industry. There are two types of contracts that regulate the activity of transport operators, and these types of contracts provide operators with different incentives to reduce costs. This analysis is based on the work by Gagnepain and Ivaldi (2002). A second example is the deregulation of European aviation. Until the beginning of the 1980s, flag operators have enjoyed monopoly power and have kept costs and prices high. The introduction of several waves of deregulation form 1985 to 1993 has allowed competition in the European industry, forcing firms to be more efficient and to reduce costs if they wanted to stay in the market. This analysis is based on the work by Gagnepain and Marin (2005).

Section 1 presents the preliminary cost frontier to be estimated using a Cobb-Douglas technology. Section 2 is devoted to the way incentives for cost reduction are introduced in this cost frontier. Section 3 and 4 present two applications on the urban transportation in France and deregulation of European airline respectively. Section 5 concludes.

1. The preliminary frontier

The aim of this section is to construct the structural cost and production frontiers of a transport operator. First, preliminary frontiers, that are conditional on effort, are obtained. Second, using the regulatory or the competitive constraints, we construct structural frontiers to be estimated.

We specify a stochastic production function as

$$\ln Y = \ln f(X, \alpha) + g(e - \theta) + \varepsilon_Y \,, \tag{1}$$

where $f(X, \alpha)$ is the production function, i.e., the locus of technically efficient production levels. Here, the levels of output and inputs are given by *Y* and *X* respectively. The parameter ε_Y is a symmetric statistical noise which accounts for measurement errors. Moreover, $\theta \geq 0$ is the exogenous technical inefficiency, and $e \geq 0$ is the effort of productivity exerted by the firm. Technical inefficiency represents the amount of knowledge, the experience of the transport operator and its ability to associate inputs with the technology available. The cost reducing effort is exerted in order to reduce the technical inefficiency θ. The function $g(e-\theta)$ provides then a measure of the global inefficiency. The nature of this function depends on the source of inefficiency and effort activity in the production process. We assume that $g(.)$ is strictly increasing with θ and strictly decreasing with *e*.

A measure of the total distortion under the production frontier is naturally defined by the ratio

$$Y / \left[f(X, \alpha) \exp(\varepsilon_Y) \right] = \exp\left[g(e - \theta) \right], \tag{2}$$

which tells us how far is actual output from the most efficient production level represented by the stochastic production function $\left[f(X, \alpha) \exp(\varepsilon_Y) \right]$.

The regulator does not know neither θ nor *e*. In order to provide the level of output *Y*, a transport operator requires quantities of input X_j, $j = 1,...n$, from a set *X* of inputs. The utilization and the management of the set of inputs are affected by technical inefficiency θ. This leads to an over-consumption of the inputs. By exerting a significant level of effort, the monopoly can reduce this excess of factors demand.

Then we distinguish X_i from X_i^*. On one hand, X_i is the physical amount of input *i* used by the producer in the process. This amount is observable by the regulator. On the other hand, X_i^* is the efficient level of input *i* which is not observable by the regulator. Hence, operating costs depend on the quantity X_i whereas the actual level of production depends on X_i^*. The relationship between observed and efficient quantities of input *i* is given by

(3) $$X_i^* = \frac{X_i}{\exp(\theta - e)},$$

that is to say, the efficient quantity is expressed as a percentage (measured by $\exp(\theta - e)$) of observed quantity. Note that θ is expected to be greater than *e*. However, we do not impose this constraint when we estimate the model.

Consider now a Cobb-Douglas technology:

(4) $$Y = A\prod_{j=1}^{n} X_j^{*\alpha_j} k^{\alpha_k} \exp\left[g(e-\theta) + \varepsilon_Y\right],$$

with one output and *n* variable inputs, where *k* stands for capital and *A*, α_k and the α_j's are parameters describing the technology. Capital is considered as a fixed input.

We turn to the construction of the dual cost frontier. Assume that the producer seeks to minimize the cost *C* of producing its desired rate of output *Y* under technical inefficiency. The associated allocation of inputs sets the factor demand X_j, $j = 1,\ldots n$. The program of the producer is then

(5) $$\min_{X_j} \sum_{j=l}^{n} w_j X_j \ ,$$

under the technological constraint (4), where w_j is the price of input *j*. The excess of factor demand above its frontier prevents the producer from reaching the theoretical level of production. Such a distortion of factor demands leads to a rise of operating costs. In logarithmic form, the associated stochastic cost frontier, $C\left(Y, w, e, \theta\right)$, is given by

(6) $$\ln C\left(Y, w, e, \theta\right) = \mathrm{K} + \sum_{j=1}^{n} \frac{\alpha_j}{r} \ln w_j + \frac{1}{r} \ln Y - \frac{\alpha_k}{r} \ln k + \frac{\left(\theta - e\right)}{r} + \varepsilon_C \ ,$$

where $r = \sum_{j=1}^{n} \alpha_j$ measures returns to scale, K is a constant and *w* is the vector of input prices. Note that the term $\left(\theta - e\right)/r$ is the total cost distortion above the cost frontier. Global inefficiency is less significant when the industry enjoys large returns to scale *r*.

Both production and cost frontiers in Equations (4) and (6) respectively allow the econometrician to estimate a technology in a similar way. The choice between estimating one functional structure or the other depends upon exogeneity assumptions. A cost function should be rather considered if output quantities are exogenous. Nevertheless, in any case, both frontiers in Equations (4) and (6) are preliminary since the unobservable structure is partially endogenous. The cost reducing effort *e* is endogenous and depends on regulatory schemes or the competitive environment set by the regulator.

We turn now to the cost reducing activity aspect of the problem.

2. Incentives

We consider a transport operator whose profit function is

(7) $$\pi = R\left(Y\right) - C\left(Y, w, e, \theta\right) - \psi\left(\mathrm{e}\right),$$

where $R(Y)$ denotes its revenue. Exerting effort is costly and leads to internal cost $\psi(e)$. A profit-maximizing operator determines the optimal effort level in Equation (7). The first order condition is given by:

(8) $$\psi'(e) = -C_e,$$

which states that the optimal effort level is chosen to equalize the marginal disutility of effort and the marginal costs savings. Let us define a specific functional form for the internal cost of effort:

(9) $$\psi(e) = \exp(\tau e) - 1,$$

where $\tau > 0$. Assume that $\psi'(0) = 0$. The first order condition (Equation 8) can then be expressed using the cost frontier (Equation 6) and the internal cost of effort (Equation 9). The level of endogenous effort exerted by the operator is obtained as

(10) $$e = \left[\frac{\mathrm{K} + \ln\frac{1}{r} + \sum_{j=1}^{n}\frac{\ln w_j}{r} + \frac{1}{r}\ln Y - \frac{\alpha_k}{r}\ln k + \frac{\theta}{r} - \ln\tau}{\tau + 1/r}\right].$$

The optimal effort level depends on inputs prices w_j, production level *Y*, capital stock *k*, the inefficiency θ and the technology available α. The optimal effort level (Equation 10) is now reintroduced in the preliminary frontiers (Equation 6) in order to derive the final structural cost frontier to be estimated:

(11) $$\ln C = \mathrm{H}_C + \xi\left[\sum_{j=1}^{n}\frac{\ln w_j}{r} + \frac{1}{r}\ln Y - \frac{\alpha_k}{r}\ln k + \frac{1}{r}\theta\right] + \varepsilon_C ,$$

where H_C is a constant and $\xi = \dfrac{\tau}{\tau + 1/r}$. Note that, when the effort of the producer is nil, the structural cost frontier is given by the expression:

(12) $$\ln C = \mathrm{K} + \sum_{j=1}^{n}\frac{\ln w_j}{r} + \frac{1}{r}\ln Y - \frac{\alpha_k}{r}\ln k + \frac{1}{r}\theta + \varepsilon_C ,$$

We propose now two applications of this model.

3. **Regulation of public transit in France**

We use a database that 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. 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.

In each urban area, a public authority is in charge to regulate the transit system which is provided by a single operator. The authority 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. This contract is a very low powered incentive scheme, as firms under this regime have no incentives to produce efficiently, since all operating costs are reimbursed ex-post.

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. This contract is a very high-powered incentive scheme as the operator is now responsible for insufficient revenues and cost overruns.

In the public transit industry, the network operator is better informed on labor inefficiency than the regulator. Note that labor costs represent more than 60% of total costs in this industry. 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 period of traffic congestion. Moreover, drivers have to deal with social and security problems, particularly in areas where the underprivileged population is large. There is an additional feature worth to be mentioned. The network structure may affect the driving conditions. On a same network, each bus route has its own characteristics of traffic lanes, route length, road access that complicates the evaluation of drivers' skills. All these remarks have the same implication: Appraising efficiency by just looking at the observed quantity of physical input is more difficult in the case of labor than in the cases of materials and soft capital whose consumption can be more easily observed and monitored by the regulator. As a result, we distinguish between observed and efficient labor forces, i.e., between the physical amount of labor forces, that is the source of cost distortions and is observable by the authority, and the efficient level of labor required to produce the output. 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 technical inefficiency and cost reducing activity are unobservable to the regulator and to the econometrician.

The empirical work involves fitting the stochastic cost functions presented in Equation (11) and Equation (12) to this panel data set of French urban transport networks. We assume that the production process requires four inputs. These inputs are labor L, materials M, soft capital S and capital *k*. To identify the cost reducing activity through effort, we need to consider that effort is nil under cost-plus regimes while it is optimal under fixed-price schemes. Hence, under fixed-price regimes, we would estimate Equation (11), while we would estimate Equation (12) under cost-plus contract. In the same database where both regulatory contracts are present, we consider the following function:

$$\text{(13)} \qquad \begin{aligned} \ln C = \rho\left\{\beta_0{}' + \xi\left[\beta_L \ln w_L + \beta_M \ln w_M + \beta_S \ln w_S + \beta_Y \ln Y + \beta_k \ln k + \beta_L \theta\right]\right\} + \\ (1-\rho)\left\{\ln \beta_0 + \beta_L \ln w_L + \beta_M \ln w_M + \beta_S \ln w_S + \beta_Y \ln Y + \beta_k \ln k + \beta_L \theta\right\} + \varepsilon_C . \end{aligned}$$

where ρ takes value $\rho = 1$ for a fixed-price contract and $\rho = 0$ for a cost-plus contract. Note that only labor is considered as the potential candidate for primal inefficiency and asymmetries of information. The parameters in (13) are all functions of the production frontier parameters. Thus, $\ln \beta_0 = \mathrm{K}$, $\beta_j = \alpha_j / r$, $j = L, M, S$, $\beta_y = 1/r$, $\beta_k = -\alpha_k / r$, $\xi = \tau / (\tau + \beta_L)$, and $\beta_0' = \ln \beta_0 + \beta_L (\ln \tau - \ln \beta_L - \ln \beta_0) / (\tau + \beta_L)$. Computations are available from the authors.

Estimating the Cobb-Douglas cost function requires measures on the level of operating costs, the quantity of output and capital and the input prices. 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. Capital k, which plays the role of a fixed input in our short-run cost function includes rolling stock. 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_S of managing single consumer travel. Summary statistics on the variables used in the analysis are given in Table I.

Table II presents the estimation. Table III lists the estimated technical inefficiency, effort levels and cost distortions over the frontier for the biggest networks included in our dataset. The other networks are available upon request. A distortion equal to 1.015, as in Toulouse for example, suggests that the observed operating costs are, on average, 1.5% above the frontier. Consider Figure 1 where we present our set of fifty-nine networks ranked according to their cost distortions. Figure 1 provides for each network, the level of the inefficiency parameter and indicates the type of contract used to regulate it. 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 ones 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. Concerning the third group, we just conclude that technical inefficiency is so high that even a highly 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.

Note that there are networks for which $e > \theta$. Since we did not impose $\theta > e$ in the course of the estimation, we obtained cases where the effort is slightly greater than inefficiency, implying negative cost distortions. In fact, these estimated negative cost distortions are not significantly different from 0. The estimated variances of the cost distortions are available upon request.

4. The deregulation of European airlines.

We study in this section the effect of liberalization on costs in the European airline industry, accounting for inefficiency and cost-reducing effort. Inefficiency and cost reducing effort are of particular importance when comparing industries subject to different incentives, or analyzing changes in firms' behavior after a structural change in the rules governing the market as it is the case here.

At the beginning of the 1980s, European aviation was regulated by restrictive bilateral air service agreements between the countries concerned. Most routes were served by a duopoly operating under perfect collusion, and the industry was characterized by a lack of incentives to improve efficiency. This situation allowed firms, in many cases subsidized by their governments, to increase costs inefficiently. Under the pressure of the US, several changes took place in the European market. First, in 1984-86, several governments started renegotiating their bilateral agreements allowing for entry and price reductions in a few international routes. Second, the European Community introduced three packages of measures in 1987, 1990 and 1992, respectively, leading to freedom to set frequencies, capacities and prices and free entry by European carriers in any international European route. This process of gradual liberalization left the industry open to international competition, introducing a significant variation in firms' incentives.

Simultaneously, European flag carriers got privatized and explicit permission by the EU authorities started to be necessary in order to receive any form of public subsidy. The new competitive pressure became the strongest incentive for carriers to reduce costs and improve efficiency. Additionally, during the second half of the 1990s, European carriers organized themselves around code-sharing agreements and international alliances that emerged after long and complex processes of negotiation.

Here, we test several scenarios of incentive pressures against each other in order to identify the one that fits the data best. Before deregulation, European airline carriers were mainly public entities regulated by bilateral service agreements. Subsidies would generally allow these firms to completely cover costs. It is therefore assumed that before deregulation, any operator would behave as a non-residual claimant firm and would not provide any effort at all. After deregulation, as already mentioned, the new competitive pressure as well as the abandonment of subsidizing practices would provide the operating firms with perfect incentives for cost and inefficiency reduction. We consider then that the optimal effort provided by a deregulated firm is given by the condition (10). The cost function to be estimated is then:

(14) $$\ln C = \rho\left\{\beta_0{}' + \xi\left[\beta_1 \ln w_L + \beta_2 \ln w_M + \beta_3 \ln Y + \beta_4 \ln k + \beta_5 NET + \beta_6 ASL + \theta\right]\right\} + (1-\rho)\left\{\ln \beta_0 + \beta_1 \ln w_L + \beta_2 \ln w_M + \beta_3 \ln Y + \beta_4 \ln k + \beta_5 NET + \beta_6 ASL + \theta\right\} + \varepsilon_C ,$$

where ρ takes value 1 if the firm operates in a deregulated industry and 0 if the firm operates in a regulated industry. Moreover, *ASL* denotes the average stage length, and *NET* is the size of the network. In the course of the estimation, several combinations will be assumed depending on the nature of the various deregulatory measures introduced in the European airlines market.

The dataset has been constructed for the period 1985-1999 from raw data included in Digest of Statistics published by International Civil Aviation Organization (ICAO), World Air Transport Statistics published by International Air Transport Association (IATA), and Economic Outlook published by the Economics and Statistics Department of the Organization for Economic Cooperation and Development (OECD). The companies under study are the flag carriers from the largest European countries affected by the European liberalization process, namely, Alitalia, Air France, Air Portugal, British Airways, Iberia, KLM, Lufthansa, Sabena and SAS.

The variables have been constructed as follows. Production, wages, capital and average stage length correspond to total operating expenses (ICAO), seat-kilometers available, flight crew salaries and expenses and maintenance and overhaul expenses over number of employees, fleet total number of seats, and total aircraft kilometers over total aircraft departures, respectively. Finally, the price of materials has been constructed as the average fuel prices for the carrier's home country and the OECD (published by OECD), weighted by the company's domestic and international operations respectively (ICAO).

This equation is estimated under alternative scenarios related to the deregulatory packages introduced by the EU and the liberal bilateral agreements signed by the UK with other countries. The following distinctions are made: 1) model with no effort and no inefficiency term, 2) firms do not make any effort to reduce inefficiency after the introduction of deregulatory measures, namely, the effect of deregulation is not accounted for, 3) deregulation affects firms' behavior after the third E.U. package of measures in 1992, and 4) deregulation affects the behavior of the firms affected by the introduction of liberal bilateral agreements, which are British Airways, KLM, Lufthansa, and Sabena, after 1985, and the remaining companies in 1993. The comparison of scenarios (3) and (4) allows us to identify whether the liberal bilateral agreements have any effect on firms' behavior. Finally, given that some new competitors like easyJet and Virgin, not included in the sample, started operating a significant number of international European routes during the period 1997-99, and this could bias our measure of rivals' prices, we construct scenario (3"), which is recovered from scenario (3) after having excluded the last two years of observations, namely 1998 and 1999.

Results are presented in Table IV. The variables are significant and have the expected sign. Costs are increasing with wages and production, while they are decreasing with the size of the network and the average stage length. The alternative scenarios are tested against each other applying a test of non-nested hypothesis. (See Vuong, 1989.) The test shows that scenario (4) is rejected against scenario (3). This suggests that liberal bilateral agreements had a limited effect on firms' behavior, probably because they affected only a reduced number of routes. In addition, the results for scenario (3") are consistent with those for scenario (3).

Scenarios (1) and (2) are rejected against scenario (3), which includes an inefficiency measure and assumes that deregulation affects firms' behavior after the introduction of the third E.U. package of deregulatory measures in 1992. Given that scenario (1) represents the standard approach proposed by the literature focusing on oligopolistic competition, its rejection advocates the construction of models including these components and indicates that we have to be cautious when interpreting the results derived from other models. For instance, the results for scenario (3) suggest that the European airline industry is characterized by constant returns to scale, while scenarios (1) and (2) suggest the existence of increasing returns. More in particular, rejection of scenario (2) shows the importance of accounting for the effects of deregulation on firms' technology and inefficiency.

5. Conclusion

This article provides evidences indicating that a structural analysis is needed to well identify productive inefficiency. Indeed the global inefficiency of a production unit results from a technical inefficiency that is exogenous and an endogenous effort that depends on technological and regulatory conditions in a very specific way. From a policy perspective, the main lesson is that, the compensation for inefficiency in public or private firms might be searched in the system of incentives and institutional constraints.

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Table I: 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 (10^3seat-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 II: Estimation results

	Standard model		Asymmetric information model	
Parameters	Estimation	Standard error	Estimation	Standard error
β_O			0.3068	0.150
β_L	0.4285	0.041	0.4491	0.048
β_S	0.1027	0.011	0.0824	0.006
β_Y	0.0400	0.037	0.1825	0.022
β_K	0.7063	0.092	0.7010	0.048
$\ln \tau$			4.2827	0.257
ν			0.5931	0.035
μ			1.8007	0.287
σ_ε	0.1300	0.012	0.0834	0.007
Log-likelihood	0.549		0.594	
Sample size	531		531	

Note: The fifty-nine firm specific constant terms β_i of the standard model are not reported here. They are available upon request.

Table III: Technical inefficiency, effort level and cost distortion for some networks

Network	Technical inefficiency	Effort	Distortion
Aix	0.067	0.089	0.990
Besançon	0.318	0.000	1.153
Bordeaux	0.086	0.000	1.039
Caen	0.749	0.103	1.337
Cannes	0.646	0.000	1.337
Clermont	0.155	0.000	1.072
Dijon	0.120	0.000	1.055
Grenoble	0.083	0.114	0.986
Le Havre	0.266	0.000	1.127
Lille	0.180	0.126	1.024
Montpellier	0.131	0.110	1.009
Nantes	0.104	0.117	0.994
Nice	0.489	0.113	1.184
Nîmes	0.035	0.097	0.972
Rennes	0.484	0.000	1.243
Strasbourg	0.806	0.117	1.363
Toulon	0.064	0.000	1.029
Toulouse	0.158	0.124	1.015
Valence	0.111	0.000	1.051

Note: Under cost-plus regulation, the effort level is equal to zero.

Table IV. Cost Function Airlines

Variable	**Coeff.**	**(1)**	**(2)**	**(3)**	**(4)**	**(3'')**
Constant	β_0	1.095 (0.724)	-0.090 (0.411)	0.049 (1.013)	-0.292 (0.747)	-0.276 (0.637)
$\boldsymbol{w_{Li}}$	β_1	0.437 (0.065)	0.393 (0.037)	0.318 (0.071)	0.375 (0.076)	0.326 (0.073)
$\boldsymbol{Y_i}$	β_3	0.864 (0.065)	0.933 (0.063)	1.009 (0.067)	1.028 (0.060)	1.051 (0.057)
$\boldsymbol{NET_i}$	β_5	-0.242 (0.084)	-0.228 (0.088)	-0.360 (0.079)	-0.368 (0.078)	-0.398 (0.074)
$\boldsymbol{ASL_i}$	β_6	-0.400 (0.088)	-0.381 (0.053)	-0.422 (0.097)	-0.345 (0.083)	-0.405 (0.101)
$\boldsymbol{T}$	β_t	0.071 (0.040)	0.068 (0.032)	0.271 (0.057)	0.097 (0.040)	0.269 (0.061)
$\boldsymbol{e_i}$	$\ln(\mu)$	-	-	3.754 (0.214)	5.088 (0.821)	3.969 (0.256)
Standard Deviation of θ		-	0.474 (0.036)	0.270 (0.077)	0.404 (0.069)	0.313 (0.054)
Standard Deviation of the error term		0.257 (0.015)	0.023 (0.026)	0.164 (0.040)	0.098 (0.057)	0.121 (0.054)
$\boldsymbol{R^2}$		0.87				
Vuong test. Scenario (3) against alternative scenarios		3.121	2.777		1.996	

Notes: Standard deviations in parentheses.

Values for the Vuong test below –2 favor the alternative model against model (3), and above 2 favor model (3) against the alternative model.

Scenarios: (1) Deregulation has no effect (e_i=0), and the model does not account for one-side inefficiency (θ_i=0).

(2) Deregulation has no effect.

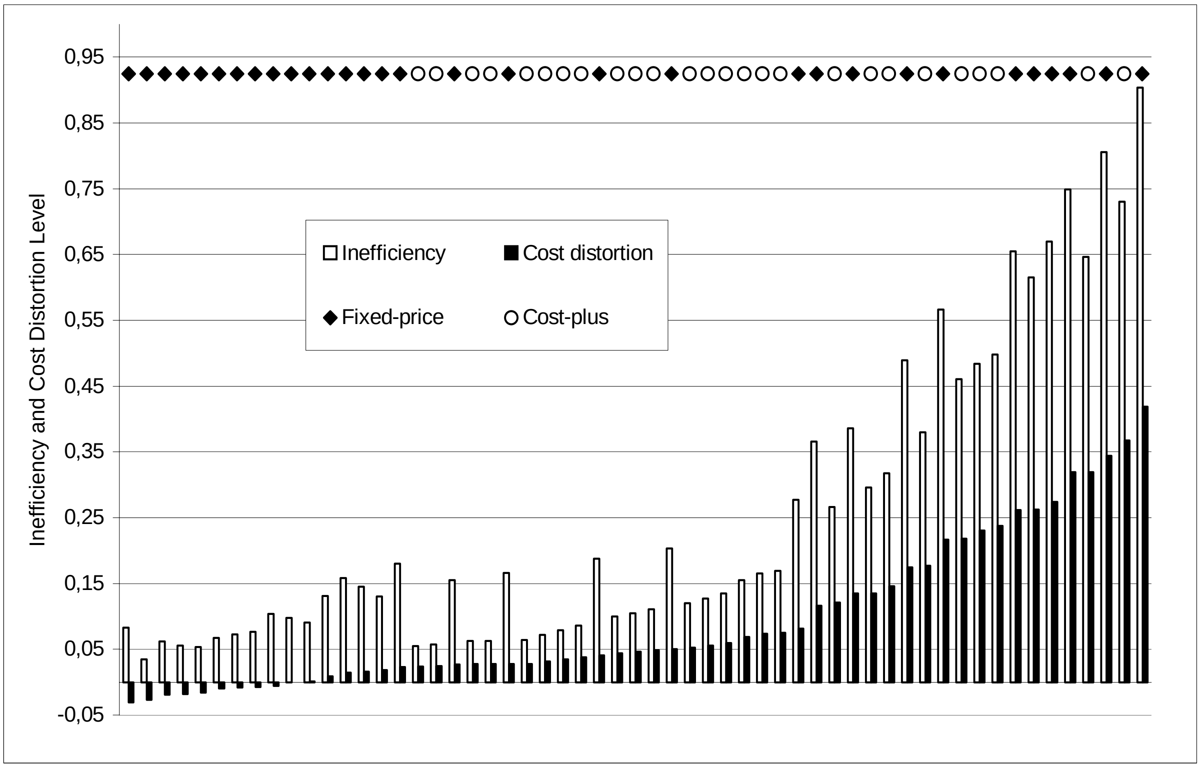
(3) Deregulation affects firms' behavior after 1992.

(4) Deregulation affects firms' behavior after 1985 for British Airways, KLM, Lufthansa, and after 1992 for the remaining companies.

(3'') As scenario (3) but dropping the observations for the last two years (1998-1999). Note that (3'') and (3) cannot be tested against each other since they consider two samples of different sizes.

In all scenarios but (1) the model accounts for one-side inefficiency term ($\theta_i \geq 0$).

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.