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Progress Towards Cost-Benchmarking Of The European ATM System

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Originator EEC - PRF (**Perf**ormance and Economy Research)	**Originator (Corporate author) Name/Location :** EUROCONTROL Experimental Centre B.P.15 F-91222 Brétigny-sur-Orge CEDEX FRANCE. Telephone: +33 (0) 1 69 88 75 00
Sponsor	**Sponsor (Contract Authority) Name/Location** EUROCONTROL Agency Rue de la Fusée, 96 B-1130 BRUXELLES Telephone: +32-(0)2-729 90 11

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PROGRESS TOWARDS COST- BENCHMARKING OF THE EUROPEAN ATM SYSTEM

Authors	Date	Pages	Figs	Tables	Annex	References
P. Enaud (PRU) G. Nero (PRU) J. C. Hustache (EEC)	07/00	V +24	5	3	0	6

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Abstract :

The study has been performed by the Performance Review Unit with the assistance of the EEC at Brétigny.
The subject of this study is to develop a framework for the cost benchmarking of the European en-route Air Navigation Services (ANS).

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Abbreviations

ACC	Area Control Centre
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CAA	Civil Aviation Authority
CFMU	Central Flow Management Unit
CRCO	Central Route Charges Office
EATMP	European ATM Programme
EEC	Eurocontrol Experimental Centre
GDP	Gross Domestic Product
NATS	National Air Traffic Services (United Kingdom)
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
PRC	Performance Review Commission
PRU	Performance Review Unit
TFP	Total Factor Productivity
UAC	Upper Area Control Centre

1. Introduction

Costing is the process of ascertaining the relationship between costs and economically relevant variables, such as output, in a way that is useful for making decisions. Knowledge of the cost implications of alternative situations is needed in order to analyse a wide variety of problems within a provider or across a range of providers, as well as in formulating or assessing public policies such as economic regulation or deregulation.

1.1 Objective

The main objective of this report is to develop a general framework for cost benchmarking analysis of en-route Air Navigation Services (ANS). Therefore, a review and the collection of relevant economic data have been performed and a series of statistical models have been proposed.

1.2 Scope

The scope of the study is limited to member countries of the EUROCONTROL Central Route Charges Office. Even though, one can notice that air navigation service providers (ANSPs) operate in a very heterogeneous environment, limiting de facto the explanatory power of simple indictors for unit cost.
In 1998:

- The amount of traffic controlled (scale of operations) varies from 49,000 flights (in Malta) to 2,300,000 flights (in Germany).
- The geographic coverage (scope of operations) is of completely different sizes. From 20,000 km^2 (in Slovenia) to 2,250,000 km^2 (in Spain).
- The economic environments are completely different, for example, the Gross Domestic Product (GDP) per capita varies from € 9,100 (in Portugal) to € 32,000 (in Switzerland).

1.3 Methodology

As the cost of each provider can be influenced by many different factors, the benchmarking exercise will have to identify the most relevant ones in order to establish a fair measure of the ANSPs cost effectiveness.

After reviewing the theoretical issues of the economic approach, this report concentrates on the estimation of statistical models for the total cost, using multiple regression techniques.

2. Theoretical analysis of the problem

2.1 Possible approaches

There are different approaches to cost benchmarking, which are, to some extent, complementary. The degree of sophistication and the implications can, however, be quite different.

2.1.1 The use of indicators

One approach is to provide (usually) readily available accounting/financial and operational key indicators on a time series basis (different time period within the same provider), and (or) on a cross section basis (same time period but across different providers). As an example, one could compute the *costs per kilometre* (see Figure 2.1) or the *unit rates* and compare these indicators across ANSPs and/or across time. This was the approach followed in PRR 1 (1999) [1] for example.

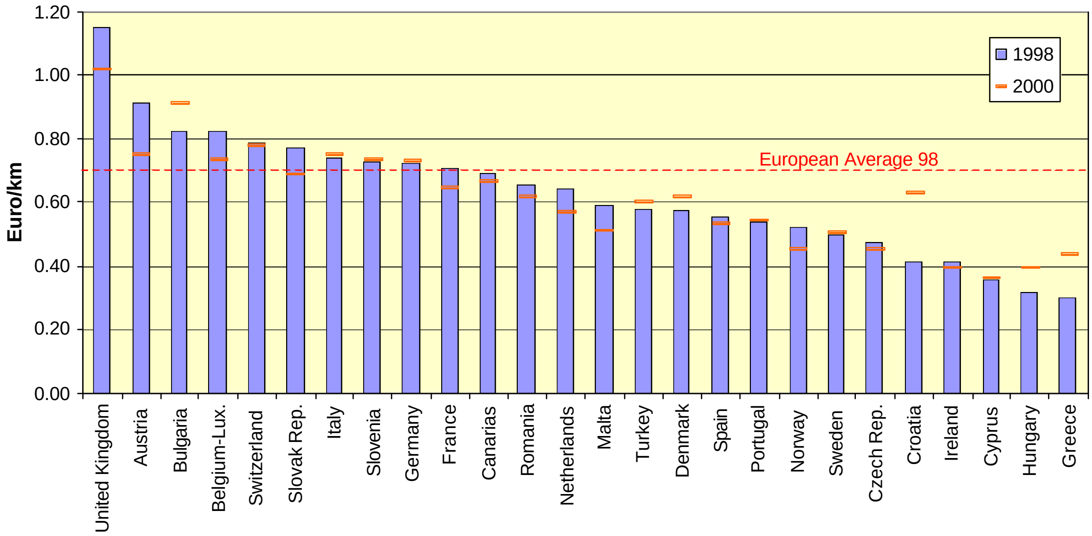


Figure 2.1: En-route costs per kilometer

Although such indicators can be relevant, most likely when taken separately they provide only a partial assessment of performance. Are low unit costs the genuine result of efficiency or the result of the large scale of operations? Similarly, is an increase in labour productivity[1] from the period n to n+1 the result of real efficiency gains or the result of some labour force being subcontracted out in period n+1 ?

This suggests that there is a need to use a battery of indicators. The problem lies in the difficulty in identifying and defining the indicators that should be included, i.e. the relevant indicators for benchmarking purpose.

[1] The use of the terms *productivity* and *efficiency* refer to the (relative) ability of individual ANSPs to produce the greatest possible output from the least possible inputs.

A related problem with measuring and comparing efficiency is that each ANSP actually produces a variety of outputs, using a similarly wide range of variety of inputs.

This has led researchers to develop complementary tools such as Total Factor Productivity (TFP) and econometric cost functions in order to overcome some of the limitations inherent with the use of indicators.

2.1.2 Total Factor Productivity

From a theoretical point of view, the economic theory of index numbers, developed by Diewert (1976) [2], and Caves, Christensen and Diewert (1982) [3], allows for a convenient indicator of aggregate output and aggregate input.

From such indicators, total factor productivity (TFP) indices or partial (e.g., labour) productivity indices can be constructed. The index number approach to TFP measurement compares the growth rate of a quantity index of all outputs with the growth rate of an input quantity index. The major problem with this method is that one needs fairly detailed data on the number of inputs, on the number of outputs, on the revenue share of outputs, and on the cost share of inputs. Hooper and Hensher (1997) [4] have recently used this (non-parametric) approach for measuring total factor productivity of airports. For the case at hand, i.e. ANS, we are presently not able to have a reliable set of data required for this approach.

2.1.3 Econometric cost function

Statistical costing methods are used to estimate the specific relationship between output(s) and costs. Usually multiple regression analysis is used to infer cost-output relations from a sample of actual operating experiences (generally making uses of financial and operational information). This allows to identify the variability of costs with output measures, after controlling of other appropriate exogenous factors.

The specification of the cost function usually satisfies a certain number of economic properties (homogeneity, symmetry, etc), according to (neo-classical) economic theory. Numerous studies on airline economics have shown the usefulness and validity of this approach.

The advantage of the cost function approach is that the estimation can provide a wide range of estimates on economically relevant parameters such as economies of scale and elasticities of substitution among inputs, depending on the degree of sophistication of the specification and the amount of available data.

Given our data limitation we suggest exploring a simple econometric cost model, i.e. a model that does not have the usual neo-classical properties. Such a statistical model would nevertheless enable us to gain insights on the cost side of ANS economics, and it could be refined later when more reliable data is available for a comprehensive cost specification.

Again, such a model should be viewed as a first approximation model. It will not answer all the questions that one might want to investigate, and, in particular, TFP cannot be addressed. However valuable information could be obtained for preliminary cost benchmarking assessments. One of the merits of pursuing immediately the statistical approach is that it will also indicate in which area information gathering is required, if we want to make improvements in our knowledge of ANS economics.

Ideally, benchmarking the cost should allow comparing the deviation of some ANSPs against an optimum theoretical cost. All parameters that are not directly under the ANSP's control, and that could influence the level of performance, should be taken into account. Thus, the difference between observed and predicted cost should only come from an ANSP's ability to efficiently organise the production.

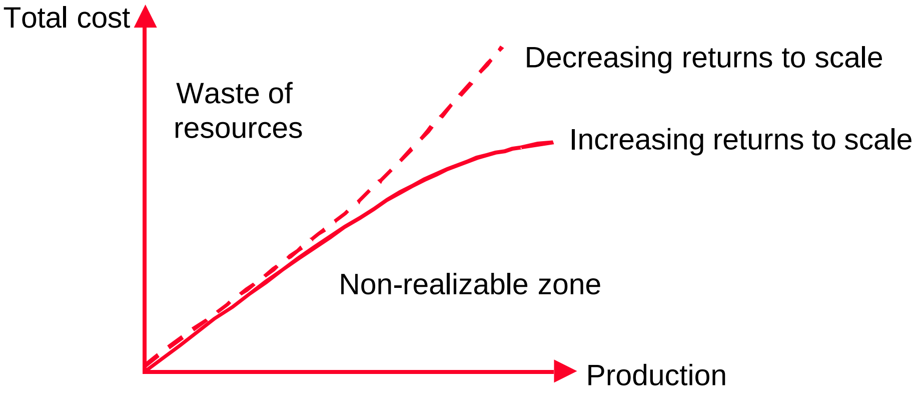


Figure 2.2 Cost Function

The figure above shows an example of the different shapes a cost function can have and the resulting interpretations. Economies of scale are a quite generic concept that can hide several phenomena. In the case of ANS, it might be interesting to distinguish at least two sources of economies:

- Economies of size: All else equal, what is the impact of controlling a higher number of kilometres? What happens if an ANSP has suddenly to carry the traffic over longer distances?
- Economies of density: In the current network what is the impact of controlling more traffic per route or per volume of airspace? High density could lead to a high rate of utilisation of the provided capacity (that should logically decrease the unit cost), but at a certain point it is probable that the complexity generated by density would result in increasing marginal costs.

2.2 Costs and Decision Making in Transportation Related Industries[2]

Determining costs, in transportation related industries, is often difficult because of the heterogeneous nature of the output or service produced, and indivisibilities in production.

2.2.1 The heterogeneous nature of the output

The heterogeneous nature of the output refers to the diverse products that are produced in transportation. The implication is that one must specify accurately just what is being supplied in order to cost it properly. The degree of accuracy required will depend on the particular question addressed.

2.2.2 Indivisibilities in production

They have several aspects:

- The single act of supplying a service can satisfy several demands simultaneously.
- When an ACC opens a sector, several users can “consume” the service simultaneously.
- Expenditures on inputs (labour, capital equipment, material, energy) are not always in relation to the level of output/service: the costs of some inputs are spread over several output units, giving rise to common costs. The production function is not necessarily continuous.

As a result of these characteristics, a variety of different outputs are provided and a composite of costs are incurred over some period of time; but it is difficult, and in some cases impossible, to identify a specific level of expenditure with a specific output.

Clearly, for decision making it is necessary to have estimates of both types of costs: those that can be identified with particular outputs, and those that can be only identified with groups of outputs. Another problem is that, in transportation related industries, typically large lump sums are required for capacity investments (capital expenditure is not linear with output).

2.2.3 Formulation and estimation of statistical cost functions

Formulation of a cost function:

- Most statistical studies of costs focus on long-run estimates. Long-run cost functions are generally estimated using a cross-section of firms. The rationale is that ANSPs operating at different output levels will have adjusted their fixed assets (capital equipment) to optimal levels with only random deviations: thus, an estimated cost function across these ANSPs should be a long-run variety. Notice that, sometimes it is the short term view that is of interest. This can be addressed by focusing on data (usually quarterly data) of a single ANSP, but this approach is currently not available.

[2] The above analysis relies heavily on W.G. Waters paper in Transportation Journal (1976). [5]

- The choice of the functional form of the relationship (i.e. whether costs are a linear or some more complex mathematical function of output) is usually solved on empirical grounds (best fit) although one might argue on an a priori ground instead.

Selection and measurement of variables for the cost function:

- The choice of an alternative output measure is a persistent problem. Often, there is no unique best measure of output of a transportation-related business. In ANS, the service can be perceived either as a distance flown under control, or as the actual sector capacities (maximum number of flights a team of ATCOs can cope within an hour time). This distinction introduces the difference between the actually used capacity and the provided capacity. The absence of measurement for the provided capacity and the difficulty to define the concept of capacity itself leads to focus on the number of flights or kilometres controlled.

- The size of the firm is often listed as a separate variable in a cost function. But “size” can be measured in various ways, e.g., total fixed assets, geographical market coverage of the ANSP, etc. The selection among competing measures is usually solved on an empirical basis, i.e., choose the measures which yield the best statistical fit.

- Introducing additional independent variables to increase the explanatory power of a regression often raises the problem of multicollinearity. This is where variations of some or all of the alleged independent variables are correlated with one another, obscuring the relationship between the dependent variable (costs) and the correlated “independent” variables. If one must choose between alternative variables, this might be done either by ex-ante specification of which variables is expected to be more important or by ex-post selection of the variables which give best statistical fit. Neither approach is completely satisfying because there may be good reasons to expect a certain variable to contribute some independent explanation of costs. However, that variable must be excluded from regression analysis because it is strongly correlated with some other variable.

2.2.4 Making Use of Statistical Cost Studies

There are two basic methods of using statistical results.

- The first consists in the projection, or prediction, of a change in costs with a change in one variable. The presence of a significantly positive constant term in a “long-run” linear cost function implies that average costs will be declining with volume.

- The second consists in the analysis of deviations of particular observations from the norm or regression equation. Here one attempts to assess relative performance (benchmarking) by the position of particular observations relative to the regression results. This is an improvement over merely comparing deviations from an average and should be more reliable.

A frequent cause of differences in (unit) cost levels among ANSPs is unfavourable “characteristics” or inherent disadvantages, e.g., smaller airspace, more complex airspace, or higher labour costs, which makes an equally efficient ANSP to show higher unit cost. If all other possible explanations are exhausted one might credit superior or poor performance to differing managerial or organisational skills (efficiency).

One problem with this approach is that it does not necessarily provide an estimation of the efficiency frontier: the regression line represents the average relationship implied by the data, not the efficient frontier. A cross-section of inefficient ANSPs would yield, all else equal, an excessively high prediction of cost levels. To adopt such cost estimates for regulatory purposes (e.g., for determining minimum unit rate levels) would allow for existing inefficiency.

If one can be sure that the expected variability in costs for any given level of output is entirely explained by inefficiencies of different ANSPs, then it would make sense to use guidelines based on the most efficient observations (i.e. the lowest observed cost-output observation rather than the “average” relationship that ordinary regression techniques yield). The difficulty of course lies in being able to identify from the residuals of the regression the inefficiency term and the genuine random error.

Finally, in cost estimation, as in most decision problems, the objective is not to attain perfection but rather to attain the best possible estimates within the stipulated time and financial constraint. The use of statistical estimates is not a substitute for judgement by managers of ANSPs or government regulators, but information to assist them in decision-making. Surely, an estimate with confidence intervals is more useful than a state of ignorance or false accuracy.

2.3 Proposed methodology

We propose to adopt a pragmatic approach, centred on statistical estimations, that shall significantly improve the level reached by the simple indicators, and take the benefits of econometric techniques, even if it is too early to estimate an economic (neo-classical) cost function.
Main steps of the proposed approach are:

- To define the key elements that shall be introduced in an ANSP cost benchmarking model.
- To collect the most appropriate and consistent data, for the maximum number of ANSPs, and the longest time series.
- To specify and estimate statistical models of the total en-route costs. The models shall be consistent with a logical understanding of the ANS activity, but also be statistically robust, and finally be transparent enough to be understood and replicated by all interested parties.
- The analysis could be completed, a posteriori, with partial information on the variables that could not be included in the model because of an insufficient number of observations. Similarly, in order to understand cost differences provided by the model, the analysis could be supplemented with an appropriate range of indicators, such as km controlled per ATCO, or km controlled per fixed asset, etc.

3. Data

In order to increase the representativeness of the estimated models, we chose to maximise the number of observations, using both time series and cross-section data. Of course, all data is not available for all States/ANSPs and all years, and depending on the variables included in the estimated model, the number of observations usable will vary.

In addition to costs, the following data is particularly important in a benchmarking exercise.

- Appropriate definitions and measures of the services that are produced.
- Description of the environment's complexity is also needed, as a more or less complex environment constrains the ANSP in its technological and organisational choices.
- Prices of all inputs should be known, as all else equal, total costs increase with input prices.
- The quality of the delivered service could also be taken into account. One measure for the quality of service is delay.

The following paragraphs present the data that have been collected for potential utilisation in a cost-benchmarking model of European ANSPs.

3.1 En-route costs

Total national en-route costs expressed in national currency for the years 1991 to 1998 (1998 is the last year for which actual figures are available) have been collected from the Central Route Charges Office.

Costs in national currency are then inflation-adjusted using the consumer price index (all items) available from "OECD Main Economic Indicators, Historical Statistics 1960/1998", and converted in Euro 1998 using the 1998 exchange rate declared in the CRCO tables.

Maastricht costs have been reallocated to the contributing States. Belgium-Luxembourg, Germany and The Netherlands contribute to Maastricht UAC costs, respectively for 38%, 42%, and 20%, in 1998. The 1998 sharing keys are applied for all years; it is assumed that they have not changed since 1991. Maastricht costs, expressed in Euro, are inflation adjusted using the Euro deflator published by Eurostat.

3.2 En-route output (production)

Output and total costs generally show a continuously increasing relation. However, more than quantifying the total costs, the real issue is to observe the behaviour of the marginal cost curve. The selection of the variables for output and for complexity has been carried out with respect to this issue. Number of kilometres flown, average route length, and density are expected to yield relevant information regarding the possible existence of economies of size and economies of density.

Data collected for potential output metrics :

- The number of internal flights, the number of international departures and arrivals, and the number of overflights are available from STATFOR for the years 1991 to 1998. The sum of those three categories represents the total number of flight controlled per year and per State/ANSP.

- The number of kilometres controlled is available from the CRCO. The km controlled by the CRCO suffers from some limitations. First, it does not take into account the route structure with a national airspace since it measures a straight line between entry and exit points. Secondly, it measures km flown over the territory of each State, not over the space controlled by each ANSP. Where possible, we have tried to allocate km controlled to each ANSP.

- The number of airport movements per country is calculated from STATFOR statistics. Airport movements = 2 x number of domestic flights + number of international departures and arrivals.

- The average flight length, calculated as the number of kilometres controlled divided by the total number of flights.

3.3 Complexity

Complexity of air traffic, and its potential impact on costs, is still an investigation area where there is no wide consensus. A first attempt at producing complexity indicators, via density and workload modelling has been carried out by the EEC and NATS. Details on the methodology and illustrative results can be found in “Investigating the Air Traffic Complexity” [6]

Two aspects of the air traffic complexity have been investigated for possible integration in the cost benchmarking models: the traffic density, and the vertical evolution of flights.

3.3.1 Traffic density

Maintaining safe separations between aircraft is obviously a more demanding task in high density areas.

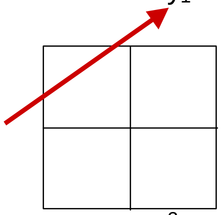
Simple density indicator computed at the States/ANSP level can however be misleading. As an example, although the London area is one of the busiest area in Europe, average density for UK is relatively low due to the presence of large areas with very low traffic. In order to build relevant indicator measures, average concentrations of traffic (in kilometres flown) have been performed for all States/ANSPs using a one-day traffic sample (12 August 1999).

The indicator used is an application of the Herfindahl concentration index (HI). It is widely used in Industrial Economics to assess the degree of concentration of a market by summing the square of each competitor’s market share. In case of a monopolistic market, the index equals one, and the more the market is shared between competitors, the more HI tends towards zero.

To measure air traffic concentration, each State/ANSP's area of responsibility for service provision is split into virtual boxes. The more the traffic is concentrated in a reduced number of boxes, the higher the index.

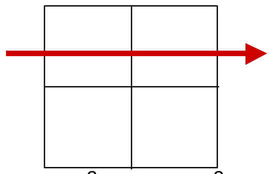
Example: $Country_1$ and $Country_2$ have to handle the same amount of kilometres, but the traffic is differently concentrated over their surface. One can see that the concentration of traffic in $Country_1$ is twice the concentration of $Country_2$.

$Country_1$



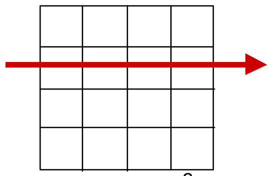
$HI = (100\%)^2 = 1$

$Country_2$



$HI = (50\%)^2 + (50\%)^2 = 0.5$

As the earth is almost spherical, the grid used to divide the airspace in virtual boxes generates smaller boxes around the North Pole than around the Equator (size of the boxes reduces with latitude). In the example let's observe the impact of a reduction in the box size in $Country_2$.



$HI = 4 \times (25\%)^2 = 0.25$

We see that the index is reduced in the same proportion as the box size. Hence the HI index must be corrected by the ratio [Number of boxes / Country surface], which compensates for the bias.

Thus, the concentration index (CI) we use for a particular State/ANSP is:

$$CI = \sum_{i=1}^{n} \left(\frac{\text{Traffic}_i}{\sum_{i=1}^{n} \text{Traffic}_i} \right)^2 \times \frac{n}{\text{Country Surface}} , \qquad (1)$$

where i stands for a virtual box, n is the number of boxes necessary to cover the State/ANSP surface, traffic i is equal to the kilometres controlled in a virtual box, and Country Surface is computed by summing the surfaces of the boxes composing the State/ANSP.

Density indicator can be obtained by multiplying the Concentration Index (CI) by the traffic:

$$Density = CI \times \text{Traffic} \ . \qquad (2)$$

One can show that equation (2) is equivalent to :

$$\sum_{i=1}^{n} \frac{(\text{Traffic}_i) \times \dfrac{\text{Traffic}_i}{\text{Volume of a box unit}}}{\sum_{i=1}^{n} \text{Traffic}_i}, \qquad (3)$$

which represents the weighted average density computed for the individual boxes.

For practical reasons it was not possible to compute the concentration index for all days and all years. Thus, it is assumed that the traffic pattern and therefore the concentration remained constant over the studied period.

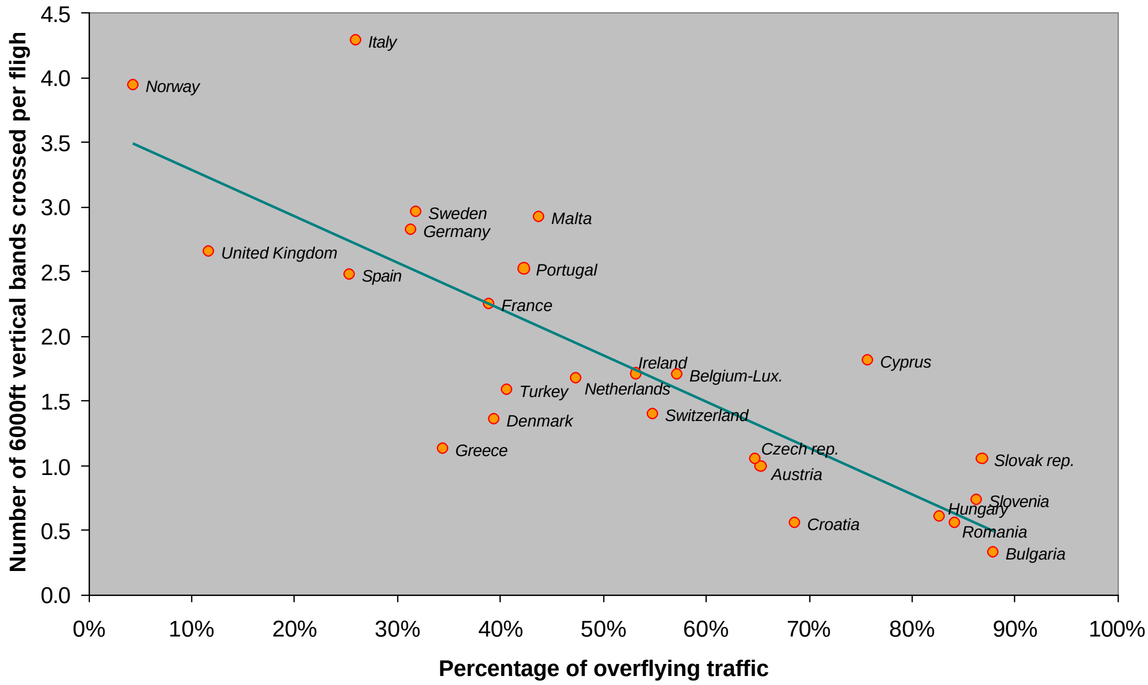
3.3.2 Vertical evolution of flights

The extent of vertical evolutions of flights can be important to capture the traffic complexity coming from the flight profile. An aircraft in climb and descent will actually be slower than in cruise, and oblige the controller to check potential conflict over several flight levels. As precise measures of this variable are not available for a time series analysis, the number of airport movements divided by the total number of flight controlled, or conversely the percentage of overflights, are used as a proxy.

In fact, these two indicators provide an information slightly different from actual vertical movements. The proportion of airport movements reflects more the need for co-ordination with approach centres. Besides, it completely ignores the fact that, for an airport movement in a small State, a large part of the climb / descent can be done in a neighbour State (this argument is especially valid for airports located near a border).

Figure 3.1 shows the correlation between the counting of 6000Ft vertical bands crossed per flight (performed for the 15th of March 1999) and the percentage of overflying traffic in 1998. The general trend and correlation coefficient are relatively good (nearly 70%). However, traffic patterns change daily, and local constraints affect the flight profile regardless of the fact that it is a domestic flight or an overflight. Consequently, for some States/ANSPs (particularly Greece and Italy) one can observe a higher dispersion around the correlation line.

Figure 3.1: Vertical evolution of traffic



3.4 Prices

There is a wide dispersion of input factor prices across EUROCONTROL Member States. Differences of input factor prices may affect both total costs and the way substitute inputs are combined in the production process. A good performance could not be automatically attributed to a high level of efficiency, when an ANSP benefits from a low cost environment.
The main input factors are staff and physical capital (equipment), with factor prices being wages (salaries) and the cost of capital, respectively. Both wages and the cost of capital are difficult to measure given current availability of data.

- Gross Domestic Product (GDP) per capita or comparative price levels could be used to capture the differences in operating input prices, in particular for staff costs. We are conscious that it is a very poor substitute for the real salaries, but it should give a first idea of the potential impact of price levels on costs.

- Long-term interest rates (nominal value) are available from “OECD Main Economic Indicators, Historical Statistics 1960/1998”. They could be used to capture the differences in the cost of capital between the ANSPs. Real values for the long-term interest rates are computed by subtracting the inflation rate from the nominal values.

As an illustration of the potential impact for an ANSP to produce with different price levels, Figure 3.2 displays costs (operating costs plus staff costs) after “correction” by the comparative price levels in 1998 (the comparative price level is defined as the ratio of purchasing power parities (PPP) to exchange rates).

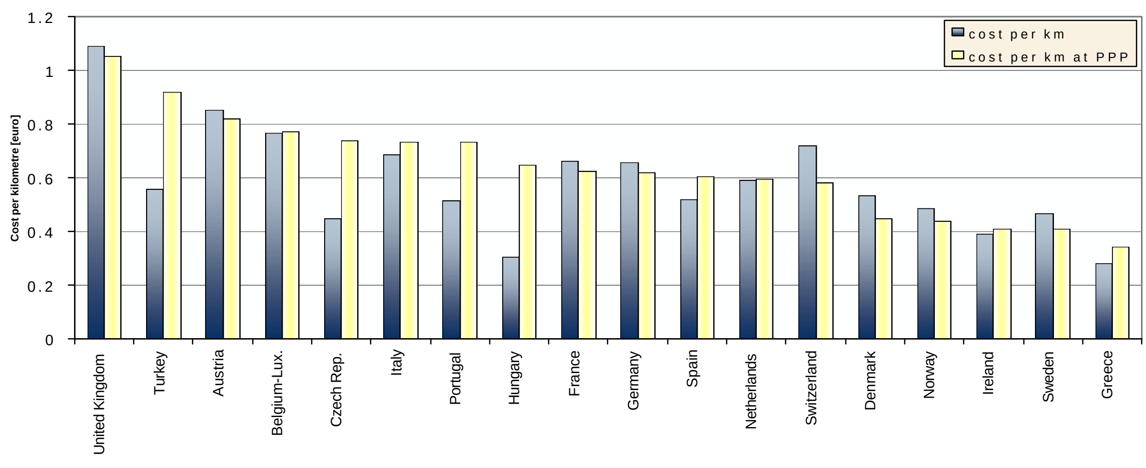


Figure 3.2: Impact of applying the comparative price levels to costs

Even if the PPP does not exactly reflect the differences in wages, this shows that the potential impact of input prices can be significant.

4. Statistical Model

4.1 Observations

The data set used to estimate the models relies on observations over 5 years (1994 –1998). Data before 1994 are either not reliable or not available for all the variables. Data for 1999 will not be available before July 2000. Moreover working with a longer time series did not change significantly the values of the estimated coefficients in the final model.

The initial criteria for including a State/ANSP in the regression is to have reached at least 100 millions kilometres controlled in 1998. Considering the wide range of ANSPs' size, this should ensure a minimum amount of homogeneity in the sample. After testing several samples and removing the statistical outliers, it appears that a rather strong robustness of the model was reached when working with the following 16 States/ANSPs: Austria, Belgium-Luxembourg, Cyprus, Czech Rep., Denmark, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom.

Working with more States/ANSPs adds noise to the model, and decomposing the sample in more homogeneous groups does not really help to benchmark. The interest of benchmarking is in fact to provide a single reference tool to which a maximum number of ANSPs can be confronted, and there is little interest in estimating one model per ANSP. It appeared that Hungary, Norway, Romania and Greece had a quite high perturbing impact on the model, leading to some interpretation difficulties. This could be related to measurement problems of some variables. On the contrary, the addition of smaller States/ANSPs such as Cyprus, the Czech Rep. and Denmark did not raise any problem.

Before integration in the statistical model, a log transformation of the data set has been performed. The advantage of such a transformation is:

- To bring more normality in the distribution of data; and,
- To facilitate the interpretation of estimated parameters that can be directly read as cost elasticities.

4.2 Retained explanatory variables

The retained explanatory variables are those which present the greatest possibility for economic interpretation and also the greatest possibility to be collected or computed, for a maximum number of ANSPs and years.

- The number of kilometres controlled is preferred to the number of flights because of a better correlation to costs, and of its additive property. Km controlled over the ECAC area is the sum of Km controlled by a State/ANSP, which is the sum of km controlled per ACC, etc. That is not the case for the number of flights.
- The mean route length of a flight (ratio between kilometres and number of flights), should allow for testing possible economies due to the size of a State/ANSP. For instance, does controlling 100 aircraft over 100 kilometres generate the same costs as controlling 10 aircraft over 1000 kilometres, given that in both cases 10000 km have been controlled?

- The density is a function of both the concentration and the volume of traffic. Density could have two opposite effects on costs. A higher rate of capacity utilisation would decrease the unit cost (economies of density) but a higher complexity could oblige to resort to more expensive operational systems (diseconomies of density) and to proportionally more staff.
- The percentage of overflying traffic accounts here for the complexity due to the flight profile. Flights in vertical evolution generate more workload than cruising traffic, and thus decrease ATCOs productivity. It is expected that the higher the percentage of overflying traffic, the lower the costs, all else equal.
- A variable "Time" is added to capture the time trend. During the 94-98 period, technical evolution, productivity gains, or modification of the service quality may have happened and affected cost effectiveness.

Proxies variables for input prices could not be retained in the statistical model since these variables were not statistically significant. Most likely, the proxies GDP per capita and long term interest rates do not sufficiently capture wages and cost of capital, respectively.

Table 4.1: Matrix of correlation between variables

	Total Costs	Kilometres	Average Route Length	Density	% overflight
Total Costs	1.00				
Kilometres	0.97	1.00			
Average Route Length	0.43	0.60	1.00		
Density	0.43	0.29	-0.37	1.00	
% overflight	-0.71	-0.68	-0.41	-0.09	1.00

4.3 Estimation of the model

The functional form selected to perform the model estimation is log linear. This form eases the interpretation of estimated parameters that can be directly read as cost elasticities. To be more precise, the relationship between total en-route costs and the explanatory variables is supposed to take the following functional form:

$$C = A \times e^{a_5 T} \times K^{a_1} \times D^{a_2} \times L^{a_3} \times O^{a_4}$$

Taking the logarithm on both side of the equation yields:

$$Ln(C) = a_0 + a_1 Ln(K) + a_2 Ln(D) + a_3 Ln(L) + a_4 Ln(O) + a_5 T$$

where $\alpha_0 = Ln(A)$, represents a constant.

The statistical results of the model are summarised in the table below.

Observations: 67 Adjusted R^2: 0.973 Fisher: 480.13 Durbin Watson: 1.66
Dependent variable: Total Costs (C)
Ln (C) = a_0 + a_1 Ln (K) + a_2 Ln (D) + a_3 Ln (L) + a_4 Ln(O) + a_5 T

Explanatory variables		Coefficient	T-Stat
Constant	α_0	-2.7204	-4.4569
Kilometres (K)	α_1	1.1162	22.7194
Density (D)	α_2	0.1860	2.9114
Average route length (L)	α_3	-0.3021	-4.0048
% Overflights (O)	α_4	-0.2436	-3.9976
Time (T)	α_5	-0.0479	-3.3047

4.3.1 Economic Interpretation of the results

97% of the variance in total en-route costs is explained by the selected cost-drivers, which demonstrates the validity of the model. It is the number of kilometres controlled that has the largest explanatory power.

The signs of the estimated coefficients are all consistent with economic intuition and with expectation. The kilometres and the density parameters have a positive impact on costs whereas the average route length and the percentage of overflights are factors that contribute to lower costs.

As traffic increases, both the kilometres controlled and the density of traffic increase. The model predicts that a 10% increase in traffic generates a 13% increase in total costs (the sum of $\alpha_1 + \alpha_2$). This suggests that although greater traffic density allows for a better exploitation of fixed inputs, it also increases the workload and thus cost. The model suggests that it is the latter effect that dominates.

On the other hand, the model predicts that there is a cost advantage in controlling flights over longer distances. An increase of 10% in the average controlled distance decreases total costs by some 3%, all other things being equal. This result indicates slight economies of scale in respect of FIR size or route length controlled. However, it should be noted that the average route length is the most sensitive variable to changes in the model specification. It is possible that with new samples and different explanatory variables the estimated coefficient for this variable change or even becomes not significant.

The model suggests that, if the percentage of over-flights increases by 10%, for a given number of flights and kilometres controlled, total costs would decrease by some 2.4%. Finally, the model captures the downward trend in total costs, which have decreased some 5% per year during the 94-98 period. This probably captures both productivity gains and reduction in the quality of service (delays) observed during the period.

These results are summarised in Figure 4.1 for 1998 and in Table 4.2 for all years. The ANSPs that lie above the regression line are somewhat less cost-effective than those providers that lie below the line. Although the United Kingdom’s unit cost is 65% higher than the European average (see Figure 2.1), once key cost-drivers are taken into account, the statistical model shows that United Kingdom costs are no more than 16% higher than predicted. Similarly, Germany, with a unit cost 4% higher than the average, is some 16% more cost-effective than predicted. In order words, simple comparisons of unit costs across ANSPs are not sufficient to assess cost-effectiveness.

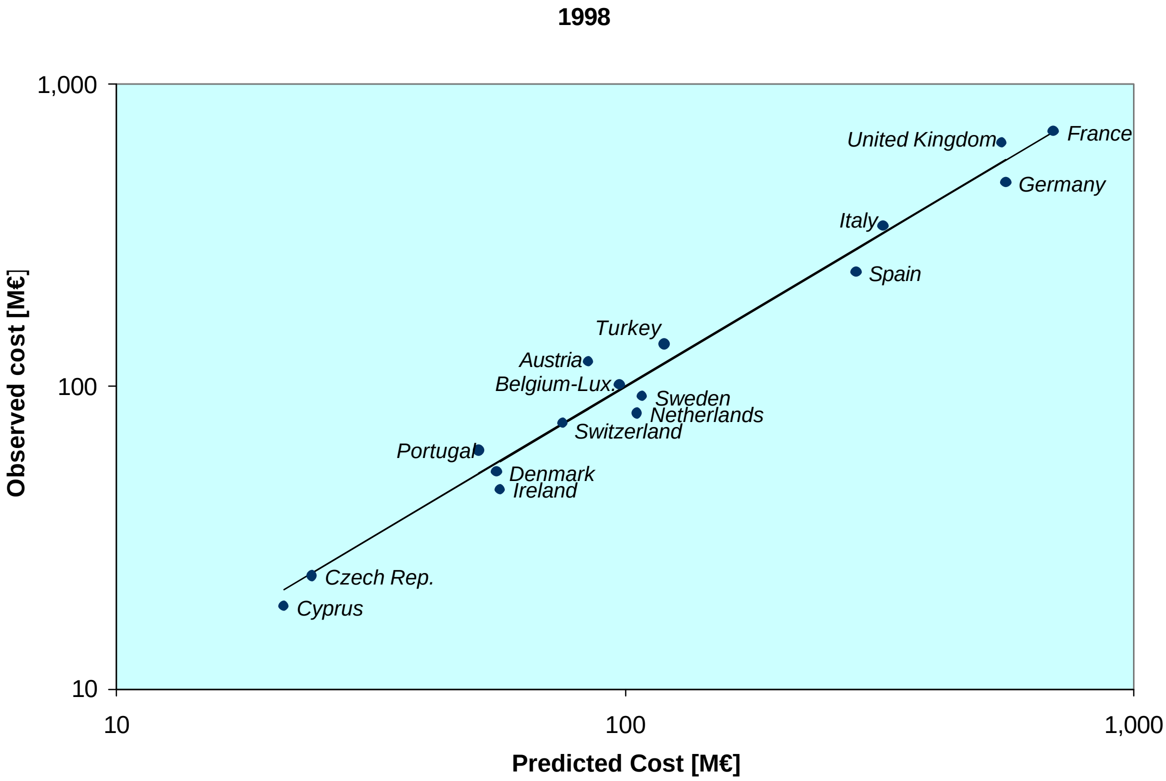


Figure 4.1: 1998 predicted versus observed costs

Table 4.2

Year	Country	Observed cost [M€]	Predicted cost [M€]	% difference
1998	Austria 98	120.9	84.7	43%
	Portugal 98	61.3	51.6	19%
	United Kingdom 98	637.9	549.7	16%
	Turkey 98	137.6	119.6	15%
	Italy 98	339.0	321.9	5%
	Belgium-Lux. 98	101.6	97.5	4%
	Switzerland 98	75.6	75.4	0%
	France 98	696.7	696.0	0%
	Czech Rep. 98	23.6	24.2	-3%
	Denmark 98	52.2	55.9	-7%
	Cyprus 98	18.7	21.3	-12%
	Sweden 98	92.7	108.0	-14%
	Germany 98	471.1	561.0	-16%
	Spain 98	238.7	285.2	-16%
	Ireland 98	45.6	56.7	-20%
	Netherlands 98	81.5	105.6	-23%
1997	Turkey 97	176.7	126.8	39%
	Portugal 97	62.4	47.9	30%
	Czech Rep 97	22.6	19.9	13%
	United Kingdom 97	588.6	520.4	13%
	Belgium- Lux 97	105.2	94.3	12%
	Italy 97	334.9	303.0	11%
	Austria 97	101.6	95.0	7%
	Switzerland 97	76.9	74.4	3%
	France 97	678.0	669.9	1%
	Denmark 97	51.6	54.3	-5%
	Sweden 97	92.9	103.8	-10%
	Germany 97	479.1	554.9	-14%
	Spain 97	234.2	271.8	-14%
	Ireland 97	44.8	53.5	-16%
	Netherlands 97	76.2	92.8	-18%
1996	Turkey 96	152.5	121.8	25%
	Switzerland 96	83.6	71.4	17%
	Czech Rep 96	25.0	21.4	17%
	Portugal 96	54.0	47.6	14%
	Austria 96	104.2	92.2	13%
	United Kingdom 96	578.9	512.4	13%
	Belgium- Lux 96	102.5	93.8	9%
	France 96	680.6	651.0	5%
	Germany 96	504.6	540.4	-7%
	Spain 96	231.8	255.9	-9%
	Denmark 96	47.2	52.8	-11%
	Ireland 96	43.3	51.0	-15%
	Netherlands 96	67.2	88.0	-24%
1995	United Kingdom 95	601.8	499.0	21%
	Austria 95	103.4	86.9	19%
	Belgium-Lux 95	101.7	93.2	9%
	Portugal 95	51.7	48.0	8%
	Switzerland 95	70.2	67.5	4%
	France 95	654.2	634.6	3%
	Denmark 95	44.4	48.5	-8%
	Spain 95	224.1	248.4	-10%
	Germany 95	458.5	531.1	-14%
	Ireland 95	40.9	48.6	-16%
	Netherlands 95	62.9	81.5	-23%
	Turkey 95	92.5	125.3	-26%
1994	United Kingdom 94	620.5	497.7	25%
	Austria 94	94.4	78.9	20%
	Switzerland 94	77.7	67.5	15%
	Belgium- Lux 94	99.0	86.6	14%
	Portugal 94	49.7	44.4	12%
	France 94	656.2	621.2	6%
	Spain 94	232.5	241.3	-4%
	Ireland 94	40.6	43.2	-6%
	Germany 94	475.3	514.7	-8%
	Netherlands 94	62.3	79.8	-22%
	Turkey 94	77.4	104.7	-26%

4.3.2 Tests

4.3.2.1 Statistical tests

- The Fisher value, which indicates if the whole set of variables is significant, is largely higher than the minimum required.
- Student tests (T-Stat), which consist of testing if the presence of the variable in the model is relevant, are good for all variables.
- The Durbin Watson test, which tests the auto-correlation of the residuals, is in the doubt zone and does not allow to reach any conclusion.

4.3.2.2 Economic tests on the sum of parameters

In Section 4.3.1 we have suggested that the sum of $\alpha_1 + \alpha_2$ could be interpreted as the presence or the absence of "economies of traffic density". If the sum of $\alpha_1 + \alpha_2$ is statistically greater than 1, we cannot reject the hypothesis of "diseconomies of density".

The methodology to test whether or nor the sum is larger that 1 consists in comparing the sum of square residuals of the estimated model (SSE_1) with the SSE of a model constrained by $\alpha_1 + \alpha_2 = 1$ (SSE_2):

$F^* = \frac{(SSE_2 - SSE_1)/J}{SSE1/(T-K)}$, with J the number of constraints (here=1), T the number of observations (67) and K the number of parameters (5).

If this empirical Fisher F* is higher than the theoretical Fisher $F^{0.05}_{J,T-K} = 4$, then the hypothesis of diseconomies of density cannot be rejected. The result is F*= 40.38. The hypothesis of diseconomies of density is thus confirmed by the test.

Similarly, the sum of $\alpha_1 + \alpha_3$ could be interpreted as the presence or the absence of "economies of size". If the sum of $\alpha_1 + \alpha_3$ is statistically lower than 1, we cannot reject the hypothesis of "economies of size". Using the same methodology we find that F* = 12.81. The test confirms the hypothesis of economies of size.

4.4 Possible refinements

4.4.1 The use of indicators to complement the regression analysis

This approach highlights cost differences but does not explain the sources of differences. As argued earlier, not all cost differences might be attributed to inefficiencies as the specification of the statistical model does not take into account all possible factors. Therefore, it needs to be complemented with more in-depth analysis. One way to complement the regression analysis would be to compute a "battery" of indicators that could potentially explain the sources of cost differences predicted by the model. A non exhaustive example of such indicators is provided in the table below.

Table 4.3

Costs and productivity concepts	Potential Indicators
Productivity of air traffic controllers (ATCOs) Productivity of other skilled labour associated with en-route control Productivity of total labour	Km controlled / number of en-route ATCOs Number of movements / number of en-route ATCOs Hours controlled / number of en-route ATCOs
Productivity of capital equipment	Km controlled / value of fixed assets Number of movements / value of fixed assets Hours controlled / value of fixed assets
Cost per ATCO Costs of other skilled staff associated with en-route control Cost per total staff	Total en-route costs / number of en-route ATCOs
Cost per km	Total en-route costs / en-route km
Cost per aircraft	Total en-route costs / en-route controlled aircraft
Cost per time	Total en-route costs / en-route controlled time

Clearly, we do not have data that would allow us to compute most of the above indicators. Under the PRC's proposition, the EUROCONTROL Provisional Council endorsed in November 1999, the principle that ANSPs should disclose economic information about their monopoly activities. Economic information disclosure, when effective, will precisely allow us to calculate relevant indicators.

4.4.2 The use of additional variables

The current version of the statistical model has some limitations:

- The service quality is not captured by the model. Under investments leading to low capacity / demand operating points could explain situations where both high cost effectiveness and high delays per flight are observed, i.e. trade-offs between cost-effectiveness and quality of service. A cost-effective State/ANSP, according to the statistical model, could also be providing a poor quality service (e.g. high delays). Unfortunately, the addition of a “delay per flight variable” automatically reduces the size of the sample, because consistent delay data at European scale are only available since 1996 (CFMU’s foundation). Moreover, on reduced samples it appears that delay per flight is not significant and brings some perturbation in the model (Average Route Length becomes not significant). Finally, it is not clear, from a theoretical point of view, how the delay term should be included when there exists a lag between costs and delay.
- The model does not capture the differences in price levels. Adding proxies for price variables, such as GDP per Capita and Interest rates confirmed the fact that they are not the appropriate variables for capturing the differences in input prices. Actually it appears that there is, within each State/ANSP, a high correlation between the GDP per capita and the volume of traffic. This situation leads to instability of the estimated parameters, which would diminish the confidence in the results.
- Complexity information, especially concerning the flight profile, needs more refinement. Using the percentage overflights showed that the flight profile has an impact on cost. However, a measure of the real vertical movements should allow for more precise interpretation.

Future work and the availability of data would allow us to alleviate some of the above limitations.

5. Conclusions

Benchmarking the cost efficiency of the European ANSPs is not a straightforward exercise. So far, only few and partial studies have been conducted.

In the United Kingdom, the Economic Regulation Group of the CAA recently launched a study to progress in this complex field. In the context of defining a system of incentives for the UK ANSP cost efficiency, the study proposes a similar approach to the one presented here. It is fair to say that there is a reasonable convergence both in the identified cost drivers and in the main results. We encourage interested parties to contribute to further understanding of ANS economics.

The methodology presented in this report is based on economic theory and econometric tools. The main advantages are the flexibility and the objectivity of the "scientific approach". The possibility of evolution towards more sophisticated cost functions is also encouraging.

The major cost drivers that could successfully be identified are the kilometres controlled, the traffic density, the flight profile complexity, and the average route length. Taking into account each ANSP particularities on those aspects allowed for a first benchmarking of their cost effectiveness.

The development of such a model often raises complex issues. The results provide an indication, a trend of the economic efficiency, but cost differences cannot simply be interpreted as inefficiencies. The model does not pretend to be perfect and, at this stage, just demonstrates its potential added value towards a better understanding of ANS economics. More work and better data are needed to increase the robustness of the model.

6. References

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Contacts

European Organisation
for the Safety of
Air Navigation

EUROCONTROL
Rue de la Fusée, 96
B-1130 Brussels

Organisation
européenne pour la
sécurité de la
navigation aérienne

EUROCONTROL
Experimental Centre
B.P. 15
F-91222 Brétigny s/Orge Cedex

Contacts	Email	Tel	Fax
P. Enaud	Philippe.Enaud@eurocontrol.be	++32 2 729 3305	9108
J.C. Hustache	hus@eurocontrol.fr	++33 1 69 88 7802	7352
G. Nero	Giovanni.Nero@eurocontrol.be	++32 2 729 3193	9108