

FIVE YEARS EXPERIENCE IN ATM COST BENCHMARKING

Giovanni Nero, Sébastien Portet

EUROCONTROL Performance Review Unit

giovanni.nero@eurocontrol.int, sebastien.portet@eurocontrol.int

Brussels, Belgium

Abstract

Since 2003 the PRC releases annual ATM/CNS cost-effectiveness (ACE) benchmarking reports. These reports are based on mandatory information disclosure provided by the European Air Navigation Services Providers (ANSPs) to the PRC. They comprise factual data and analysis on cost-effectiveness and productivity, including historic and forward-looking trend analysis. The scope of the ACE reports is both en-route and terminal navigation services (i.e. gate-to-gate). The main focus is on the ATM/CNS provision costs as these costs are under the direct control and responsibility of the ANSP. Costs borne by airspace users for less than optimal quality of service are also considered. The report describes a performance framework for the analysis of cost-effectiveness. The framework highlights three key performance drivers contributing to cost-effectiveness (productivity, employment costs and support costs). In 2006, the Performance Review Unit (PRU) commissioned NERA to carry out an econometric analysis of ANSPs costs using ACE data for the period (2001-2004) to examine ANSPs relative cost efficiencies. This more normative analysis sets out a methodological framework based on sound economic theory. Stochastic Frontier Analysis (SFA) is used to attempt to identify cost inefficiencies. However, the model estimation is affected by several problems, including the too small size of the sample, multicollinearity and, the fact that potential exogenous factors are not identified.

Introduction

Did you know that, in 2004, the costs of providing Air Navigation Services (ANS) in Europe amounted to over €7,000 million?

These costs are fully funded by charges collected from airspace users and are reflected in the ticket prices paid by the travelling public. Thus, many people have a keen interest in the level of these charges and how the revenues are used.

Airspace users point out that en-route charges account for some 6% of the operating costs of the

major airlines. On top of these come charges for terminal air navigation and airport services. Until the recent fuel cost rise, total charges were of the same order as fuel costs (10% of operating costs).

Because ATM is provided on the basis of a statutory monopoly and because charges, except in the UK, are based on the full cost recovery principle, it is essential from an economic efficiency point of view, that best practice performance is identified and promoted.

For these reasons, the PRC and PRU have pioneered open and transparent “benchmarking” for Air Navigation Service Providers (ANSP) in Europe.

Adoption of the Single European Sky legislation further reinforces the role of benchmarking in European Air Navigation Services.

Benchmarking in Europe

Benchmarking is a tool or a means to initiate and direct continuous improvement processes throughout European ANSPs, in particular in the field of economic effectiveness and quality of services.

In essence, benchmarking relies on (1) disclosure of relevant and specific information, (2) the development of one or some specific Key Performance Indicators (KPI), (3) comparisons of performance, and (4) analysis of best practice and improvement potential.

In this context, ANSP disclosure of relevant and specific information should be seen as a normal obligation imposed on statutory monopoly as the counterpart of its monopoly rights.

Since 1999, Member States have been required to ensure that ANSPs provide users, other ANSPs and the PRC/PRU with information on:

- *Separate accounts for their air traffic management activities, prepared in accordance with Generally Accepted Accounting Principles and independently audited;*
- *A limited separation of key revenue, cost and asset items into those for en-route and those*

for approach and airport activities, also independently audited;

- Information on the physical inputs used by the ATSP and the outputs/capacity produced;
- plans which show how ANSPs will meet projected demand, covering staff, investment and training, and supported by appropriate resourcing plans including projected charges.

This information must be provided annually and in compliance with the PRC's "Specification for Information Disclosure", which came into force in 2001.

The PRC set up an ad-hoc ATM Cost-effectiveness (ACE) Working Group to analyse and process the operational and financial data provided by ANSPs. The ACE WG consists of representatives of ANSPs, airspace users, regulatory authorities, and of the PRU.

The value of benchmarking increases through time, as data availability, consistency, comparability and common understanding grow. There is a learning process for all the stakeholders.

One should recognise the inherent limits of data comparability given heterogeneity in the sample of European ANSPs. Notwithstanding the considerable effort by the Working Group participants to ensure greater comparability, this is a complex task which will require further work in the coming years. Some caution must therefore be exercised in the interpretation of the analysis contained in the ACE reports.

Benchmarking can be performed across ANSPs ("cross-section") and across time ("time-series"). Cross-sectional benchmarking requires comparing "apples with apples", which is challenging given the wide heterogeneity of European ANSPs. Time series benchmarking is less subject to comparability caveats since it focuses on comparing performance trends within a given ANSP.

ACE Reports

Every year, the ACE Working Group presents a benchmarking analysis of ATM cost-effectiveness for ANSPs in Europe [1], based on the information provided by ANSPs under Decision N° 88 of the EUROCONTROL Permanent Commission.

Such information is valuable for many stakeholders:

- Policy makers can make more informed decisions;
- Regulators can compare the organisations they regulate with similar organisations;

- Airspace users, airports and ANSPs have comprehensive information for consultations on future plans and performance;
- ANSP managers are provided with a tool to identify areas where potential performance improvement is possible, and staff can see where they fit in the overall European picture.

The analytical framework for cost-effectiveness used in the ACE analysis has been extensively used by ANSPs, airspace users, and regulators as a basis for performance measurement. Several ANSPs have used factors mentioned in ACE reports to optimise their own performance.

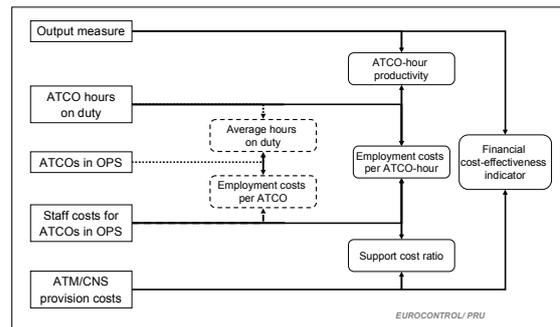


Figure 1. Benchmarking framework

This simple framework helps in understanding differences in the financial cost-effectiveness KPI by breaking it in three economic drivers:

- ATCO-hour productivity – defined as the ratio of the output measure to the number of ATCO hour.
- ATCO employment costs, which will be partly within management's control (reflecting the outcome of negotiations over wages and working practices) but will also reflect local economic conditions that are outside of management's control; and
- support costs, and in particular the ratio of total ATM/CNS provision costs to ATCO employment costs.

The overall economic cost-effectiveness Key Performance Indicator (KPI) can be obtained by adding the monetary value of ATFM delays generated by ANSPs to the financial cost-effectiveness indicator shown in Figure 1.

ACE 2004 data

The ACE Working Group's latest benchmarking report is the ACE 2004 report, which has been published in June 2006. It focuses on cost-effectiveness and productivity KPIs and contains an analysis of 2004 data from 34 European ANSPs.

ACE reports focus on the ANSP cost-effectiveness performance, based on costs which are under their direct control, i.e. ATM/CNS provisions costs. ACE reports are purely factual, record differences in different performance indicators, and do not attempt to assess expected level of performance.

Key Data for the European ANS system		2004
ANSPs		34
Area Control Centres (ACCs)		66
En-route sectors at maximum configuration		613
Approach Units (APPs)		203
Towers (TWRs)		419
AFIS units		94
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Flight-hours controlled (M)		11.8
IFR airport movements (M)		14.2
Total Air Navigation Services (ANS) staff		53 913
Air Traffic Controllers in Operational duty (ATCOs in OPS)		15 836
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Gate-to-gate ANS costs (€ M)		7 017
Gate-to-gate ANS revenues (€ M)		7 233
Gate-to-gate ATM/CNS capital employed (€ M)		7 593

Figure 2. Key data at system level

Total ANS costs for the European system in 2004 were around €7 000M, of which some €6 150M (88%) related directly to the provision of gate-to-gate ATM/CNS, and which are the subject of benchmarking (see Figure 2 and Figure 3). Figure 3 shows how these total ANS costs were apportioned. More than 60% of these costs are related to staff indicating that ATM is a labour intensive activity.

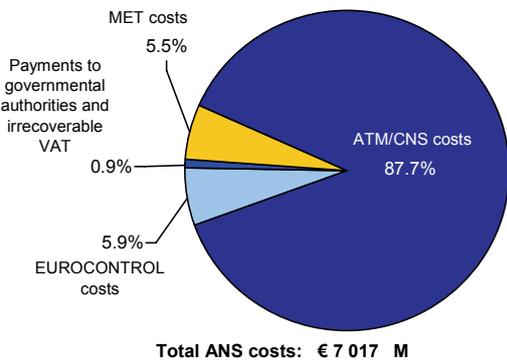


Figure 3. Apportionment of ANS Costs

The European ANS system employed some 54 000 staff, of which some 15 800 (29%) were air traffic controllers working on operational duty (ATCOs in OPS). On average, 2.4 additional staff were required for every ATCO in OPS.

The capital employed by ANSPs for the provision of gate-to-gate ANS was some €7 600M. In other words, approximately 1 Euro of fixed asset capital is required to generate 1 Euro of revenue, indicating that ATM is also capital intensive.

The financial cost-effectiveness indicators for each ANSP are shown in Figure 4. In 2004 the financial cost per composite flight-hour varies over a wide range. The European system average is €392 in 2004.

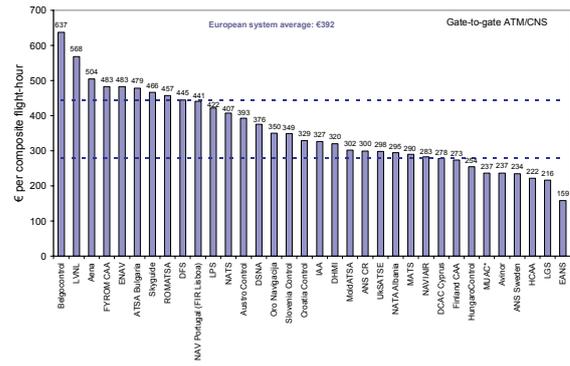


Figure 4. Comparison of financial cost-effectiveness KPIs, 2004

The breakdown of this indicator into its three components is illustrated in Figure 5, Figure 6, and Figure 7 below.

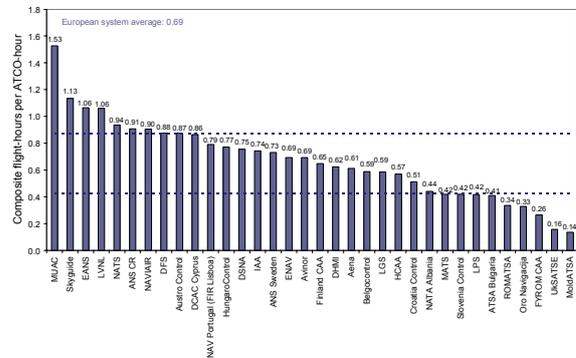


Figure 5. ATCO-hour productivity (gate-to-gate), 2004

Raising the European productivity from the present average (0.69) to the 25th quartile value (0.87, top line) would improve cost-effectiveness by 27%. It is interesting to observe that the best productivity levels tend to be achieved by ANSPs operating in a complex environment (see complexity indicators in Figure 9 below).

Productivity improvements could be achieved by optimising and rationalising the actual processes for ATM/CNS provision and/or by more effective OPS room management making better use of existing resources (adaptation of rosters and shift times, adaptation of sector opening times to traffic demand patterns, etc).

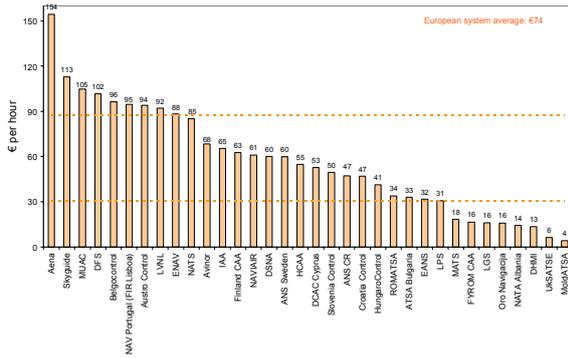


Figure 6. Employment costs per ATCO-hour (gate-to-gate), 2004

The average unit ATCO employment costs in the European system amount to €74 per ATCO-hour. The wide dispersion mirrors, to some extent, the variations in the prevailing wage rates and standards of living in the different European countries.

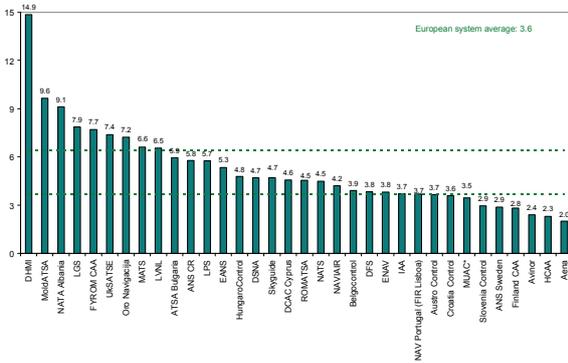


Figure 7. Support costs ratio (gate-to-gate), 2004

The average support cost ratio for the European system is 3.6. In other words, for every Euro spent in ATCO employment costs, an additional 2.6 Euro is spent on other costs. As support costs represent on average 75% of total ATM/CNS provision costs, significant cost-effectiveness improvements could be achieved by reducing support costs.

A recent PRC report [2] estimates the cost of fragmentation of en-route ATM/CNS services to some 1000 million euro per annum. Reducing the current level of fragmentation would reduce support costs, and improve cost-effectiveness.

The ACE report also compares changes in the components of financial cost-effectiveness between 2002-2004 at both ANSP and system level. At European level, unit costs slightly decreased during the 2002-2004 period (-2.2% in real terms), although this has not been uniform for all ANSPs.

Figure 8 shows how the various component ratios have contributed to this -2.2% decrease.

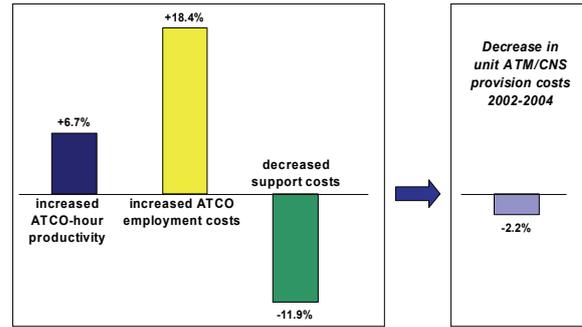


Figure 8. Breakdown of changes in cost-effectiveness (2002-2004 in real terms)

The increase in unit ATCO employment costs (+18.4%) is more than compensated by the increase in ATCO-hour productivity (+6.7%) and the fall in the support cost ratio (-11.9%), resulting in an overall decrease in unit cost of -2.2%.

Exogenous factors affecting benchmarking comparisons

Clearly, factual comparisons of KPIs at ANSP level should be seen in the light of exogenous factors which can vary significantly among ANSPs, in particular traffic complexity [3] and cost of living. Related indicators are shown in Figure 9 and Figure 10 respectively.

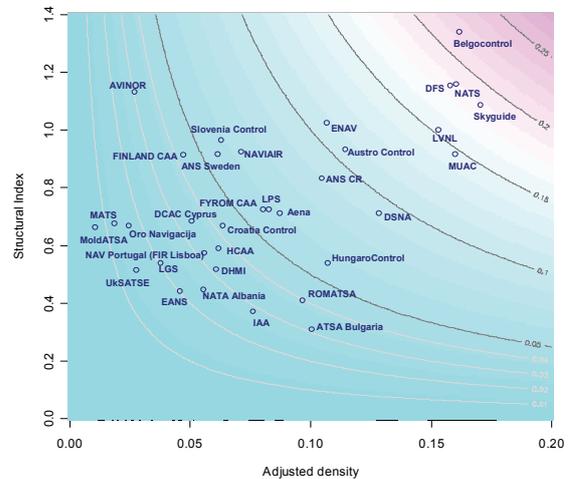


Figure 9. Traffic complexity metrics (2004)

ANSPs with the greatest traffic complexity (e.g. Belgocontrol, NATS, DFS, Skyguide) are shown in the area close to the top-right corner of Figure 9. These ANSPs experience both high “adjusted density” and high “structural complexity”, the two dimensions of the traffic complexity scores identified with a group of experts. Note that complexity does not have negative impacts only: higher traffic density allows for more effective use of existing resources and

exploiting scale effects which are likely to be significant given the fixed infrastructure costs.

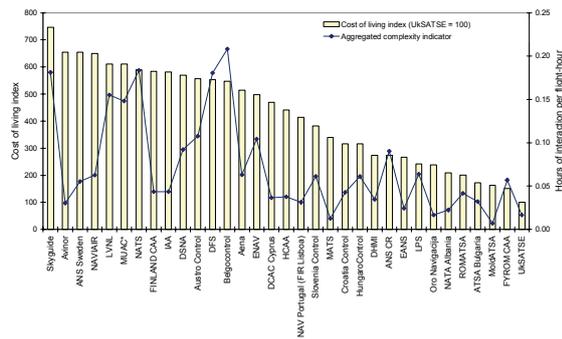


Figure 10. Cost of living and traffic complexity (2004)

ANSPs facing the highest cost of living, and hence higher employment costs, are shown on the left part of Figure 10. As indicated in Figure 10, ANSPs operating where the cost of living is high, also tend to experience greater traffic complexity (correlation ~ 60%).

It is only through a sound econometric model, explicitly taking account for these important exogenous factors, that their influence on cost-effectiveness performance can be statistically quantified, and the relative level of cost-efficiency of each ANSP can be assessed.

Econometric Cost Benchmarking of European ANSPs

Recently, the PRU commissioned NERA to carry out an exploratory analysis of the ANSPs costs in Europe using “state-of-the-art” econometric modelling [4].

One of the objectives is to examine what the ACE data set available at present (2001-2004, 116 observations) can tell about the nature of ANSP costs (for example, identification of the main cost drivers, the existence of economies of scale or density, etc) and also about the relative efficiency of individual ANSPs. More importantly, this analysis provides a methodological framework for a more normative assessment of ANSPs cost efficiency (contrary to the purely factual analysis in the ACE Benchmarking Reports).

Specification of a cost function for ANS provision

The economic theory underlying the formulation of an industry cost frontier supposes that the minimum costs achievable by a firm, when using the most efficient technology available, are a function of its output and the prices of its factor inputs. The cost function is based on the behaviour

of a representative cost-minimising producer who is able to control the amount of each input used subject to producing a given output.

A Cobb-Douglas functional form (see Equation (1) below) is used to estimate ANSPs costs. This form has been widely used in empirical studies of cost functions and has the virtue of being simple to understand and analyse.

The ANSPs cost function is written as:

$$\ln TC = \alpha + \beta_1 \ln WL1 + \beta_2 \ln WL2 + \beta_3 \ln WK + \beta_4 \ln WDOC + \phi \ln Y + \delta \ln N + \omega_1 \ln ZVAR + \omega_2 \ln CSCORE \quad (1)$$

Since Equation (1) is log-linear, the parameters in the equation can be interpreted as elasticities. Thus, for example, the β_j parameters capture the percentage changes in total costs that would result from a change in each of the input prices.

In Equation (1), ANSPs costs are a function of:

- The output (Y) which is the number of composite flight-hours controlled by each ANSP. This measure is a weighted average of en-route flight-hours controlled and the number of IFR airport movements controlled. The weighting used in the calculation reflects the relative unit costs of terminal and en-route services on average across European ANSPs (see [1] for further details).
- The labour input prices measured as the hourly Air Traffic controller (ATCO) employment costs (WL1) and by the unit employment costs for non-ATCO staff (WL2).
- The capital input price (WK) measured as the ratio of capital-related costs to an aggregated capital input measure.
- The non-staff operating input price (WDOC) captures all the remaining costs not included in either labour or capital. This category includes, among other things, energy, communications, spare parts, insurance and any contracted services such as cleaning and security.
- Exogenous factors such as the network size (N) measured in terms of the size of airspace controlled by an ANSP, the traffic variability (ZVAR) and the traffic complexity (CSCORE) which is the product of the adjusted density and the structural complexity (see Figure 9 above).

The existence of economies or diseconomies of scale in the industry can be inferred from the cost

function. This is done by examining the impact on unit costs when output increases. In the context of network industries, however, a variable capturing the size of the network is generally added to the cost function. This allows distinguishing economies of scale from economies of density. The former arises if unit costs fall following a proportional increase of the output and of the network size. Economies of density exists if unit costs fall when output increases holding the network size constant.

Econometric estimation

The cost function is estimated using models for panel data sets. Panel techniques are particularly useful for the analysis of very heterogeneous firms (such as the ANSPs in the ACE data set), since they exploit the variability over time to identify economic relationships over and above cross-section differences. They capture persistent individual ANSP features and estimate cost elasticities net of these ANSP-specific individual factors. The panel data equation for the total cost model (1) is written as:

$$\ln TC_{it} = \alpha_i + \beta_1 \ln W L 1_{it} + \beta_2 \ln W L 2_{it} + \beta_3 \ln W K_{it} + \beta_4 \ln W D O C_{it} + \phi \ln Y_{it} + \delta \ln N_{it} + \omega_1 \ln Z V A R_{it} + \omega_2 \ln C S C O R E_{it} + \varepsilon_{it} \quad (2)$$

The central difference between cross-section and panel data estimators is whether the constant, α , is restricted to be the same across the whole sample (cross-section models), or alternatively, whether a different (fixed or random) constant α_i , is estimated for each ANSP i or time period t (panel-data models). For the purposes of this analysis, Equation 2 is estimated using a random effects model.

ANSPs cost efficiencies are estimated using Stochastic Frontier Analysis (SFA) techniques. The key departure point for SFA is the inclusion of an asymmetric error term ε_{it} which is assumed to comprise two elements:

- u_{it} , which has a strictly non-negative distribution and represents the cost inefficiency component; and
- v_{it} , which has a symmetric distribution and represents stochastic error.

Results

The main results for the random effects SFA model are presented in Figure 11 (see next page). Insignificant coefficients – meaning that statistical tests cannot prove, with a reasonable degree of confidence, that the true coefficient is different from zero – are in grey. These estimates are likely to be unreliable. Point estimates of the significant

coefficients are presented with an indication of the level of significance.

In Figure 11, columns I to V show the results of five specifications of the SFA random effects model. The coefficients shown in Figure 11 can be interpreted as cost elasticities, e.g. a 10% increase in ATCO hourly employment costs would result in some 2.5% increase in ATM/CNS provision costs. Column I is an estimate of a basic model, while the next four include variables for seasonal variation, complexity score and its components (adjusted density and structural complexity) in various combinations.

The output coefficient is statistically significant in columns I and II. Nonetheless, the value of the coefficient (around 0.2) is considered to be too low since it would imply that there are huge economies of scale. This low value could be due to multicollinearity, which can lead to inaccuracy in estimated coefficients, as output is relatively correlated with network size (correlation coefficient of 0.7).

In columns III to V, output is not statistically significant following the inclusion of different measures of traffic complexity. This could be driven by the correlation between the output and the complexity score.

In all five specifications there is strong statistical evidence that the prices of ATCO and non-ATCO labour inputs, capital inputs and inputs associated with non-staff operating costs are significant drivers of total ANSP costs. The input price coefficients are relatively stable across the model specifications. The sum of the coefficients on labour input prices implies that the share of labour costs in total costs is about 72 per cent.

The results suggest that a substantial share of unexplained variability is due to the ANSP-specific inefficiency error component. This is summarised by the ratio of the inefficiency-related residuals variance to the total residuals variance $\sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$, which is shown at the bottom of Table 6.1. In columns I to V, 98% of the unexplained variability is attributed to inefficiency. This implies that there are important unobserved differences (i.e. heterogeneity) across ANSPs (e.g. in terms of governance arrangements, political influence, managerial skills, etc.) which are not measured and which have an impact on ANSPs costs.

Dependent variable: Total costs		Random Effects model				
Regressors:	(I)	(II)	(III)	(IV)	(V)	
Output	0.224 [0.102]**	0.198 [0.103]*	0.143 [0.138]	0.179 [0.136]	0.139 [0.140]	
ATCO hourly employment cost	0.249 [0.065]***	0.255 [0.064]***	0.239 [0.070]***	0.234 [0.072]***	0.237 [0.070]***	
Non-ATCO unit employment cost	0.497 [0.049]***	0.486 [0.049]***	0.475 [0.052]***	0.489 [0.052]***	0.475 [0.052]***	
Capital input price	0.195 [0.039]***	0.187 [0.039]***	0.192 [0.040]***	0.2 [0.040]***	0.192 [0.040]***	
Non-staff operating input price [§]	0.059 [n/a] ‡	0.072 [n/a] ‡	0.094 [n/a] ‡	0.077 [n/a] ‡	0.096 [n/a] ‡	
Network size	0.409 [0.094]***	0.399 [0.096]***	0.427 [0.107]***	0.434 [0.106]***	0.428 [0.107]***	
Seasonal variability		-0.55 [0.466]	-0.573 [0.467]		-0.571 [0.466]	
Complexity score			0.073 [0.123]	0.062 [0.125]		
Adjusted density					0.079 [0.127]	
Structural complexity					0.056 [0.153]	
Constant	1.883 [1.303]	2.525 [1.433]*	3.246 [1.897]*	2.452 [1.745]	3.296 [1.916]*	
σ_u (inefficiency error component)	0.65	0.68	0.68	0.65	0.68	
σ_v (stochastic noise error component)	0.09	0.09	0.09	0.09	0.09	
Ratio of $\sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	98%	98%	98%	98%	98%	
Economies of density (ED)	4.46 (no complexity effect)	5.05 (no complexity effect)				
Economies of scale (ES)	1.58	1.68	2.34 (no output effect)	2.30 (no output effect)	2.34 (no output effect)	

Source: NERA.

Notes: All variables are in logs. Based on 125 observations. Standard errors in square brackets; *significant at the 10 per cent confidence level; ** significant at 5 per cent confidence level; *** significant at 1 per cent confidence level. ‡ not calculated. The dependent variable in each model is the log of total costs.

The standard error of the non-staff operating input price is not shown since this coefficient has been inferred by subtracting the other three input price coefficients from 1. In order to make the estimation numerically tractable total costs and labour and capital input price coefficients have been normalised using the direct operating cost deflator as denominator. This procedure is equivalent to including all input prices and constraining all (four) coefficients of input prices to equal 1.

Figure 11. Main results from econometric analysis

In Figure 11, an estimate of economies of scale, E_s , is calculated using the sum of the cost elasticities with respect to output and with respect to network size, according to the formula: $E_s = [1/(\phi + \delta)]$, where ϕ is the coefficient on output and δ is the coefficient on network size. A value of E_s greater than 1 implies economies of scale and a value less than 1 implies diseconomies of scale. The presence of economies of scale implies that, all else equal, total costs grow less than proportionally with increases in both output and network size.

The economies of scale values are estimated to range between 1.58 and 2.34. The existence of economies of scale is determined by two factors:

- the small increase in costs when output grows (the estimated coefficients on the output variable are 0.22 in column I and 0.20 in column II); and
- the less than proportionate responsiveness of costs to changes in network size (the coefficient of network size is always positive and significant and ranges between 0.40 and 0.43).

However, since the output coefficient is too small, the resulting estimates of economies of scale are unreliable.

An estimate of economies of density, E_d , is calculated as $[1/(\phi + \omega_2 b_1)]$, where ϕ is the coefficient on output and ω_2 is the coefficient on the overall complexity score. The first component, ϕ captures the direct effect of output on total costs (when there is no change in network size). The parameter b_1 measures the impact of output changes on complexity (while keeping network size fixed and all else equal) and has been estimated by the following auxiliary regression:

$$\ln CSCORE_{it} = a + b_1 \ln Y_{it} + b_2 \ln N_{it} + e_{it}$$

A value greater than 1 for E_d implies economies of density and a value lower than 1 implies diseconomies of density.

In calculating E_s and E_d , any insignificant coefficients were interpreted as zero.

Economies of density could only be calculated for models I and II since the estimated coefficients for output and complexity are both insignificant for the other models. In models I and II, the economies of density are a direct function of the estimated impact of output on costs. However, these measures of economies of density (4.46 and 5.05 for models I and II respectively) are overestimated

because we are unable to calculate the indirect effect of an increase in output on complexity – since the coefficients are not statistically significant.

In all five model specifications in Figure 11, the coefficients on the variability, density and complexity variables are not significant, even at the 10 per cent level. Moreover, inclusion of the density and complexity variables in the regression models results in output coefficients that are lower and less significant than those in models I and II. This may be due to multicollinearity, because of the relative correlation between the output and density and complexity measures.

Possible directions for future research

The analysis would clearly benefit from a larger sample size. As additional years of data will be progressively added to the panel, it is possible that there will be sufficient variability in the regressors for a given ANSP to identify the effect of exogenous characteristics over and above persistent individual differences, and to improve the performance of the model. A larger dataset may also lead to improved results by allowing the application of more refined panel SFA techniques.

A higher number of observations may also provide scope for achieving better results using a more flexible functional form such as the translog specification, even if the number of parameters that would be required (for example for a single output and four input prices model) will still be cumbersome for a sample twice as large as the current one. A more flexible specification could offer improvements, for example if there were an underlying quadratic relationship between costs and output. A translog cost function with just three input prices (using a single compounded input price for labour inputs and a similar index for capital inputs) might make the estimation more tractable.

There are likely to be other characteristics of ANSPs and their operating environment that are not captured, but which influence costs and are outside the control of managers and so should not be considered as inefficiency. If such factors are identified in future research, then they should be included in the analysis to provide a better characterisation of ANSPs' performance.

Conclusion

The objective of this paper is to provide an overview of the cost benchmarking activities carried out by the EUROCONTROL Performance Review Commission (PRC) and Unit (PRU).

Since 2003 the PRC releases annual ATM/CNS cost-effectiveness (ACE) benchmarking reports. These reports are based on mandatory information disclosure provided by the European Air Navigation Services Providers (ANSPs) to the PRC. They comprise analysis on cost-effectiveness and productivity, including historic and forward-looking trend analysis. ACE reports are purely factual, record differences in different performance indicators, and do not attempt to assess expected level of performance.

In 2006, the PRU commissioned NERA to carry out an exploratory analysis of the ANSPs costs in Europe using “state-of-the-art” econometric modelling to examine ANSPs relative cost efficiencies for the period (2001-2004). The main objective of this analysis is to set out a methodological framework based on sound economic theory. Panel data models and SFA are used to shed light on both ANSPs’ inefficiency and the relationship between output, input prices and costs. Panel techniques are very useful tools for the analysis of data from very heterogeneous ANSPs, since they exploit the variability over time to identify economic relationships over and above cross-section differences. They capture persistent individual ANSP features and estimate cost elasticities net of these ANSP-specific individual factors.

A model of total costs regressed on output, input prices and network size produces coefficients that are significant, have the “right” sign and appear to be robust – though the output coefficient is lower than we might have expected (this could be due to multicollinearity, which can lead to inaccuracy in estimated coefficients, since the output and network size variables are relatively correlated). The seasonal variability, adjusted density and traffic complexity coefficients are not statistically significant. The cost inefficiencies seem to be overestimated; but this is expected given the empirical difficulties in distinguishing between ANSP heterogeneity and cost inefficiency under a short panel of data that varies little over time and because of unobserved heterogeneity. A larger dataset may lead to improved results by allowing the application of more refined panel SFA techniques and more flexible cost function specifications.

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- [4] NERA (2006), *A Cost Benchmarking of Air Navigation Service Providers: A Stochastic Frontier Analysis*, a report commissioned by the PRU

Reference [1] is available on the PRC web site at the following address:

http://www.eurocontrol.int/prc/public/standard_page/doc_ace_reports.html

References [2], [3] and [4] are available on the PRC web site at the following address:

http://www.eurocontrol.int/prc/public/standard_page/doc_other_reports.html

Key words

EUROCONTROL Performance Review Commission - Economic information disclosure - ATM/CNS cost-effectiveness comparisons - 34 European Air Navigation Services Providers (ANSPs) - Gate-to-gate (en-route and terminal) inputs and outputs metrics - Performance framework - Key Performance Indicators (KPIs) - Productivity analysis - Employment costs analysis - Support costs analysis - Complexity metrics - Econometric analysis - Panel data - Heterogeneity - Stochastic frontier analysis - Economies of scale – Economies of density - Inefficiency measurement.

Biographies

Mr Sébastien Portet: He obtained a Master degree in Transports and Industrial Economics from Toulouse University in 2001. Since 2004, he works as an economist in the EUROCONTROL Performance Review Unit.

Dr Giovanni Nero: He obtained a PhD in Industrial Organisation from the European University Institute in 1996. Since 1999, he works as an economist in the EUROCONTROL Performance Review Unit.