Benchmarking of German Airports – Some first Results

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I. Introduction: Why benchmark German Airports?

There is an increasing number of performance and benchmark studies on the former public utilities especially on transport. This is quite natural for an industry which has been the object of institutional change and economic reform in the past three decades. Have these reforms been successful? Have privatisation and liberalization in particular increased efficiency and economic welfare? These basic questions guide directly or indirectly most if not all studies on performance. In this respect airports are nothing special. They are just another industry worthwhile studying in order to gain knowledge on the effects of institutional change. Having said this there are however some good reasons to focus on measuring the performance of German airports.

Firstly, up to now only a few German airports have been benchmarked. On an annual basis the Air Transport Research Society (ATRS) and TRL Ltd. publish benchmarking reports comparing international airports worldwide. But both analyse airports with high passenger volumes as Frankfurt and Munich. Overall, the German airport are ranked low.
In the ATRS Report in 2003 for example, all German airports in the sample (Frankfurt, Munich, Düsseldorf, Hamburg and Cologne) achieve below average results in labour productivity and average results in capital productivity. Also the Total Factor Productivity (TFP) of Frankfurt, Munich, Düsseldorf and Hamburg is far below the average. These German airports achieve scores on the bottom of the ranking (ATRS 2003).

The results of TRL Ltd. go in the same direction. According to the Airport Performance Indicators Report (TRL 2003) German airports show some below but mainly average results. In particular, Frankfurt airport has a low Labour productivity as the ratio of passengers per employee was around 6,000 compared to over 50,000 in Brisbane or Calgary. Also, total revenue per employees and assets per employee are relatively low with 90,322 SDR[1] per employee and 272,266 SDR per employee respectively 1,444,875 SDR per employee and 22,977,953 SDR per employee respectively are the best practice airports in these categories.

Secondly, there are only a few studies of small and medium sized airports. More or less, these airports have been neglected, although they are vital for regional economic development and an efficient decentralized system of airports is the goal of German aviation policy. Questions, like will regions attract more business and investment if their regional airport becomes more efficient; is there an efficiency gap between hub airports and regional airports giving hub cities with their cluster a competitive advantage to attract economic activity; how has the productivity of secondary hubs relative to hubs and regional airports developed are interesting for regional economics and policy.

Thirdly, the government structure of German airports is changing, as in many other countries, but these changes result in particularities, which should be studied on their own and in relation to other countries. Germany has a wide spectrum from publicly owned to partly privatised airports. No German airport so far has been fully privatised. One effect of partial privatisation is an accelerating commercialisation and reorganisation. In addition the liberalization of ground handling has lead airport operators to react differently. Some have adopted a new organizational structure of profit centres, trying to reduce costs and increase competitiveness, while others did not change much their organization and strategy. Regional municipalities and federal states, as the owners of the majority of German airports, view their airports as instruments of regional development. This kind of federal competition brings with it some competi-

[1] Standard Drawing Right (SDR) „ is a unit based on the trade-weighted values of a group of major currencies from the G8 nations. “ (TRL 2003: 53)

tion among airports although probably not on a great scale as federal governments prefer co-operative solutions for airports in a close vicinity. German federalism results also in a variety of different regulatory systems ranging from low powered cost plus regulation to high powered incentive price cap regulation. Regulatory economics would predict that, ceteris paribus price capped airports, would become more productive and efficient. But these predictions are often difficult to verify as things are changing. In this respect Germany offers the unique opportunity to study the effects of regulation in the same institutional environment. Given the world wide trend of privatisation airports are increasingly seen as ordinary business and less as part of the public infrastructure. These tendencies are also observable in Germany, although more in the western parts of Germany. In the new federal states airports were seen as public infrastructure and as an instrument to enhance economic development. How have these public utility type of airports performed compared to more commercialised airports is one of the questions resulting from German unification?

In summary, we find many good reasons for benchmarking German airports and so we have taken the first step of research, namely benchmarking German airports with Data Envelopment Analysis (DEA) and with limited resources and time to acquire data in depth. The method and results are presented in section II. This first step does not provide a full analysis of the above questions and problems. On the contrary it is highly preliminary. Therefore we draw in section III the conclusion that more research is necessary and propose a research agenda.

II. Airport Benchmarking in Germany

In our analysis we focus on technical efficiency. We want to know whether or not inputs German airport use inputs in such a given way that given a certain level of production and given the currently available technology the reduction of one input must be offset by an increase of some other input. An answer to this question does not provide answer to the overall question of allocative efficiency that is whether the airport chooses from the possible technical efficient ways of production the combination of inputs which minimizes its costs. To answer this question the relative prices of inputs must be known which we could not acquire. Confining our analysis to technical efficiency nevertheless gives us important information as technical efficiency is a necessary condition of allocative efficiency and equally important an analysis of technical efficiency indicates X-inefficiency, a waste of resources, which regulatory economics expects from state-owned or cost plus regulated public utilities and which many industry analysts suspects supposes to exist in the form of gold plating and excessive capacity.

In the first section of this chapter we explain the methodology, thereafter the data set and then the results of our study.

II.1 Methodology

The underlying methodology of our study is DEA which measures the relative efficiency of Decision Making Units (DMUs) according to Farrell (1957). DEA is a non-parametric approach which uses linear programming to construct a piece-wise linear frontier which is built by the efficient DMUs of an analysis. The concept of linear programming was first introduced by A. Charnes, W. W. Cooper und E. Rhodes in 1978 (Førsund und Sarafoglou 2000). DMUs on the frontier are operating with 100% technical efficiency and Charnes und Cooper (1985) defined it in the following:

"*100% efficiency is attained for (a unit) only when:*

- *None of its outputs can be increased without either (i) increasing one or more of its inputs, or (ii) decreasing some of its other outputs;*
- *None of its inputs can be decreased without either (i) decreasing some of its outputs, or (ii) increasing some of its inputs*."

An advantage of DEA compared to other non-parametric methods is that it can handle multiple inputs and outputs in a single analysis without having any difficulties of aggregation. Instead of weighting factor quantities as outputs as for total factor productivity (TFP), DEA optimises the weights with the linear programming.

DEA can either do input minimisation with a constant output or can focus on output maximisation having a constant input. The decision usually depends on what to analyse (Pels 2000). However, very often the decision is up to the management and on which variables it has an influence, i.e. if the management has an influence on inputs an input minimisation model would be most appropriate.

Suppose we have an output maximisation model and assume constant returns to scale (CRS) with a database of k=1,…,K DMUs. Furthermore we need n=1,…,N inputs x_n^k and m=1,…,M outputs y_m^k. For every DMU *k'* the linear programming is

$$\begin{aligned} & \max \theta^{k'} \\ & s.t. \\ & \qquad \sum_{k=1}^{K} z^k y_m^k \geq \theta^{k'} y_m^{k'}, \mathrm{m} = 1,\dots,\mathrm{M} \\ & \qquad \sum_{k=1}^{K} z^k x_n^k \leq x_n^{k'} \quad , \mathrm{n} = 1,\dots,\mathrm{N} \\ & \qquad z^k \geq 0 \end{aligned}$$

where $\theta^{k'}$ indicates the efficiency score of every DMU *k'*. z^k are the weights that are determined by the optimization process. A value of $\theta^{k'}=1$ indicates a point on the frontier and thus a technically efficient DMU according to Farrell (1957). This linear programming problem must be solved *K* times, once for each sample, thus $\theta^{k'}$ will be obtained for each firm.

In general, this formula now tries to increase the outputs $y_m^{k'}$ for DMU *k'* as much as possible holding all inputs constant. Simultaneously, the weighted combination of efficient DMUs should produce at least as much output as possible but always uses less input than *k'* (Coelli et al 1998).
Because of the use of panel data, the application of Malmquist-DEA is the most appropriate form to investigate the performance of the airports. This DEA-like program together with a Malmquist-TFP Index calculates besides the technical efficiency scores the indices of TFP-change between two periods.

Färe et al (1994) developed a DEA based (output maximized) Malmquist-Index as the geometric mean of two Malmquist-Indices between two periods *t-1* and *t*:

$$M_{t-1,t} = \left[\left(\frac{D_{t-1}(x_t, y_t)}{D_{t-1}(x_{t-1}, y_{t-1})} \right) \cdot \left(\frac{D_t(x_t, y_t)}{D_t(x_{t-1}, y_{t-1})} \right) \right]^{1/2}$$

A Malmquist-Indices of greater than 1 ($M_{t-1,t} > 1$) indicates a positive TFP-growth from *t-1* to *t*. An Index that equals 1 ($M_{t-1,t} = 1$) is the result of a constant development and an index that is smaller than 1 ($M_{t-1,t} < 1$) indicates a decline in TFP-growth (Chen und Ali 2003).

The above formula can also be transformed in the formula below: the first part indicates an efficiency change and the latter a change in technology. Here, a positive change in efficiency means that the DMU moves closer to the production frontier and a positive change in technology i.e. innovation results in a shift of the production frontier. Hence, the change in TFP can be decomposed in to the two components efficiency change and technological change, so the Malmquist TFP change index is:

$$M_{t-1,t} = \underbrace{\left(\frac{D_t(x_t, y_t)}{D_{t-1}(x_{t-1}, y_{t-1})} \right)}_{\text{efficiency change}} \cdot \underbrace{\left[\left(\frac{D_{t-1}(x_t, y_t)}{D_t(x_t, y_t)} \right) \cdot \left(\frac{D_{t-1}(x_{t-1}, y_{t-1})}{D_t(x_{t-1}, y_{t-1})} \right) \right]^{1/2}}_{\text{technological change}}$$

Malmquist-DEA is defined using distance functions *[$d_o(x,y)$]* which allows one to describe a multi-input, multi-output production technology without the need of a condition as cost minimisation or profit maximisation. The advantage of Malmquist-Indices compared to a Tornqvist or Fisher Index is that it does not require financial data. To measure the TFP-change one calculates the distances of each data point relative to a common technology. Thus, for every DMU, one must calculate four distance functions to measure the TFP change between two periods *t* and *t-1*. As the distance functions are calculated by DEA-like linear programming problems, a distance function is the inverse of the efficiency score according to Farrell (Coelli et al 1998).

$$\begin{aligned} &\left[d_o^{\,t}(x_t, y_t) \right]^{-1} = max\, \theta^{k'} \\ &s.t. \\ &\qquad \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \geq \theta^{k'} y_m^{k',t}, \mathrm{m} = 1,...,\mathrm{M} \\ &\qquad \sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^{k',t} \quad, \mathrm{n} = 1,...,\mathrm{N} \\ &\qquad z^{k,t} \geq 0 \end{aligned}$$

$$\begin{aligned} &\left[d_o^{\,t-1}(x_{t-1}, y_{t-1}) \right]^{-1} = max\, \theta^{k'} \\ &s.t. \\ &\qquad \sum_{k=1}^{K} z^{k,t-1} y_m^{k,t-1} \geq \theta^{k'} y_m^{k',t-1}, \mathrm{m} = 1,...,\mathrm{M} \\ &\qquad \sum_{k=1}^{K} z^{k,t-1} x_n^{k,t-1} \leq x_n^{k',t-1} \quad, \mathrm{n} = 1,...,\mathrm{N} \\ &\qquad z^{k,t-1} \geq 0 \end{aligned}$$

$$\left[d_o^{\,t}(x_{t-1},y_{t-1})\right]^{-1} = max\,\theta^{k'}$$
$$s.t.$$
$$\sum_{k=1}^{K} z^{k,t} y_m^{k,t} \geq \theta^{k'} y_m^{k',t-1}, \mathrm{m} = 1,...,\mathrm{M}$$
$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^{k',t-1} \quad , \mathrm{n} = 1,...,\mathrm{N}$$
$$z^{k,t} \geq 0$$

$$\left[d_o^{\,t-1}(x_t,y_t)\right]^{-1} = max\,\theta^{k'}$$
$$s.t.$$
$$\sum_{k=1}^{K} z^{k,t-1} y_m^{k,t-1} \geq \theta^{k'} y_m^{k',t}, \mathrm{m} = 1,...,\mathrm{M}$$
$$\sum_{k=1}^{K} z^{k,t-1} x_n^{k,t-1} \leq x_n^{k',t} \quad , \mathrm{n} = 1,...,\mathrm{N}$$
$$z^{k,t-1} \geq 0$$

II.2 The Data

Our study includes 17 of the 18 international airports in Germany (BRE, CGN, DRS, DTM, DUS, FMO, FRA, HAJ, HAM, LEJ, MUC, NUE, SCN, STR, SXF, THF and TXL). Erfurt (ERF) is missing in our sample as were unavailable.

Furthermore, it was difficult to receive financial data from most of the airports because not every airport was willing to provide their annual reports. Therefore the data only includes traffic data and physical data. The missing financial data is also a reason why the analysis only considers the technical efficiency, thus to investigate if the inputs that are used are ‘transformed’ to maximize outputs.

The data collected include the time series 1998-2002. An exception was made for Düsseldorf. Because of the fire in April 1996, the airport recommended using data from 1994 to 1996 and 2001 to 2002. From 1996 till the opening in summer 2001 the airport only used 20% of its capacity. Hence, to use data from 1998-2002 would have influenced the results for Düsseldorf more negatively than to use a different time series. An analysis of panel data and especially this specific time series is very interesting because incidents like the terror attacks in September 2001 and the general recession are included. Furthermore, many airports in Germany have increased their capacity through new terminal buildings or additional runways from 2000 to 2002. Though, it is interesting to investigate if the terror attacks in New York together with the capacity expansion have influenced the productivity and efficiency of the airports and how fast the airports could react.

As in the benchmarking studies of Gillen and Lall (1997, 1998) and Pels et al (2001), the airport was divided into the airside and the terminal side to analyse the performance separately. This means, that the outputs *aircraft movements* and *passengers volumes* were not included in a single analysis. Instead the number of aircraft movement is the output of airside operations and the number of passengers is the output of terminal side operations. The reason for a separation is the different production technology of both areas. Gillen and Lall (1998) argued, that on the airside of an airport constant returns to scale (CRS) have to be assumed whereas on the terminal side one can identify increasing returns to density which means, that average costs decline with an increase of passengers (e.g. due to the use of larger aircrafts).

For the landside or terminal side we have chosen the number of passengers as the output and the number of employees, terminal size (in sqm), number of check-in-counters, number of gates and the number of parking spaces as inputs.
The airside has the number of movements as output and the number of employees, the airport size (in ha) and the number and the total length of runways as inputs.

Unlike Gillen and Lall who assumed CRS for the airside and variable returns to scale (VRS) for the terminal side we assumed constant returns to scale (CRS) for both operational areas. The reason is because Tatjé and Lovell (1995) when assuming VRS when using Malmquist-DEA found out, that an increase or a decrease of the total factor productivity through scale effects was calculated inaccurately (Coelli et al 1998).

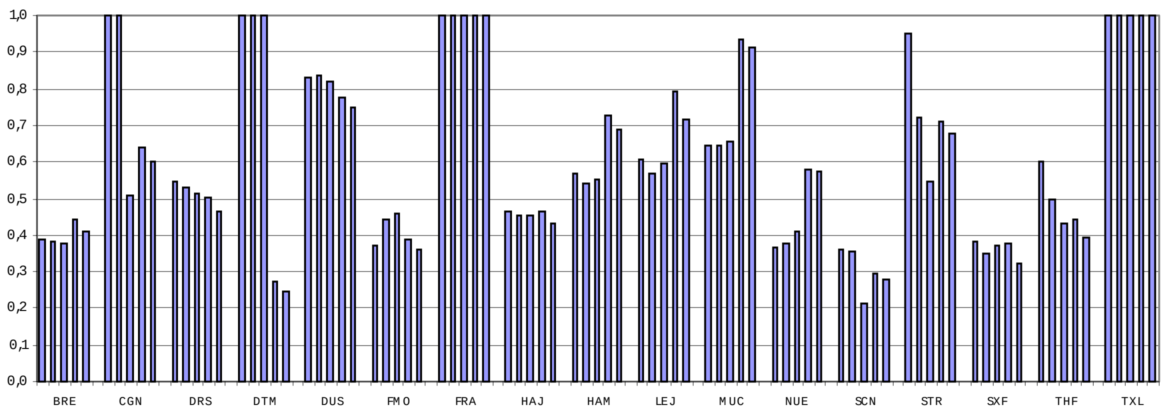
II.3 Results

<u>The performance of the terminal side</u>

On the terminal side there are substantial differences in efficiency scores among the DMUs. Whereas FRA and TXL were operating 100% efficient during the whole period, BRE, FMO and SXF achieved efficiency scores below 50%.

Except for the constant efficient airports FRA and TXL one can see, that the technical efficiency was decreasing from 2001 to 2002 as the number of passengers declined. This leads to the assumption that there might be an influence of the September 11th especially in 2002. That the terrors attacks are most responsible for the decline in 2002 can also be seen that all airports with increasing efficiency scores before 2002 (HAM, LEJ, MUC and NUE) had interrupted their trend.

Abb. 1: Technical Efficiency on the terminal side (1998-2002)



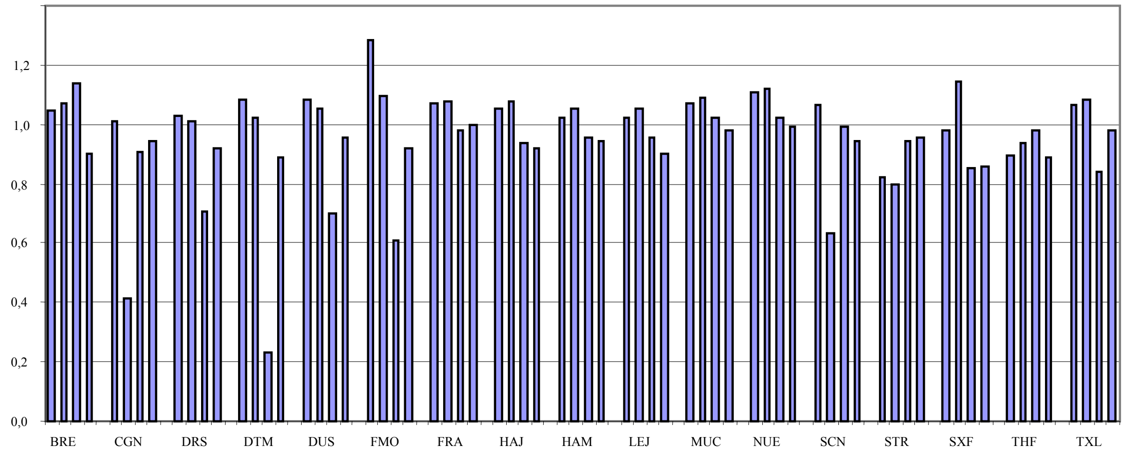
A nearly constant decline in technical efficiency can be seen in CGN, DRS, DTM, DUS, SCN, STR and THF.
With an exception of THF all decreases can be explained with the capacity expansion on the terminal side within the last years. CGN and DTM especially show huge losses in efficiency

as they operated with an efficiency of 100% before the openings of their new terminal. This development is not surprising. When the construction of new terminals was planned no one has thought of a crisis in the aviation industry as it has been a growing industry.

A reason for the outstanding result of FRA and TXL relative to the other airports here may also be, because technical efficiency is about either input minimisation or output maximisation. Because both airports are suffering under capacity constraints, their output is relatively high to their resources. For CGN and DTM, on the other side, one can observe that after the expansion on the terminal side, the technical efficiency decreases as their relation they had more resources compared to the previous years.

The TFP-change shows, that there was already a decrease in productivity before 2002 because the negative technical change from 2000 to 2001 was bigger than the increase in technical efficiency, thus all in all there was a decrease in TFP.
On average the TFP-Growth amounts to 3.8% from 1998 to 1999. From 1999 to 2000 there was already a downward tendency of 4.1% which was primarily due to a substantial decrease of 58.9% in CGN. At most airports there were still an increase in TFP. From the year 2000 the productivity was only be increased in BRE, MUC and NUE and from 2001 to 2002 it decreased at all airports.

Abb. 2: TFP-change on the terminal side (1998-2002)



Fluctuations in TFP over the years were especially at airports with capacity expansions because they took place in the years of terminal openings. This is for example CGN with a decrease of 58.9% from 1999 to 2000 or DTM from 2000 to 2001[2] with more than 75%. However, these rates could recover in the following years again.

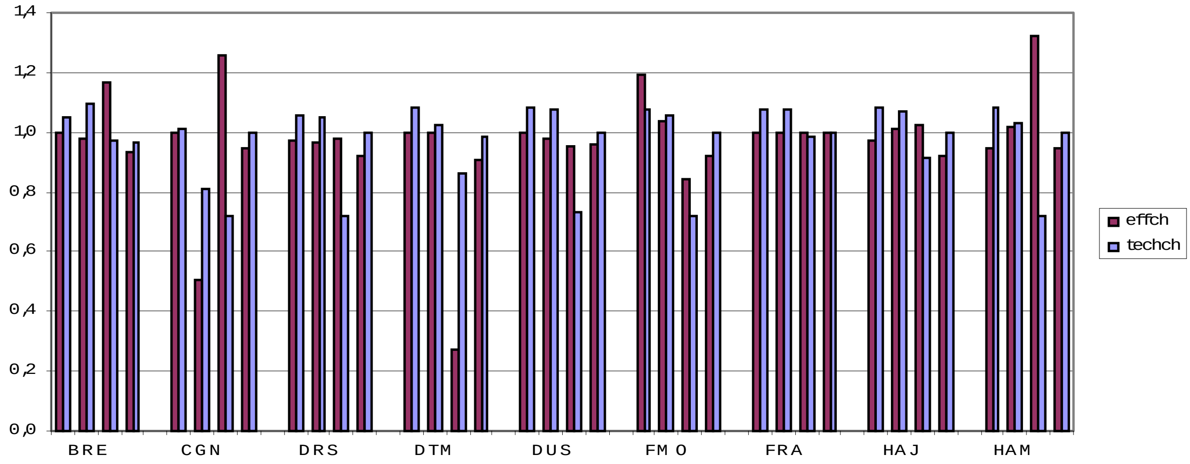
The fraction of efficiency change and technical change indicates the effort of innovation of an airport. An increase in TFP merely through technical change means an innovation and shifts the production frontier. In our analysis the TFP was mostly a combination of technical and efficiency change, only some airports indicated innovation. These airports are CGN (98/99), DTM (98/99 and 99/00), DUS (98/99) and FRA (98/99 and 99/00).

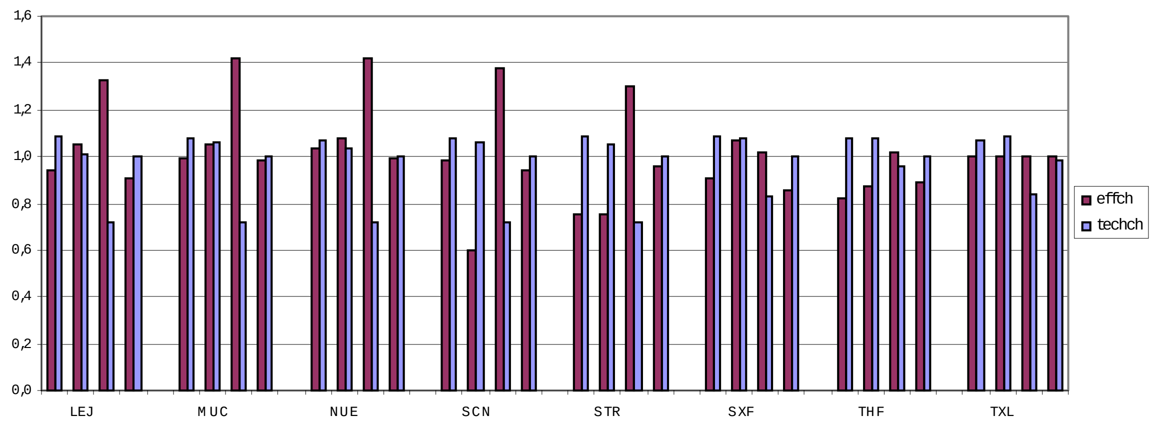
A reason for a technical change at airports could be the pressure of the airlines or other airports, especially hubs and airports in the same region as a result of increased competition. This assumption can be confirmed for the innovative airports in our analysis: in 1998, Luf-

[2] Expansion of the terminal side: CGN: 2000; DRS: 2001; DTM: 2001; DUS: 2001; FMO: 2001; SCN: 2000 and STR: 2000

thansa opened its second hub in Munich. Therefore FRA had to change its strategy and be more innovative to remain competitive to MUC. Also, CGN, DTM and DUS are in the same region in North Rhine-Westphalia and could be competitive to each other even the size and structure of the airports are completely different and the density of population higher than in other regions in Germany.
As a matter of fact, one might assume that BRE, HAM and HAJ are competitive to each other as well, but this could not be confirmed in this analysis.

Abb. 3: Efficiency change and technical change on the terminal side 1998-2002





<u>The performance of the airside</u>

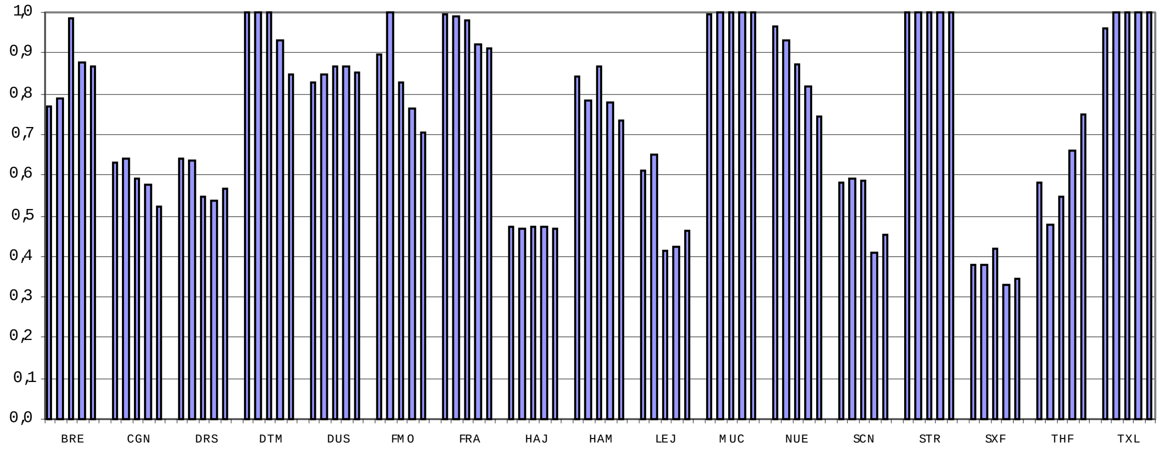
As with the terminal side the airside indicates differences in technical efficiency scores as well. Airports that operate with a relative low efficiency are CGN, DRS, HAJ, LEJ, SCN and SXF. Only STR could achieve constant efficiency scores during the whole period.

A slight decrease of technical efficiency of all airports, maybe because of the terror attacks could be observed as well. Nevertheless, different to the terminal side, not all airports were affected. In DUS, HAJ, MUC, STR, SXF and TXL the efficiency scores remained constant and THF increased its efficiency. For MUC and STR, for example, the constant performance can be explained through increasing aircraft movements. Because the number of passengers was decreasing in the same period, the airlines must have used smaller aircrafts. Except for

MUC and STR this measure of airlines can only be recognized at FRA but is a usual reaction after September 11th.

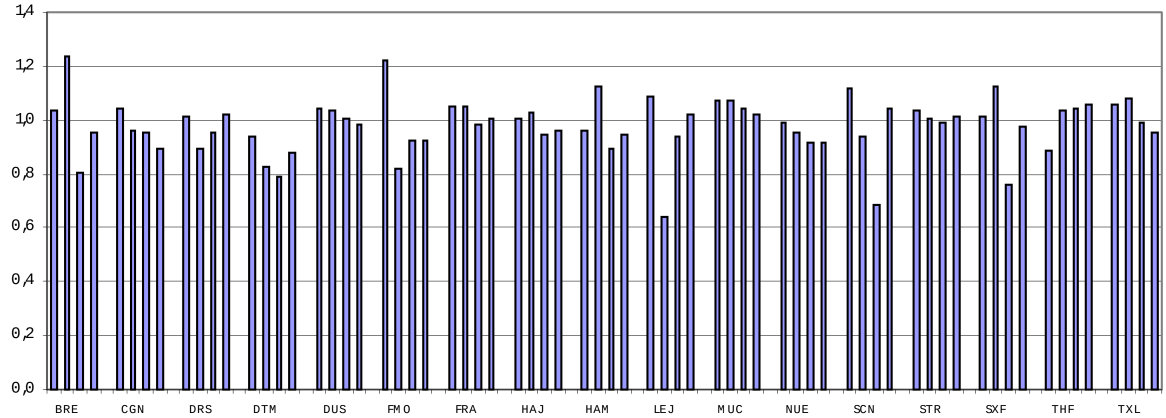
Substantial decreases in technical efficiency as seen for the terminal side are not the case for the airside. A reason might be that the intensity of capacity expansion is not as high as for the terminal side. This is not surprising as an expansion on the airside is more complicated in terms of administrative expenditures. From 1998 to 2002 there were only expansions in DTM and LEJ[3]. At these airports there were decreases but they could recover in the following years again.

Abb. 4: Technical Efficiency on the airside (1998-2002)



The TFP-change does not show such big fluctuations as the terminal side. Also, not all airports seemed to suffer under the terror attacks. On the terminal side nearly no airport could increase its TFP from 2000 to 2001 and from 2001 to 2002 but on the airside some airports were able to increase its TFP (DRS, DUS, FRA, LEJ and SCN).

Abb. 5: TFP-change on the airside (1998-2002)



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[3] Expansion of the airside: DTM: 2001 (runway extension) and LEJ: 1999 (additional runway)

As for the technical efficiency, the TFP does not show large fluctuations over the five years which could have arisen due to the constructions on the airside. Only in LEJ the productivity decreased by 36.2% from 1999 to 2000. In DTM, the decrease amounted only 7.1%. At both airports the TFP could recover in the following years again.

The most innovative airports on the airside are FRA, MUC and STR. Opportunities for innovative strategies are for example shorter turn around times due to faster fuelling and unloading of aircrafts.

When comparing both operating areas one can see that over the whole period the technical efficiency on the airside is bigger than on the terminal side as 12 airports achieved a higher efficiency there. A reason for this result might be the different magnitude of constructions.

No airport could achieve 100% efficiency in both areas but it can be observed that at the airports where the technical efficiency in both areas were high or low, there was no big change during the whole period. This is the case for DUS, FRA, HAJ, SXF and TXL.

Big differences over the whole period can be seen for BRE, FMO, NUE and SCN. At these airports the weak performance of the one operational side can be compensated by a good performance of the other side.

Abb. 6: Technical efficiency in comparison – 1998

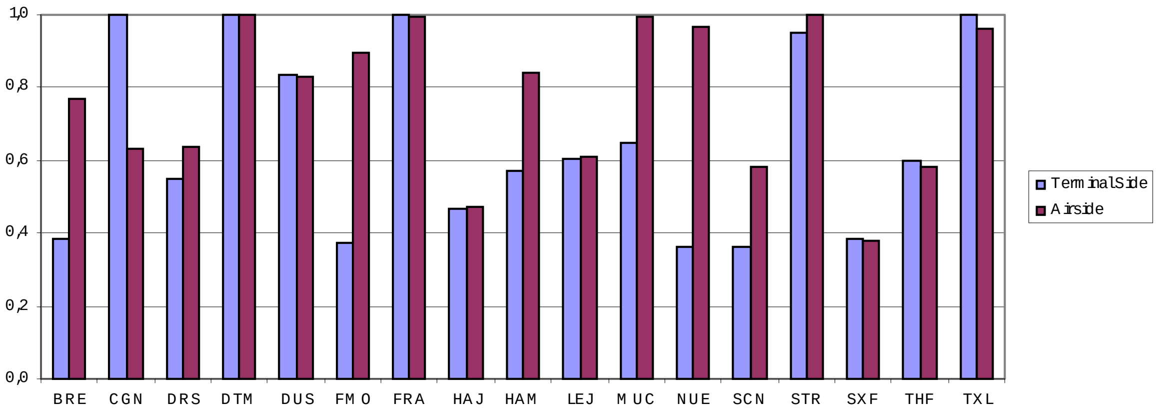


Abb. 7: Technical efficiency in comparison – 1999

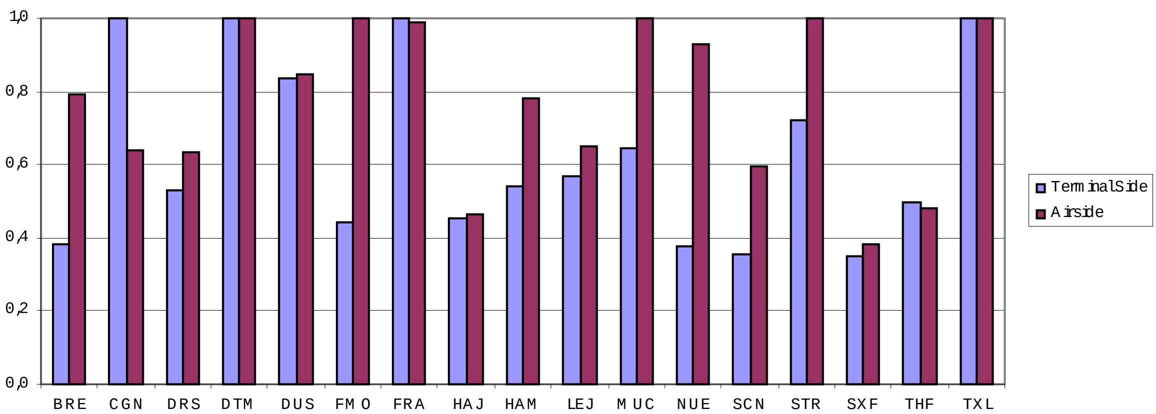


Abb. 8: Technical efficiency in comparison – 2000

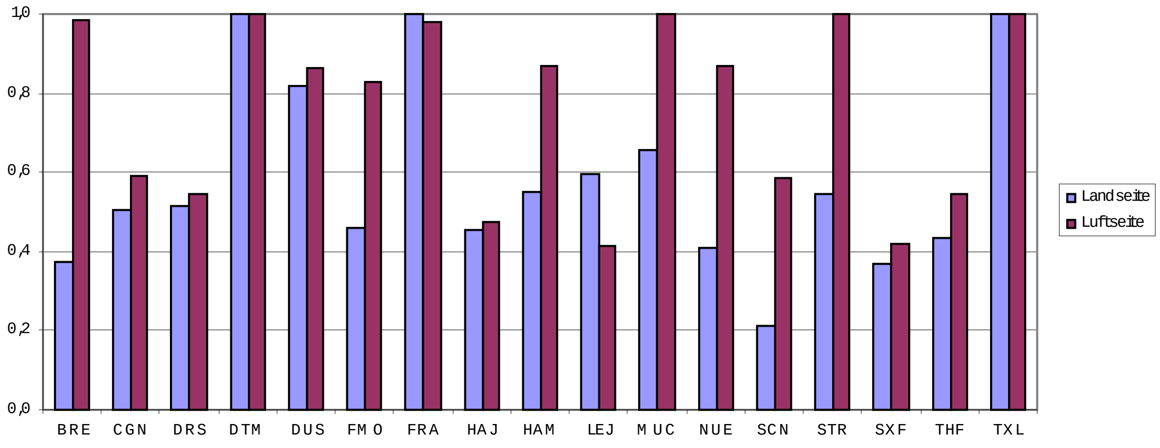


Abb. 9: Technical efficiency in comparison – 2001

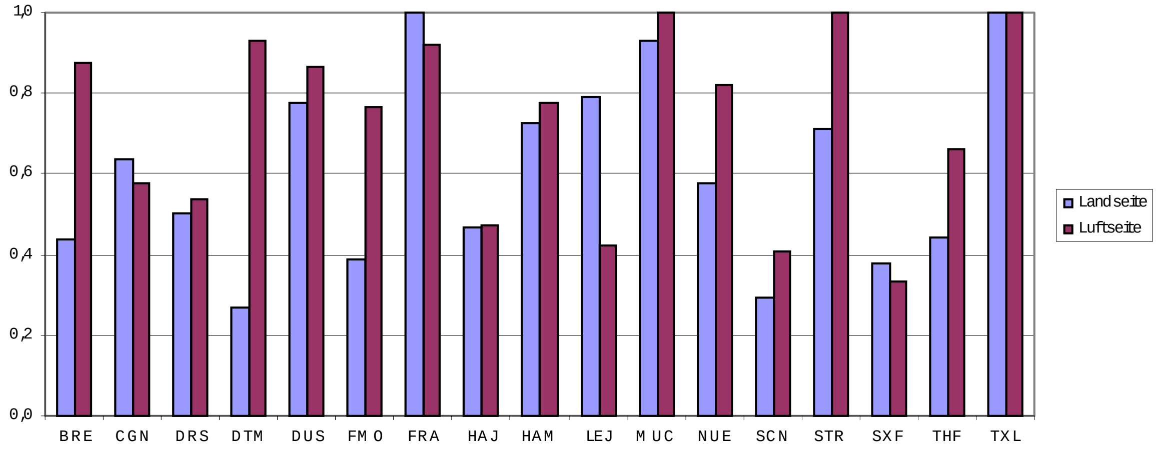
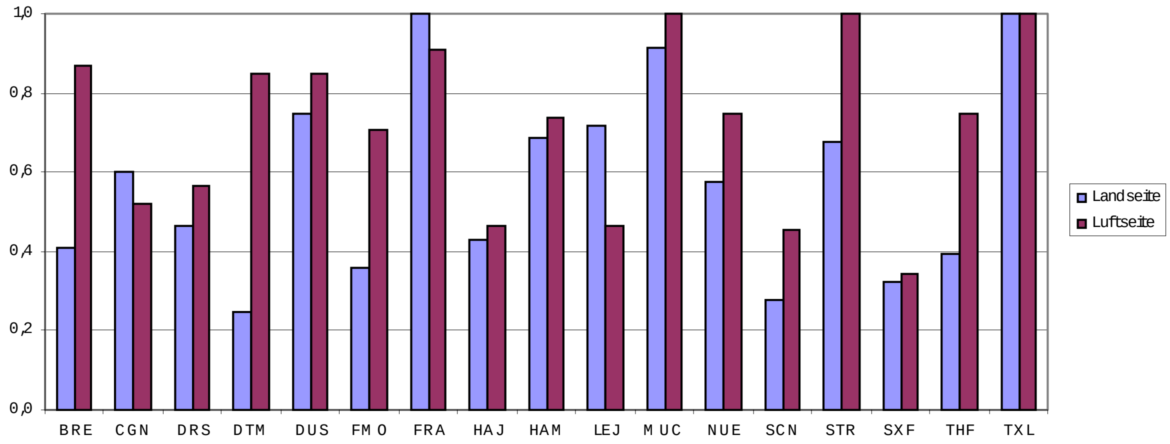


Abb. 10: Technical efficiency in comparison - 2002



The TFP-change indicates that the growth from 1998 to 1999 was very similar but with a slight higher growth on the terminal side. From 1999 to 2000 there were high fluctuations, especially the loss of productivity in CGN on the terminal side and LEJ on the airside can be seen and explained by the capacity expansions. A similar development was at DRS, DTM, DUS and FMO from 2000 to 2001 as their terminal buildings were opened in 2001.

Abb. 11: TFP in comparison- 98/99

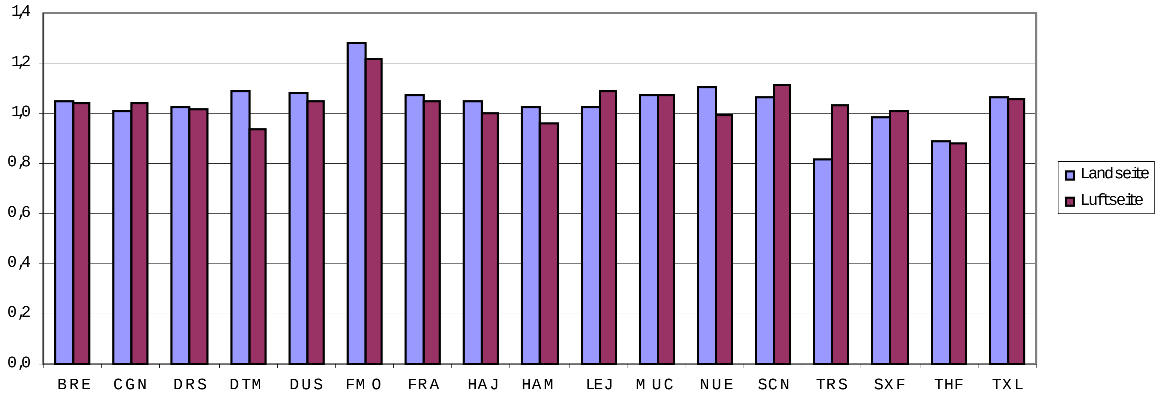


Abb. 12: TFP in comparison- 99/00

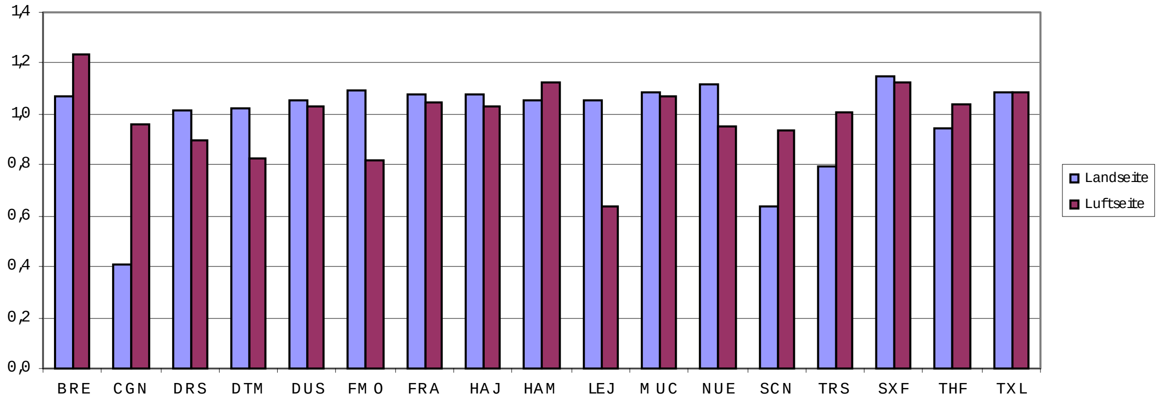
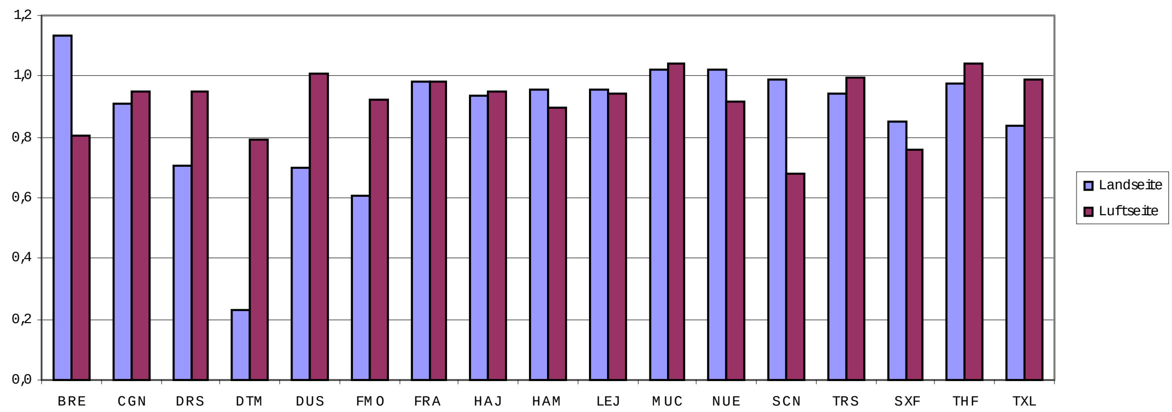


Abb. 13: TFP in comparison- 00/01



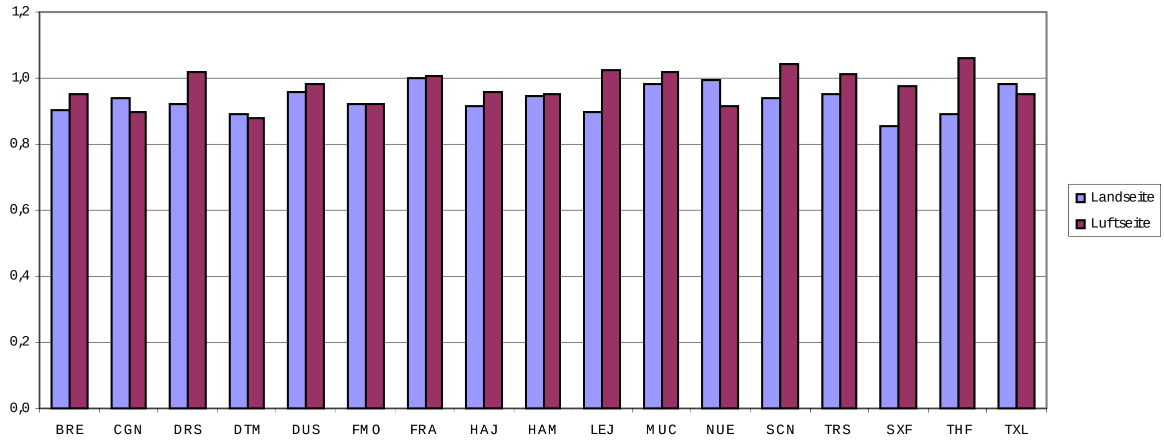


Abb. 14: TFP in Comparison - 01/02

III. Conclusion

All in all, the results of the Malmquist-DEA correspond to our expectations that the performance at nearly every airport decreased from 2001, mainly due to the aftermaths of September 11th in 2001. As presumed, most airports lost in technical efficiency and productivity. This was especially the case for the terminal side because the capacity expansions in form of new or additional terminal buildings increased excess supply. Nevertheless, the airports can only be responsible to a certain extent for their decline in performance because when they began to expand their services and buildings, an increase in passenger volumes was forecasted due to the continuing growth in the aviation sector.

DEA as the underlying methodology is often used to measure the efficiency because it can handle multiple inputs and outputs in a single analysis. Nevertheless, the results should be viewed with caution. For further investigation, economies of scales should not be only assumed but measured Pels (2000). On the other side, Grifell-Tatjé and Lovell (1995) advised assuming CRS when using Malmquist-DEA because increases and decreases due to scale effects are calculated inaccurately. However, especially for the airport industry, an assumption of VRS seems to be more appropriate as airports are often of different size. Thus, when assuming VRS inefficiencies can also result from scale inefficiencies and not merely technical efficiency (Coelli et al 1998). Furthermore, it should be compared if it is more appropriate to separate the two operational sides of an airport or include them in a single analysis.

From our point of view future research is necessary and can also be interesting for several stakeholders who are involved in the aviation industry:

- An *airport* is interested in its performance relative to other airports. Furthermore with benchmarking it can identify and adapt best practices to increase its efficiency and productivity.

- For *Airlines* then performance of airports becomes more important due to increasing competition from low cost airlines. While in the short run they are locked in to certain airports in the long run they will prefer efficient airports.

- *Communities and municipalities* need an efficient and competitive market to gain tourists for its region and to offer attractive connections for inhabitants. Furthermore, there is an interest for efficient airport as long as it is not fully privatised but partly owned by the community.

- The *Federal Government* is interested in international comparison as the knowledge of the relative efficiency of German airports is vital for its aviation and infrastructure policy (Sarkis 2000).

- When an airport is privatised, *Investors* are interested in new business investments and can decide where to invest to benchmarking results. This has a positive effect on the airport because further investments improve and expand the infrastructure at an airport.

- At last *Regulators* can also benefit from benchmarking as they are interested that airports offer their services at minimum feasible prices.

Further research should be directed in close cooperation with these stakeholders to bring in their knowledge and expertise. Form our viewpoint the following questions should be addressed the:

First, the productivity measurers should be refined in order to get reliable results. The above mentioned productivity differences demand explanation and this might involve intensive field work with airports on how they produce the various products. Especially the contracting out of services such as ground handling is an important issue to look at.

Second, how can the ownership influence the performance of an airport? An example would be to compare some German airports with airports that have a different structure in ownership to analyse its influence. This would be on the one hand Scandinavia where the airports are all state-owned and operate centralized as in Finland. Another example would be UK because some airports e.g. LHR and LGW have been fully privatised since the end of the 80s.

Third, how does competition between airports and market structure influence the performance of airports? This question could analyse by comparing airports which are natural or for legal reasons monopolies with areas in which more airports are operating and more or less competing. For e.g. the Northern German airports which are probably natural monopolies could be compared to airports in the Cologne-Düsseldorf region or with the Berlin region. This analysis could be extended to other European regions.

Fourth, does intermodal and intramodal competition in aviation affect performance? A comparison of German airports with airports in Australia can be interesting. In Germany we have an intermodal and intramodal competition because of the density and size of Germany. This is not the case for Australia where there is no competition between airports or airports and other transportation modes.

Fifth, are airports allocating their resources efficiently? Because most of the airports did not supply financial data the investigation of allocative efficiency was not possible. Concerning the pricing of airport charges, it would be possible to see if price discrimination can affect the efficiency. The airport in Frankfurt as an example, suffers under capacity constraints. To optimize existing capacities, FRA could introduce congestion pricing. Does this improve economic performance?

Sixth, how does regulation affect performance? As an example, one could investigate if the form of regulation can influence the efficiency and productivity. Hamburg and to a certain extent Frankfurt are airports with Price-Cap Regulation based on a dual till principle, all other airports are still regulated under the traditional rate of return regulation based on single till. Regulatory economics would predict that incentive regulated airports would outperform cost-based regulated airports.

Seventh, how do different management strategies affect the performance? Airports are increasingly developing new strategies to develop aviation and non aviation business. While some airports are aggressively developing the low cost carrier business some are more reluctant. Another open point refers to the extent of outsourcing at airports. In UK, ground handling was completely outsourced. Also, in Germany we can find different degrees of outsourcing, e.g. for HAM and FRA. This will lead to differences in costs and revenues and thus in differences in efficiencies and should be investigated as well.

All in all, the results show that further research is necessary to investigate the situation and position of German airports in a national and international context. The analysis has already found results but further research has to be made to find reasons for the individual scores the airports achieved. Therefore, cooperation with airports, airlines and ministries as well as with ATRS, TRL and other researchers through GARS workshops are important for a proper analysis and consistent results.

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REFERENCES

AIR TRANSPORT RESEARCH SOCIETY (2003) *Airport Benchmarking Report – 2003: Global Standards for Airport Excellence*. Vancouver: ATRS

CHARNES, A. AND COOPER, W.W. (1985) *Preface to Topics in Data Envelopment Analysis*. Annals of Operations Research. 2, 59-94

CHEN, Y. AND ALI, A.I. (2003) *DEA Malmquist productivity measure: New insights with an application to computer industry*. European Journal of Operational Research. (forthcoming)

COELLI, T., RAO, D.S. AND BATTESE, G.E. (1998) *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers

FARRELL, M.J. (1957) *The measurement of productive efficiency*. Journal of the Royal Statistical Society. Series A, 120 (III), 253-281

FØRSUND, F.R. AND SARAFOGLOU, N. (2000) *On the origins of Data Envelopment Analysis*. Memorandum. 24. Department of Economics. University of Oslo

GILLEN, D. AND LALL, A. (1997) *Developing Measures of Airport Productivity and Performance: An application of Data Envelopment Analysis*. Transportation Research Part B. 33, 261-273

GILLEN, D. AND LALL, A. (1998) *Non-Parametric Measures of Efficiency of U.S. airports. Economic Working Papers*. Wilfried Laurier University. Waterloo

GRIFELL-TATJÉ, E. AND LOVELL, C.A.K. (1995) *A Note on the Malmquist Productivity Index*. Economics Letters. 47, 169-175

PELS, E. (2000) *Airport Economics and Policy: Efficiency, Competition, and Interaction with Airlines*. PhD dissertation. Research Series. Vrije Universiteit Amsterdam

PELS, E., NIJKAMP, P. AND RIETVELD, P. (2001) *Relative efficiency of European airports*. Transport Policy. 8, 183-192

SARKIS, J. (2000) *An analysis of the operational efficiency of major airports in the United States*. Journal of Operations Management. 18 (3), 335-351

SCHEEL, H. (2000) *Effizienzmaße der Data Envelopment Analysis*. Wiesbaden: Gabler

STARKIE, D. (2002) *Airport regulation and competition*. Journal of Air Transport Management. 2, 63-72

TRANSPORT RESEARCH LABORATOY (2003) *Airport Performance Indicators* 2003. Wokingham: TRL