BENCHMARKING OF GERMAN AIRPORTS – SOME FIRST RESULTS AND AN AGENDA FOR FURTHER RESEARCH

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This paper outlines some first results of a study on the technical efficiency and total factor productivity (TFP) of 17 international airports in Germany. The analysis was undertaken with panel data from 1998 - 2002. According to the Malmquist-DEA 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 the form of new or additional terminal buildings increased excess supply whereas the passenger volume was decreasing.
This study is the first step of a larger research project on measuring the performance of German airports.

Keywords: Benchmarking, Airports, Data Envelopment Analysis

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 the Transport Research Laboratory (TRL Ltd.) publish benchmarking reports comparing international airports worldwide. But both only analyse German airports with high passenger volumes as Frankfurt and Munich. Overall, the German airports are ranked low.

In the ATRS Report of 2003 for example, all German airports in the sample (FRA, MUC, DUS, HAM and CGN) achieved below average results in labour productivity and average results in capital productivity. Also, the Total Factor Productivity (TFP) of FRA, MUC, DUS and HAM was far below the average. These German airports achieved 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, FRA has a low Labour productivity as the ratio of passengers per employee has been around 6,000 compared to over 50,000 in Brisbane or Calgary.

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 which 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 competition among airports although probably not on a great scale as federal governments prefer cooperative 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 in section III we draw the conclusion that more research is necessary which we propose in section IV including a research agenda for our research project "German Airport Performance" (GAP).

II. Airport Benchmarking in Germany

In our analysis we focus on the measurement of technical efficiency. We want to know whether or not German airports use inputs in a 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 efficiency which also includes the measurement 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 Data Envelopment Analysis (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 determined by the efficient DMUs of an analysis. The concept of linear programming was 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 any difficulties of aggregation. Instead of weighting factor quantities as for total factor productivity (TFP), DEA optimises the weights by linear programming.

DEA can either assume input minimisation with a constant output or can focus on output maximisation holding the inputs constant. 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 might be more appropriate. A further decision for DEA is to assume constant returns to scale (CRS) or variable returns to scale (VRS). The decision on which returns to scale to assume depends on whether all DMUs can operate at an optimal scale. If not, it is more appropriate to assume VRS because it decomposes the technical efficiency score into scale inefficiency and 'pure' technical efficiency so that the effect of scale inefficiency can be adjusted.

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

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

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 DMU.

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 any inefficient *k'* (Coelli et al 1998).

Because of the use of panel data in our analysis, the application of Malmquist-DEA is the most appropriate form to investigate the performance of different airports over a certain period. This DEA-like program together with a Malmquist-TFP Index calculates apart from the technical efficiency scores the TFP-change between two periods.

Malmquist-DEA is defined using distance functions *[D(x,y)]*. The advantage of Malmquist-Indices compared to a Tornqvist or Fisher Index is that it does not require financial data as well. To measure the TFP-change one calculates the distances of each data point relative to a common technology.

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*:

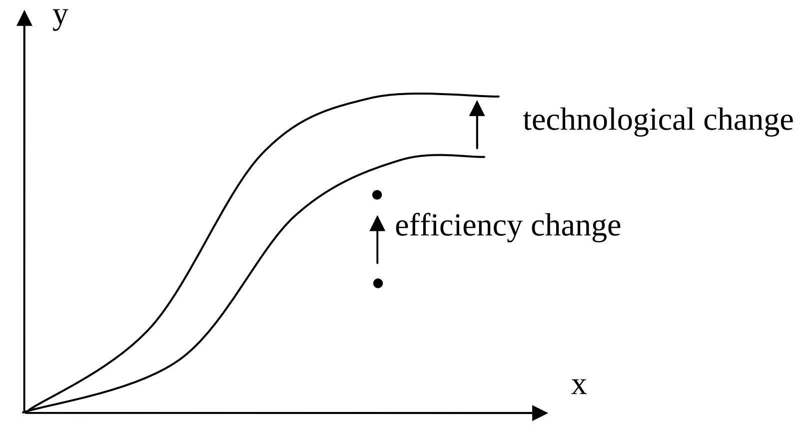
$$M_{t-1,t} = \left[\left(\frac{D_{t-1}(x_t, y_t)}{D_{t-1}(x_{t-1}, y_{t-1})} \right) \cdot \left(\frac{D_t(x_t, y_t)}{D_t(x_{t-1}, y_{t-1})} \right) \right]^{1/2}$$

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 ($M_{t-1,t} < 1$) means a decline in TFP-growth (Chen und Ali 2003).

The above formula can also be transformed in the formula below which means, that the change in TFP is decomposed of a change in technical efficiency and a change in technology. 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 an upward shift of the production frontier:

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

Fig. 1: Technological change vs. efficiency change



For every DMU, one must calculate four distance functions to measure the TFP change between two periods *t* and *t-1*. The distance functions are calculated by DEA-like linear programming problems and are the inverse of the efficiency score according to Farrell (Coelli et al 1998).

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

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

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

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

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 appropriate data was 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 technical efficiency.

The data collected include the time series 1998-2002. An exception was made for DUS. 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 DUS 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 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) should 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 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.

In our analyses we have assumed output maximisation for both operational sides and as Gillen and Lall (1998) VRS on the terminal side and CRS on the airside.

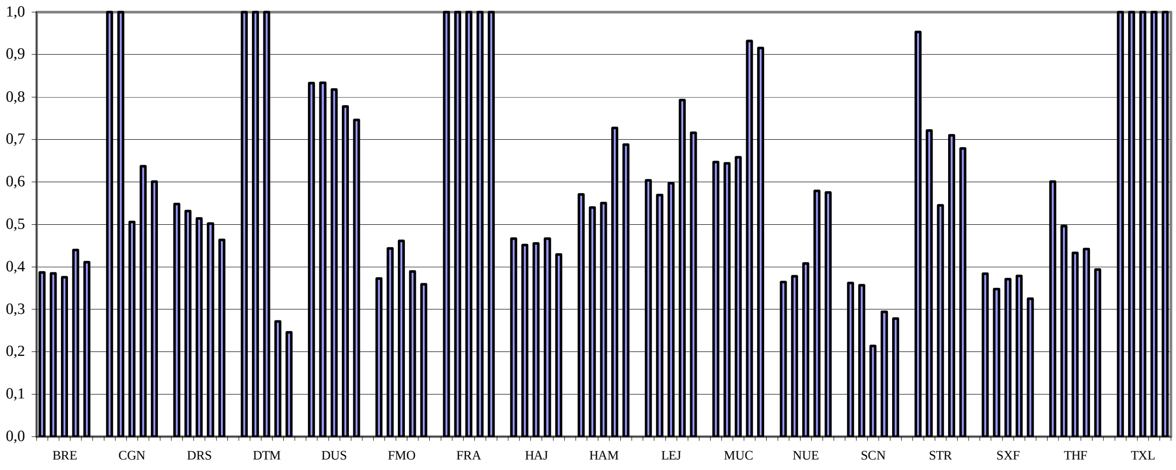
II.3 Results

II.3.1 All Airports

On the **terminal side** there are substantial differences in technical efficiency scores among the DMUs. Whereas FRA and TXL were operating 100% technically efficient during the whole period, BRE, FMO and SXF achieved technical efficiency scores below 50%. Note, that an efficiency score of 0.5 means that 50% of the output that can be potentially produced has been realised.

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 with e.g. 7% and 8% respectively in BRE and FMO and nearly 15% in SXF. This leads to the assumption that there might be an influence of the September 11th especially in 2002 on the airports performances. That the terrors attacks might be responsible for the decline in 2002 can also be seen that all airports with increasing technical efficiency scores before 2002 (HAM, LEJ, MUC and NUE) had stopped their positive trend.

Fig. 2: 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.

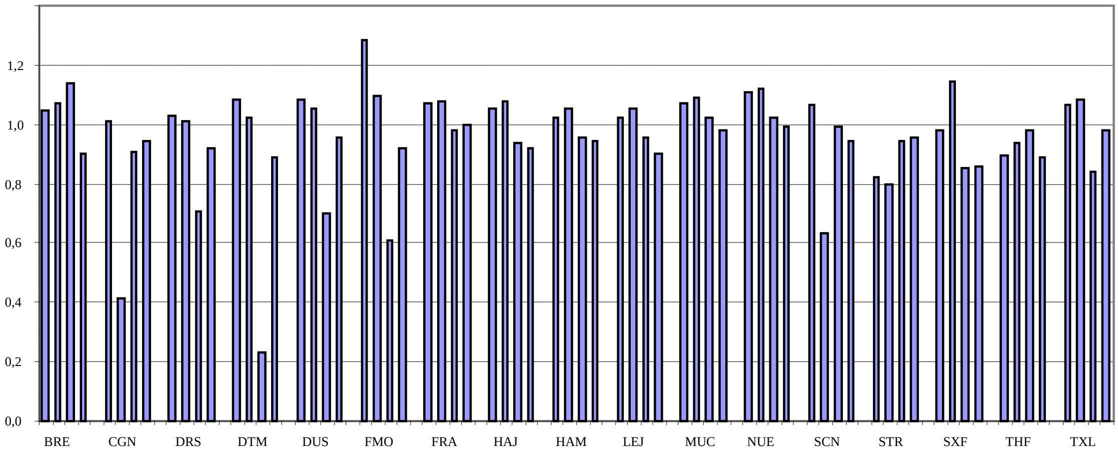
With an exception of THF all decreases could be explained with the capacity expansion on the terminal side within the last years. CGN and DTM show huge losses in efficiency as they operated with an efficiency of 100% before the openings of their new terminals. This is not surprising because when the construction of new terminals was planned no one has considered a crisis in the aviation industry but a growing industry.

A reason for the outstanding results of FRA and TXL relative to the other airports here is, 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 contrary, one can observe that after the expansion on the terminal side, the technical efficiency decreased as they had more resources compared to the previous years together with declining passenger volumes. Therefore, having had financial data would have led to more sophisticated results.

The TFP-Growth amounts on average 3.8% from 1998 to 1999. From 1999 to 2000 there had been a downward tendency with 4.1% which was primarily due to a substantial decrease of 58.9% in CGN. At most airports there still had been an increase in TFP. From the year 2000 the productivity could only be increased in BRE, MUC and NUE and from 2001 to 2002 it decreased at all airports. This result is not surprising: TFP-change is decomposed of technical change and technical efficiency change and nearly all airports show declining efficiency scores from 2001 to 2002.

FMO indicates an outstanding increase in TFP from 1998 to 1999 of 28.4%. This was primarily through an increase in technical efficiency as the airport reduced its staff from 400 to 227 employees.

Fig. 3: TFP-change on the Terminal Side (1998-2002)



Fluctuations in TFP (primarily through changes in technical efficiency) over the years have happened especially at airports with capacity expansions. This is for example CGN with a decrease of 58.9% from 1999 to 2000 or DTM from 2000 to 2001[1] with more than 75% due to a huge loss in technical efficiency compared to the previous year. However, these rates could recover in the following years again because the efficiency change has not altered as much as in the year before.

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 upward. In our analysis the TFP was mostly a combination of technical

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

and efficiency change, only some airports indicated pure 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 an innovation at airports could be the pressure of airlines or other airports, especially hubs and airports in the same region due to increased competition. This assumption can be confirmed for the innovative airports in our analysis: in 1998, Lufthansa opened its second hub in MUC. 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 is higher than anywhere else in Germany.

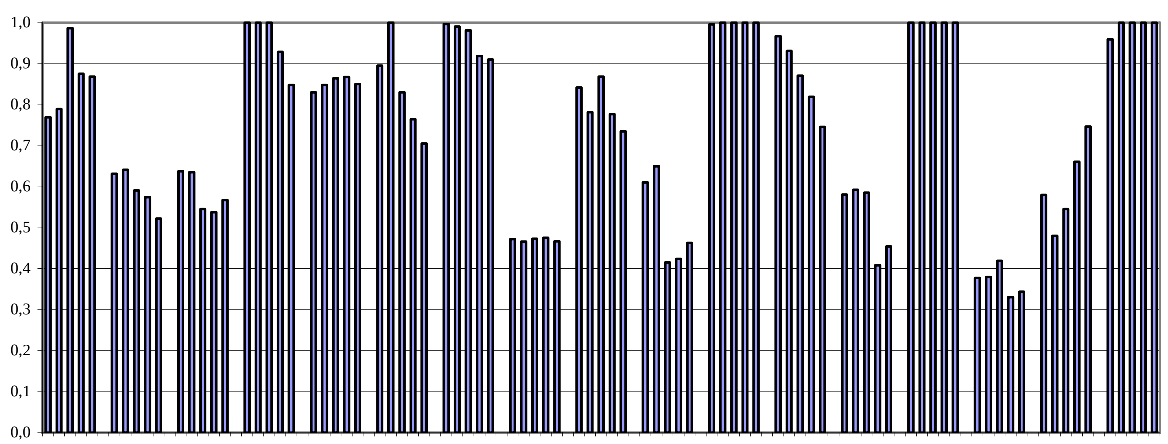
Actually, one might assume that BRE, HAM and HAJ are competitive to each other as well, but this could not be confirmed in this analysis.

As with the terminal side the **airside** indicates differences in technical efficiency scores as well. Airports that operate with relatively 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, perhaps because of the terror attacks, could be observed as well. Nevertheless, different to the terminal side, not all airports seemed to be affected. In DUS, MUC, STR and TXL relatively high efficiency scores remained constant. In 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. This measure of airlines can also be recognized at FRA but should be a normal reaction after September 11th.

Substantial decreases in technical efficiency 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 because an expansion on the airside with its administrative processes and permission are more complicated. From 1998 to 2002 there were only expansions in DTM and LEJ[2] but especially DTM does not show substantial effects. The runway extension in DTM merely led to a decrease in technical efficiency from 100% to 93%. LEJ could first improve its efficiency slightly by 4% from 61% to 65% but then decreased to about 40% in the following years.

Fig. 4: Technical Efficiency on the Airside (1998-2002)



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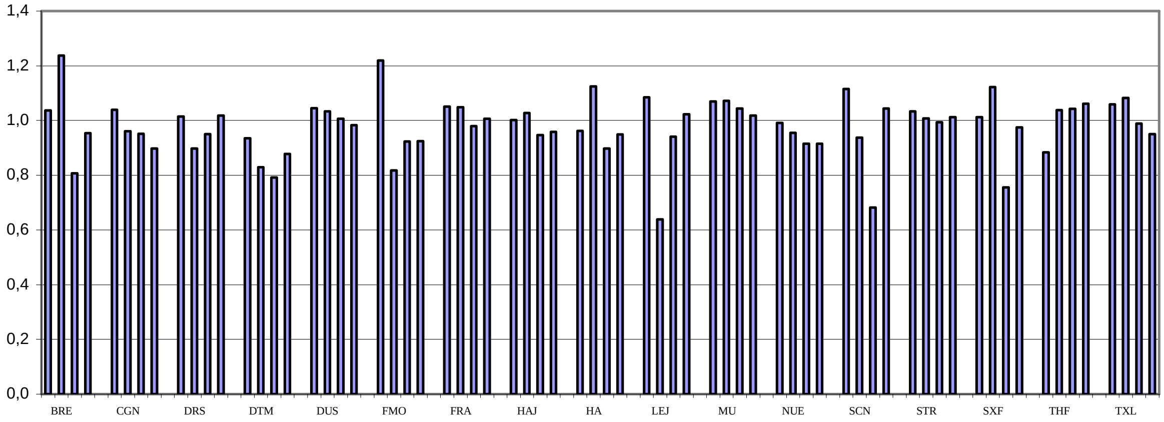
[2] Expansion of the airside: DTM: 2001 (runway extension) and LEJ: 1999 (additional runway)

The TFP-change does not show high fluctuations as on the terminal side indicating that the terror attacks were not seriously threaten the airside. 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 showed a slight positive TFP-change in the same period (DRS, LEJ, MUC, STR and THF).

The capacity expanded airports indicated a decrease in TFP: in LEJ the productivity decreased by 36.2% from 1999 to 2000. However, in DTM, the decrease amounted only 7.1%.

Fig. 5: TFP-change on the Airside (1998-2002)

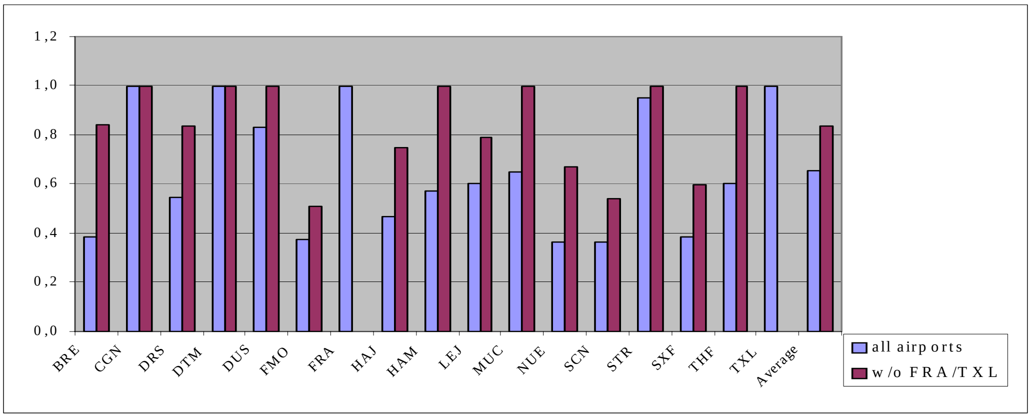


II.3.2 Sensitivity Analysis

In a further analysis we have excluded FRA and TXL of our dataset. The reason is that these airports were operating with 100% technical efficiency on the terminal side over the whole period. As already said, this was due to capacity constraints. In comparison to them especially smaller airports like BRE, FMO, NUE and SCN were achieving low efficiency scores.

Because DMUs are compared against each other when using DEA, having removed FRA and TXL must have an effect on the results on the **terminal side**: the average efficiency score has increased from 0.6 to 0.85. Especially the smaller airports with weak performances in the previous analysis like BRE, FMO, NUE and THF have improved their efficiency. Whereas BRE was operating with a technical efficiency score of 39% before, by having removed FRA and TXL, BRE is now operating with a technical efficiency of 83% in 1998 and in 2001 and 2002 it achieved 100% efficiency.

Fig. 6: Technical efficiency Terminal Side without FRA and TXL - 1998

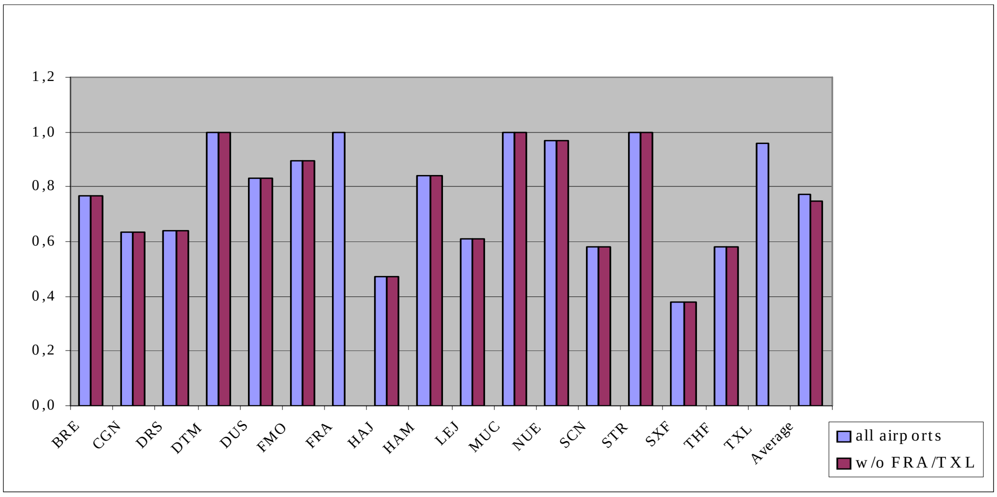


It is also worth saying that there are some other airports apart from BRE that operate under 100% technical efficiency in 2001 and 2002 when having excluded the constrained airports. This is the case for HAJ, HAM and STR. An explanation might be, that these airports were not expanded with capacity during the whole period thus although having lost passengers after September 11th, their performance was obviously relatively better than of capacity expanded airports. In other words, this result shows, that BRE, HAJ, HAM and STR were only increasing its efficiency score due to lower efficiency of capacity expanded airports, so that in comparison to others they performed better, but it does not say that they improved their real performance.

The improved average efficiency scores lead to the assumption that having been compared to these big airports that are suffering under capacity constraints is a disadvantage for small airports. This can be confirmed as DUS and MUC as the airports with the highest passenger volumes in this new sample are operating with 100% technical efficiency over the whole period and seemed to be the peers for most of the airports. This indicates that VRS exist on the terminal side as expected by Gillen and Lall (1998).

For the **airside** the average technical efficiency has not altered very much. Only in 2001 and 2002 some airports had slightly higher efficiency scores than in the previous analysis. As on the terminal side this was predominantly the case for smaller airports like SCN and THF. Again, all airports with spare capacity e.g. LEJ and SXF have achieved low efficiency scores. Also, HAJ with three runways and a massive airport area compared to FRA (HAJ has around half the area and also three runways) performed very poorly.

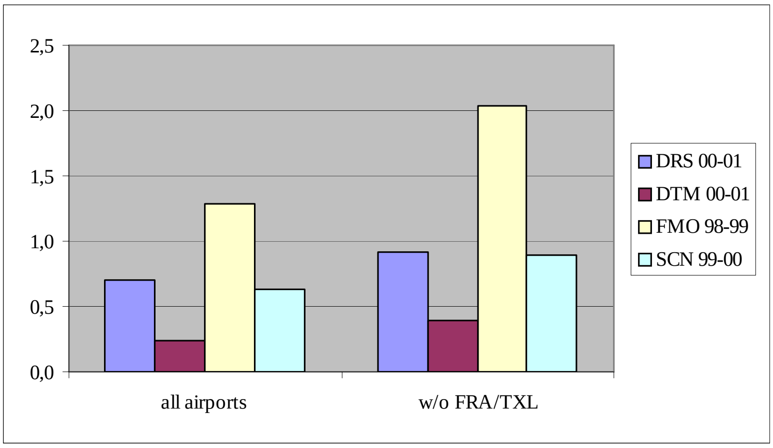
Fig. 7: Technical efficiency Airside without FRA and TXL - 1998



This was an expecting result because on the airside, beside FRA and TXL also MUC and STR were performing quite well, so that the two terminal constrained airports did not have the massive influence as on the terminal side.

In comparison to the technical efficiency the TFP-change on the terminal side does not change very much, just at some airports we could find essential differences to the previous analysis. This is not surprising as TFP-change is a result of technical efficiency change and technical change. Just by having excluded two airports the technological change can not be altered and thus the effect of technical efficiency improvement is smaller. The airports with essential TFP-changes were again small airports like DRS, DTM, FMO and SCN who could improve their TFP by more than 30% in one year, basically through improvements in technical efficiency.

Fig. 8: TFP-change Terminal Side without FRA and TXL



To categorize the airports in three classes with small, middle-size and big airports our sample is too small. Having tried this, especially for the five biggest airports (DUS, FRA, HAM, MUC and TXL) every airport was operating efficiently relative to each other. Therefore, clustering airports to make the groups more homogenous, one needs a database with more airports.

We have also excluded the hub airports in a further analysis to investigate whether these airports have an effect on the efficiency score of the smaller airports. Without FRA and MUC the analysis did surprisingly bring the result that nothing has changed on both operational sides compared to the first analysis where all airports in the sample were included. All airports achieved exactly the same efficiency score and TFP-change.

Because the exclusion of FRA and TXL had an effect on the technical efficiency of smaller airports we excluded both separately in a further step. The reason was to proof that only TXL had the influence on the other airports technical efficiency. On the one hand this leads to the assumption that TXL as the smaller airport must have a more similar mix of inputs and outputs and thus reacts as a reference airport for the inefficient DMUs. On the other hand, this might also mean that TXL is more capacity constraint than FRA and thus operates more technically efficient which cannot be measured.

Indeed, our expectations were supported. Having ran the model without FRA did not have any effect on the technical efficiency on any airport. On contrary, when just having excluded TXL brought exactly the same result as in the first sensitivity analysis.

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. Therefore, in this period it was nearly impossible to catch-up to the technically efficient airports. 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.

To remove the effects of the airports that are suffering under capacity constraints and are therefore operating with 100% technical efficiency we excluded FRA and TXL for a second analysis. The result was that on the terminal side, especially the smaller airports have increased their technical efficiency.

In a third analysis we have eliminated FRA and MUC as hub airports from our sample and ran the model once more. The result was, that technical efficiency and TFP-change did not change at all, what leads to the assumption that hub airports do not have an effect on the technical efficiency of smaller airports.

To investigate the magnitude of influence of FRA and TXL we also excluded both airports separately and our expectation, that only TXL had an influence on the other airports performance were supported.

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). Especially for the airport industry, an assumption of VRS seems to be more appropriate as airports are often of different sizes. 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.

All in all, this study shows preliminary results where financial data and further airports (e.g. LCC airports) should be extended. Then more convenient results and conclusions can be made and the effects of capacity constraints can be removed.

IV. Research Project

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 airports 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.

For this reason, the University of Applied Sciences Bremen, in cooperation with the University of Applied Sciences Berlin and the International University of Applied Sciences Bad Honnef has started a research project on airport benchmarking called '*German Airport Performance (GAP): An Efficiency Measurement of German Airports in Comparison to Europe*' this year.

The target of this project is to investigate the changing nature of airports together with commercialization but also to analyse whether airports in competitive areas should be further regulated in contrary to airports with less competition.

Reasons for an increasing competition between airports are different. It can be the deregulation of the airlines, the ongoing privatisation-process of the airports or the growing presence of Low Cost Carrier (LCC). Therefore an investigation of these factors for German airports in comparison to airports in other countries where the process is already in further stages is necessary. Germany as a focus of investigation is also highly interesting as the airports are very heterogeneous with respect of ownership and regulation.

From our viewpoint the following questions should be addressed:

First, the productivity measures should be refined in order to get reliable data and thus reliable results. The 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 Scandinavia where the airports are all state-owned and operated centralized as in Finland. Another example would be the 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 be analysed 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 the performance? A comparison of German airports with airports in Australia will be interesting in this case. 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 in 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 the 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.

Eighth, is there an increasing efficiency at airports with densely populated areas such as the Ruhr area or Berlin since the liberalisation? Airports in these regions in Germany are e.g. CGN and DUS. The question is whether competition has been increased or if the airports do not see competitors in each other as they provide different services (e.g. tourism vs. LCC vs. business and short haul vs. long haul).

Ninth, what is the effect of external factors on efficiency? For example, how different is the Air Traffic Control worldwide? What an effect do the weather (snow, rain, sun etc.) and the structure of the runways have on the performance of an airport?

Tenth, how do basic conditions affect the efficiency? Especially open skies vs. bilateral agreements and differences in slot allocation are of question here. But also the influence of environmental restrictions is of essential importance.

Last but not least, the research project plans to investigate, how many airports are already using Benchmarking as a Management-Instrument for optimizing their performance and if our project can gain from the experience of other Benchmarking studies in other areas of the public sector (e.g. water).

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.

V. 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