The Relative Efficiency of German Airports[1]

An Application of Partial Factor Methodology and Data Envelopment Analysis

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Section I: Introduction

Regulatory reforms and recent changes in the institutional structure of large European airports have resulted in the revival of benchmarking analyses to assess resulting changes in airport performance. Only through said comparisons do questions regarding the appropriateness of such regulatory and organizational adjustments have the opportunity to be addressed. Therefore, a healthy amount of academic literature regarding the benchmarking of airports has appeared in recent time. Long term airport benchmarking initiatives, such as ATRS and TRL, have also emerged with the goal to develop effective cross sectional benchmarking methodologies and to arrange a ranking of the world's top airport hubs in different categories such as labor productivity and technical efficiency.

Unfortunately, these studies often contradict one another due to the relatively unsystematic nature of airport benchmarking. Table 1 provides a comparison of labor productivity estimations between ATRS and TRL in 2000. An improvement in efficiency scores was prevalent for Munich and Vienna Airports; however efficiency scores in Frankfurt remained consistent. This stresses the increased need to pursue further research in the area, and to consider numerous methodologies to unchanged samples of study. Proven methods of efficiency analysis in the context of airports include linear approaches, such as partial factor comparison, and more complex non-parametric and parametric statistical methods, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA).

		ATRS 2000	TRL 2000		
1	ARN	26.352	26.241	ARN	1
2	OSL	22.955	23.531	AMS	2
3	ZRH	22.249	22.627	ZRH	3
4	AMS	20.270	22.447	OSL	4
5	LGW	17.814	19.066	LHR	5
6	LHR	17.002	18.092	LGW	6
7	GVA	16.008	18.032	MUC	7
8	CPH	12.617	17.979	GVA	8
9	MAN	7.067	14.632	VIE	9
10	MUC	5.714	13.174	CPH	10
11	VIE	4.879	10.692	MAN	11
12	FRA	3.459	8.050	FRA	12

Table 1: Ranking Discrepancies: Labor Productivity in Passengers per Employee[3]

[3] *Kamp et.al.*, Can We Learn From Benchmarking Studies of Airports and Where Do We Want To Go From Here?, GARS Conference Vienna, November 2005, p. 10.

However, one consistency noticeable in recent benchmarking studies, more specifically in the reports of ARTS and TRL, is the poor performance of selected German international airports.[4] Figure 1 represents the labor productivity (PAX per Employee) of German airports compared to other airports in the studies of ATRS and TRL in 2001. According to this statistic, MUC, DUS, HAM, CGN, BER and FRA all performed well below the European average.

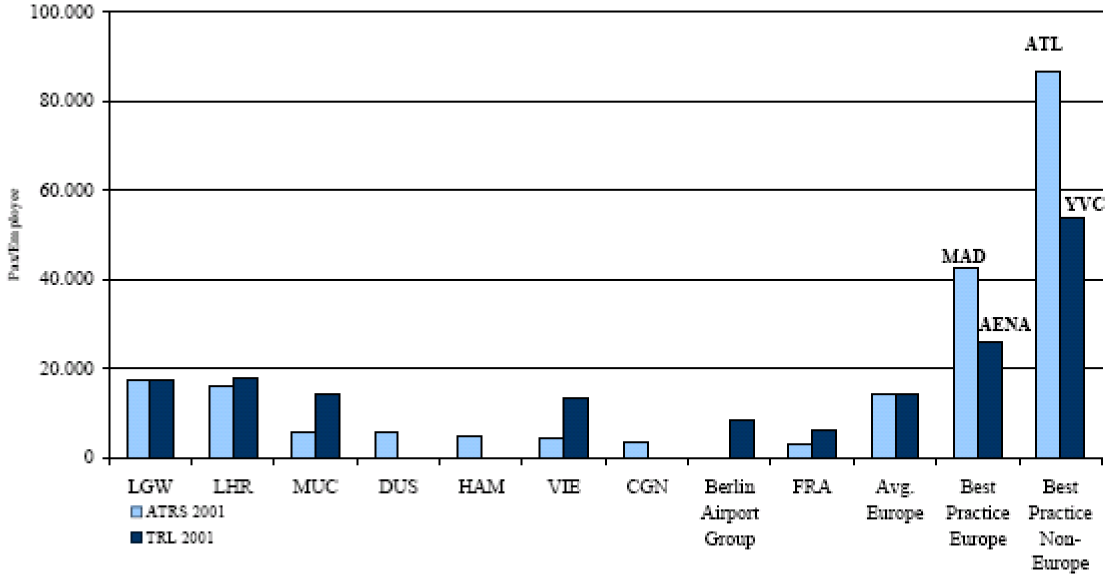

Figure 1: Below Average Labor Productivity of German Airports: ARTS and TRL (2001)[5]

Another noticeable problem with recent airport industry studies is the exclusion of small to mid-sized airports from the airport benchmarking discourse. Concentration on a comprehensive national comparison has its advantages, the most important of which referring to the comparability of airports subject to similar economic and regulatory restrictions. This, combined with the historically poor performance of German international airports, has motivated the creation of the *German Airport Performance* (GAP) research project to engage in a combined study to develop benchmarking approaches which address different aspects of airport operations, with a country specific application to Germany.

[4] See *Pels et.al.* (2001), ATRS 2003, TRL 2000,

[5] *Kamp et.al.,* Can We Learn From Benchmarking Studies of Airports and Where Do We Want To Go From Here?, GARS Conference Vienna, November 2005, p. 6.

The goal of this article is then to provide an initial analysis of the financial performance of German airports (where data is available) using partial indicators. Similar partial indicators will also be calculated to address labor and capital productivity of the sample; then using averaged indicators, the overall performance of German airports will also be discussed. After measuring relative efficiencies in individualized categories, a frontier check comparing the overall inefficiency of German airports will be presented using Data Envelopment Analysis.

The paper is then organized as follows: First, the methodology of the paper will be discussed; including advantages and disadvantages regarding implementation of each method. Then, a short summary of collected data and data adjustments will be given. In sections IV and V, empirical results regarding airport inefficiencies will be presented, followed by conclusions and future considerations in section VI.

Section II: Methodology

In this article, the relative efficiency of German airports will be measured using partial factor productivity methodology and Data Envelopment Analysis (DEA). This allows for a detailed analysis of various cross sections (including financial performance and technical efficiency) and for an overall efficiency check through comparison with a DEA efficient frontier. Holvad and Graham (2000) argue that the appropriate recommendation for efficiency analysis is to combine partial factor productivity calculations with Data Envelopment Analysis to obtain as much information as possible about the observations, after an analysis of the Pearson Correlation Coefficient between DEA efficiency scores and partial productivity indicators yielded a positive and significant relationship between the two methods.

a.) Partial Factor Measures

The partial productivity indicators calculated and their applications are shown in Table 2.

Area of Measurement		**Indicator**
Financial Performance		Real Costs[6] per WLU[7] Real Revenues per WLU Real Aeronautical Revenues per WLU Real Commercial Revenues per WLU Aeronautical/Total Revenue (%) Revenue/Expenses Ratio
Capital Productivity	Terminal Capacity	PAX(000) per Gate PAX per M^2 (Terminal Side)
	Runway Capacity	Movements(000) per Runway
Labor Productivity		PAX per Employee Movements per Employee WLU(000) per Employee

Table 2: Overview of Selected Partial Indicators and Areas of Application

Partial factor measures can be used in order to derive simple and relative comparisons between one input and one output factor (e.g. PAX per employee). Calculation of these indicators is fairly elementary, requiring only to divide one factor by another. They also

[6] Costs, in the context of the comparisons made in this article, refers to operating costs; more specifically material costs, employee costs and accumulated depreciation.

[7] WLU, or Work Load Unit, is an aggregated output indicator for passengers and cargo. One WLU can be defined as one passenger or 100kg of air freight.

provide for comparisons in specific areas, such as unit costs in respect of particular services, or comparisons of costs of particular types of facilities.[8] The ease of computation of such ratios along with the simplicity to distinguish performance between observations makes them the logical starting point for analysis of the data set. Only a limited amount of data is prerequisite in order to conduct such comparisons.[9] However, when considering more complex methods of efficiency analysis, a larger selection of data is usually more desirable.

As with other methods of efficiency analysis, the results of such a cross sectional comparison do not come without its problems and criticisms. One cannot question the credibility of a ratio analysis of airports with similar ownership structures, degree of vertical integration, economies of scale, declared capacity, regulatory regimes and tariff structures. Unfortunately, differences in these areas have certain implications on the way that partial productivity measures present relative efficiencies. Therefore, it is important to understand the disadvantages and dangers regarding partial measures when investigating the findings. For example, certain types of efficiency comparisons could be corrupted when the input mix of the sample airports vary to a large degree, an instance of which can be observed with labor productivity indicators. In this case, a relatively favorable efficiency score in labor productivity could be the result of aggressive outsourcing behavior, which does not necessarily indicate highly efficient labor usage or per employee output.

The degree of vertical integration, therefore, plays an influential role when considering labor productivity. Larger disturbances when benchmarking airports are mainly evident regarding ground handling services. Luckily, in the case of Germany ground handling remains a mainly internal operative branch, with the exception of Berlin Airports which continues to fully outsource its ground handling operations to GlobeGround Berlin and BLAS. Security measures have also been a widely discussed issue post 9/11, and airports may choose to outsource this to private security agencies. Such outsourcing activities unintentionally deflate the number of employees included in an efficiency check, which skews labor productivity numbers positively. Researchers need to consider the necessity of data adjustments in order to level the playing field, for example including the outsourced activity as an airport activity, whereby the private firm's employees would be considered as airport employees.

[8] *Civil Aviation Authority,* "The Use of Benchmarking in the Airport Reviews", Consultation Paper, December 2000, p. 14
[9] See ATRS 2003, I-12.

Revenues and expenses are also unfairly compared when observations in the sample come from airports which outsource ground handling services and those that do not. Cost efficiencies and profitability are hence compared unevenly.

Similar difficulties are palpable when analyzing runway capacity. For example, the construction of an additional runway does not necessarily result in proportional increases in runway capacity. The effect on runway capacity depends on multiple factors, the most important of which are the type of multiple runway system and regulatory restrictions. At Frankfurt Airport, the parallel runway system there allows for takeoffs and landings at the same time, whereas at others consecutive takeoffs and landings are restricted due to regulation, such as Düsseldorf. Köln-Bonn Airport maintains one of their runways mainly for historical purposes. Airports located in areas which are susceptible to erratic weather changes also might build a runway which is orientated at a different degree. Dangerous cross-winds, which could cause massive delays at airports with only one runway or a parallel runway system, therefore become a non-issue at airports which prepare for this by building a runway at a different angle, allowing airplanes to land more safely. These runways cannot be used concurrently because they usually intersect one another, an example of which can be seen at Dublin airport, where both runways intersect at their ends and disallow concurrent takeoffs and landings. Many benchmarking studies, such as ATRS, do not take these factors into consideration and simply apply the total number of runways in their calculation of runway capacity. In this case, data adjustments should be considered in order to present a more accurate measure of runway efficiency.

Others argue that runway capacity is merely a political decision made by airport stakeholders, and that it completely depends on the degree of slot allocation, otherwise known as the "declared capacity" of airports. Also, noise and environmental restrictions can have a large effect on runway capacity. Similar types of externalities need to be considered when addressing the appropriateness of such comparisons.

These examples are meant to only present the ambiguity of partial indicators, and to spark considerations for adjusting them. However, it is important to make adjustments in only the most important areas, because extensive changes will in turn make your own observations ambiguous.

b.) Data Envelopment Analysis

Traditional data envelopment analysis (DEA) was implemented to assess the relative efficiency of German airports. DEA is a nonparametric approach determining a piecewise linear efficiency frontier along the most efficient firms to derive relative efficiency measures of all other firms. It is widely used in efficiency analysis, including empirical work on the performance measurement of airports because of its simplicity and the useful interpretation of results it yields, even with limited data sets. Either a constant returns to scale (CRS) or a variable returns to scale (VRS) approach can be approached within this framework. The CRS hypothesis suggests that companies are flexible to adjust their size to the one optimal firm size. By contrast, the VRS approach is less restrictive in that it compares the efficiency of companies only within similar sample sizes; this approach is adapted if the airports are not free to choose or adapt their size. The comparison between the two approaches also provides some information about the underlying technology: if the results of the CRS and the VRS approaches are similar, then returns to scale do not play an important role in the process. Figure 2 below shows a case of 3 utilities for the two input one output case. Point B is efficient both under the CRS and VRS assumption, whereas point A is inefficient under the stricter CRS assumption. Point C is inefficient in both cases.

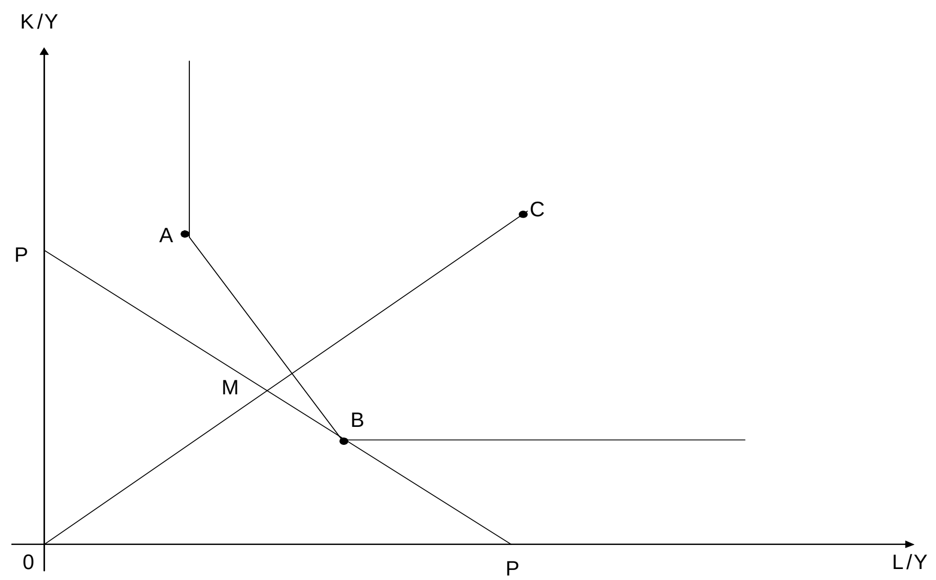

Figure 2: Data Envelope Efficiency Frontier for the Input oriented Case (two inputs, one output)[10]

[10] Jamasb, T. and Pollitt, M. (2003, 1611).

The determination of the efficiency score of the *i*th firm in a sample of N firms in the CRS model is equivalent to the following optimization:

$$\min_{\theta,\lambda}\theta$$
$$\text{s.t.}$$
$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0.$$

Θ is the efficiency score, and λ a Nx1 vector of constants. Assuming that the firms use E inputs and M outputs, X and Y represent E*N input and M*N output matrices respectively. The input and output column vectors for the *i*th firm are represented by x_i and y_i. The constraints ensure that the *i*th firm is compared to a linear combination of firms similar in size. To determine efficiency measures under the VRS assumption a further convexity constraint $\sum\lambda = 1$ has to be considered. The system is solved once for each firm (see Jamasb and Pollitt, 2003, 1612, and Coelli, et al., 1998, chapter 6).

DEA is a relatively uncomplicated approach. The determination of an explicit production function is not required. However, since DEA is a nonparametric approach the impact of the respective input factors on each respective efficiency score cannot be determined. Furthermore, DEA does not regard possible noise in the data and outliers can have a large effect on the outcomes.

1.) Overview of Different Models in Literature (Input – Output Combination)

In this subsection, a short overview of the different model specification used in empirical literature will be presented. Anne Graham (2000) defines employees (measured in number of full-time employed), capital costs (measured in Australian $) and other costs (measured in Australian $) as input and terminal passengers (measured in number of persons) and cargo (measured in tons) as output. Gillen and Lall (1997) specify two separate classes of services: the terminal services and movements. The outputs for the terminal services are number of passengers, and pounds of cargo whereas the inputs are defined by number of runways, number of gates, terminal area, number of employees, number of baggage collection bells, and number of public parking spots. The outputs for movements are air carrier movements, commuter movements. They use airport area, number of runways, runway area and number of employees as outputs. Referring to Pels (2001), terminal output is specified as PAX (total number of passengers) and aircraft movements and as inputs: terminal size, number of aircraft parking positions at the terminal, number of remote aircraft parking positions, number of check-in desks, and number of baggage claims.

In this article, the approach by Gillen and Lall has been adopted for the performance measurement of German airports and as verification and validation methods for the partial productivity indicators. Thus, there are two separate classes of services, and models for each are defined as:

Model 1a: Terminal Services	**Model 1b: Air traffic movements**
Outputs: Total PAX, Air freight (approx. by WLU) *Inputs:* No. of runways No. of gates Terminal Area (in m^2) No. of employees No. of baggage collection belts No. of public parking spots	*Outputs:* Air traffic movements *Inputs:* Airport area (in m^2) No. of runways Runway area (approx. by length of runway) No. of employees

Table 3: Estimated DEA Models

In both cases a Pooled DEA is estimated as the first step, which means that a pooled data set is assumed, so each observation is considered as an individual DMU[11] without taking into account the panel data structure. One frontier was estimated for the whole observation period without taking into account the technical change of the production process. This is motivated by relatively small data availability.

[11] An acronym for Decision Making Unit

Section III: Data

Time series cross-sectional data from 1998 to 2004 was used for calculation of partial indicators and the frontier check. Due to the aggregation of several airports into airport groups, sample sizes of cross sectional comparisons which include financial data are undesirably smaller than comparisons which analyze technical efficiency.

a.) Financial Data

The following data has been collected for the financial comparison:

Data	Airport Group	IATA Code/Codes
Total Operating Expenses Total Revenue Aeronautical Revenue Non-aeronautical revenue	Berliner Flughafen GmbH	TXL, THF, SXF
	Flughafen Bremen GmbH	BRE
	Flughafen Dortmund GmbH	DTM
	Flughafen Düsseldorf GmbH	DUS
	Fraport AG	FRA, HHN, HAJ, SCN
	Flughafen Hamburg GmbH	HAM
	Flughafen München GmbH	MUC
	Flughafen Nürnberg GmbH	NUE
	Flughafen Stuttgart GmbH	STR

Table 4: Financial Data

Immediately noticeable is the aggregation of Berlin Airports and airports which are partially owned by Fraport AG. This absence of individualized airport data results in discrepancies in methodology. The study then shifts towards an efficiency analysis of airports to an efficiency study between airports and airport groups. Fraport AG is the more problematic comparator between the two, attributable to its international involvement and engagement in other sectors. Unfortunately, the only cure for this is in the area of data ascertainment, and since the aim of this analysis is to obtain a first glance at the German airport industry, current data will suffice. Individualized data is necessary in order to compare efficiencies more fairly.

Other problems with annual reports include the airports' classification of airport activities. The definition of non-aviation can be disputed here, and changes in the definition can result in data shifts. This also addressed the need for disaggregated financial data in order to be able to identify core airport activities, distinguish between other activities, and make appropriate adjustments to the data.

In order to account for the price impact on annual figures, observations have been adjusted for inflation using the total German CPI from 1998 to 2004.

b.) Capacity Data

Technical data and specifications for 17 German international airports between 1998 and 2004 were collected. A short overview of input and output data and the sample is as follows:

Data	**Airport**	**IATA Code**
Outputs:	Bremen	BRE
Aircraft Movements	Dortmund	DTM
Passengers	Dresden	DRS
Work Load Units (WLU)	Düsseldorf	DUS
Cargo and Air Freight (in tons)	Frankfurt	FRA
Inputs:	Hamburg	HAM
No. of Gates	Hannover	HAJ
Terminal Size (in m^2)	Köln-Bonn	CGN
No. of Check-in counters	Leipzig	LEJ
Total Runways	München	MUC
Total Length of Runways (in m)	Nürnberg	NUE
Employees	Saarbrücken	SCN
	Stuttgart	STR
	Münster-Osnabrück	FMO
	Berlin Schönefeld	SXF
	Berlin Tegel	TXL
	Berlin Tempelhof	THF

Table 5: Capacity Data

A rough adjustment of employee data from each Berlin airport has been applied to improve labor productivity results. Total GlobeGround employees have been divided between each Berlin airport according to a weight determined by the total number of aircraft movements. Albeit a very rough adjustment, it will depict a more fair labor efficiency score in the results.

Section IV: Empirical Results - Partial Indicators

In this portion of the paper, the findings of the partial productivity analysis will be presented. The partial indicators calculated will be shown not only individually, but also averaged in order to examine the overall performance of the German airport industry. Afterwards, conclusions on labor productivity, capital productivity, and financial performance for individual airports will be made.

a.) Average German Performance

Average Performance of German Airports 98-04		
Indicator	FY 1998	FY 2004
WLU per Employee	4.76	5.11
Real Costs per WLU	17.61 €	19.51 €
Real Revenues per WLU	19.85 €	18.67 €
Real Aeronautical Revenues per WLU	12.78 €	11.28 €
Real Commercial Revenues per WLU	6.07 €	5.64 €
Aeronautical/Total Revenue (%)	63.85%	60.50%
Rev:Ex Ratio	1.16	1.06
PAX per Employee	4279.23	5000.34
Movements per Employee	113.58	93.51
Movements (000)/ Runway	65.48	63.58
PAX(000) per Gate	257.50	201.95
PAX/ SqM (Terminal Side)	110.04	90.44

Table 6: Average Performance of German Airports from 1998 to 2004

Table 6 shows the average performance of German airports in 1998 and 2004. A performance index for each indicator from 1998 to 2004 can be seen in figures 3 and 4. The first observation to be made here relates to cost and revenue efficiency. Since 1998, costs per WLU have increased and revenues per WLU remained stagnant until 2004 when the indicator fell to its lowest level. Cost efficiency saw one of its larger decreases between 2001 and 2002, perhaps attributable to increased security costs. Expansions in infrastructure at 6 major airports (CGN, DTM, DUS, FMO, SCN, and STR) have been made in the period between 1999 and 2001, which also could be the reason for the negative effect on cost efficiency. Pressure from low cost carriers on the airports to maintain relatively low levels of airport charges can also decrease revenue efficiency.

The share of revenue from aviation activities has also decreased. This is expected, due to a large orientation towards commercial activities from many airports as a means of other income.

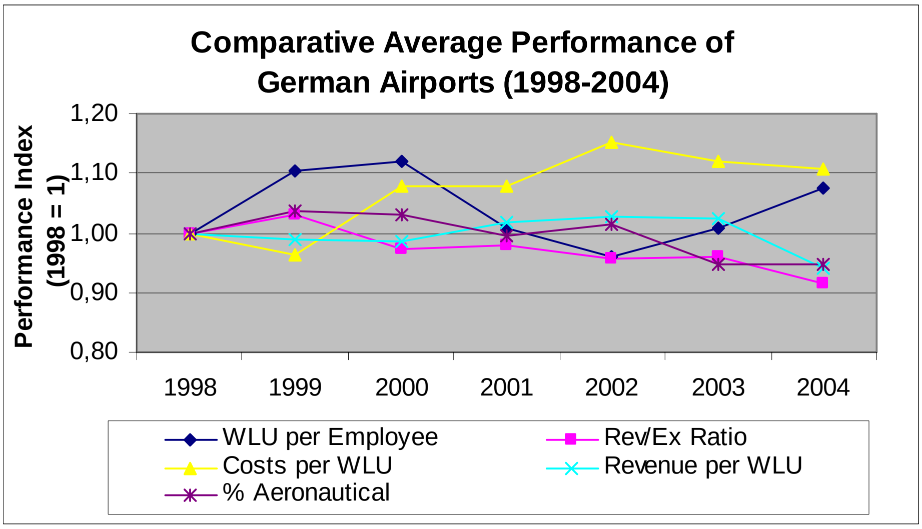

Figure 3: Comparative Average Performance of German Airports from 1998 to 2004

Distinct relationships can be discerned when looking at the average labor and capital productivity of German airports. For one, 2001 saw large decreases in labor and capital productivity, most notably in terminal efficiency. This is attributable to the terminal expansions mentioned before and a concurrent decrease in average PAX at German airports, decreasing from 8,447,477 in 2000 to just 8,000,758 in 2002.

Runway capacity has remained stable. LEJ was the only airport to expand its runway infrastructure during the sample time period.

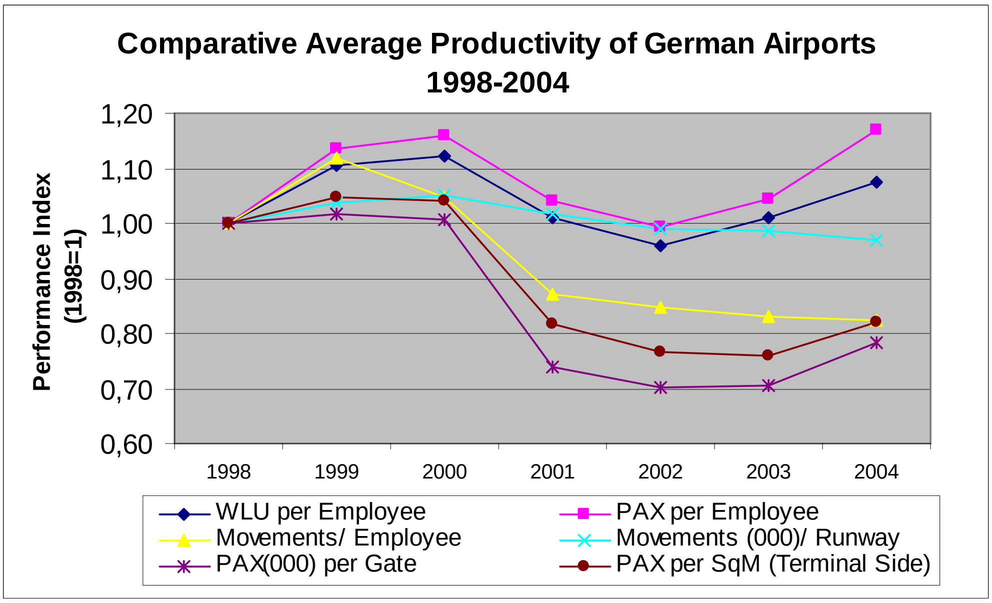

Figure 4: Comparative Average Productivity of German Airports from 1998 to 2004

Average Commercial Performance at German Airports for Fiscal Years 1998-2004							
	1998	1999	2000	2001	2002	2003	2004
Commercial Revenue per WLU (2000 terms)	6.07	5.52	5.63	6.28	6.03	6.34	5.64
% Aeronautical Revenue	63.85%	66.24%	65.82%	63.57%	64.69%	60.39%	60.50%

Table 7: Average Commercial Performance at German Airports from 1998 to 2004

Table 2 shows the average commercial performance of German airports. Although commercial revenue per unit of output has decreased from 6.07€ to 5.64€, the share of aeronautical revenue to total revenue has decreased from 63.85% to 60.50%.

b.) Average Financial Performance and Productivity by Size

Average Productivity of German Airports by Size 1998-2004		
Indicator	Small*	Other
WLU(000) per Employee	4.10	5.11
PAX per Employee	4158.78	5078.38
Movements per Employee	127.31	83.82
Movements(000) per Runway	33.02	95.77
PAX(000) per Gate	173.07	260.46
PAX per SqM (Terminal Side)	78.07	116.47

* Small < 3.000.000 PAX in 2001

Table 8: Average Productivity of German Airports by Size from 1998 to 2004

Scale economies are evident when comparing productivity between small and large German airports. However, the smaller German airports are more efficient in movements per employee (127.31 compared to 83.82), which means a higher degree of smaller aircraft and cargo related movements at smaller German airports. This, alongside a proportionately lower number of employees compared to larger airports provides for this number.

Table 4: Average Performance of German Airports by Size 1998-2004		
Indicator	Small*	Other
WLU(000) per Employee	4.10	5.11
Real Costs per WLU	24.79	16.80
Real Revenues per WLU	19.95	19.77
Real Aeronautical Revenues per WLU	11.83	12.86
Real Commercial Revenues per WLU	6.48	5.73
Aeronautical/Total Revenue (%)	59.87%	64.97%
Rev:Ex Ratio	0.90	1.20

* Small < 3.000.000 PAX in 2001

Table 9: Average Performance of German Airports by Size

Larger airports have been more cost efficient, most likely because of apparent scale economies. Cost efficiency is also better managed at larger airports, showing a significantly higher revenues to operating expenses ratio. Smaller airports show a stronger orientation towards non-aviation activities, which on average equalled roughly 40% of revenue from ’98 to ‘04 as opposed to 35% of revenue for larger airports.

c.) Individual Financial Performance

Individual growth rates for each indicator were calculated for every German airport using the compounded annual growth rate, or CAGR.

CAGR = (End Year/ Beginning Year)^(1/Time periods)

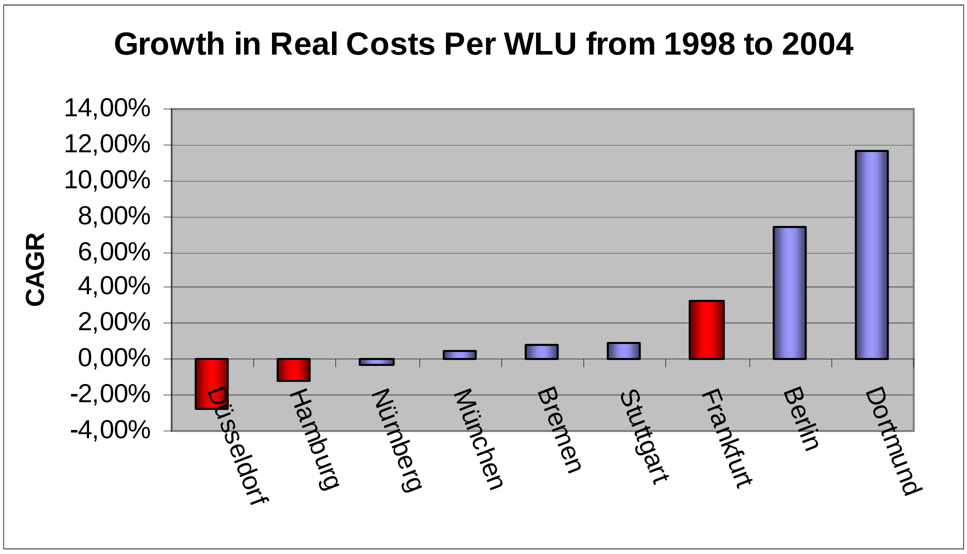

Figure 5: Growth in Real Costs per WLU for German Airports from 1998 to 2004

Cost efficiency has decreased for most airports, the worst case being DTM, which saw an increase in real costs per WLU of 11.27%. DUS and HAM, both of which have recently been partially privatized, saw a fair decrease of real costs per WLU of 2.74% and 1.17%, respectively.

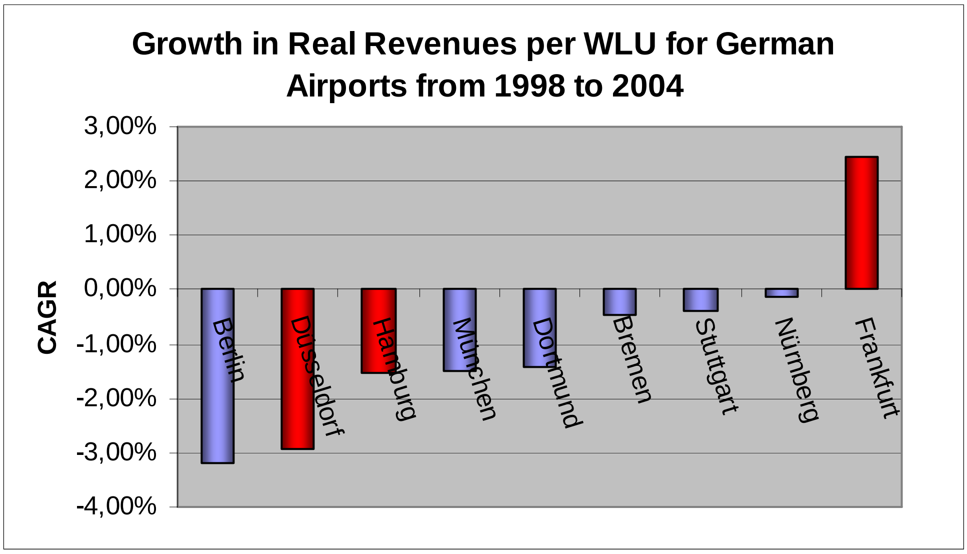

Figure 6: Growth in Real Revenues per WLU for German Airports from 1998 to 2004

Real revenues per WLU have also been decreasing at most German airports since 1998, however, not to a devastating degree. Worst case is Berlin Airports, with a decrease in revenue efficiency of 3.17%. Fraport AG has seen a marginal increase in real revenue of 2.43%. DUS and HAM have also shown negative revenue growth between 1998 and 2004 of -2.93% and -1.52%, respectively.

Observation of the revenue/expenses ratio yields results that concur with revenue and cost performance behavior. DTM saw the largest decrease in profitability.

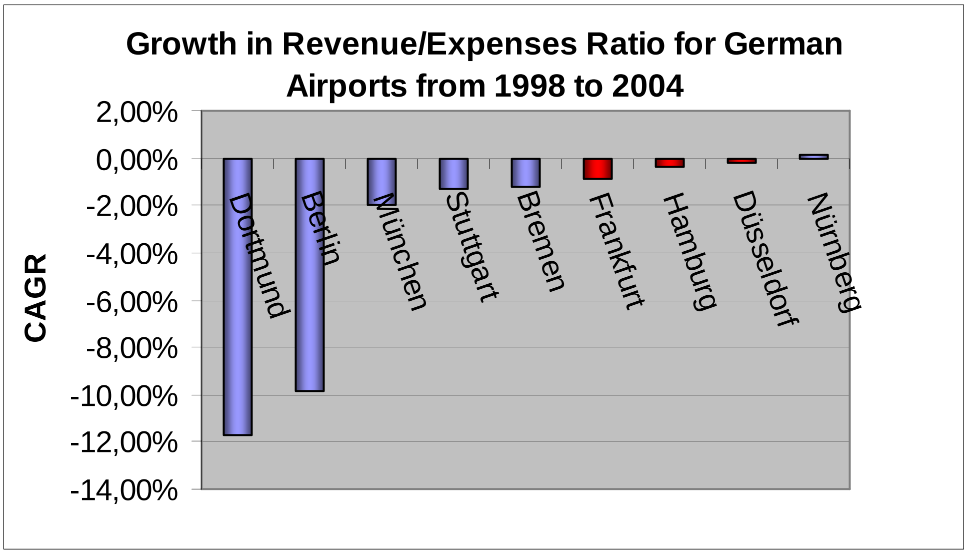

Figure 7: Growth in Revenue/Expenses Ration for German Airports from 1998 to 2004

Non-aviation performance of individual airports has also been considered. Figure 6 depicts levels of real commercial revenue per WLU for 1998, 2001, and 2004.

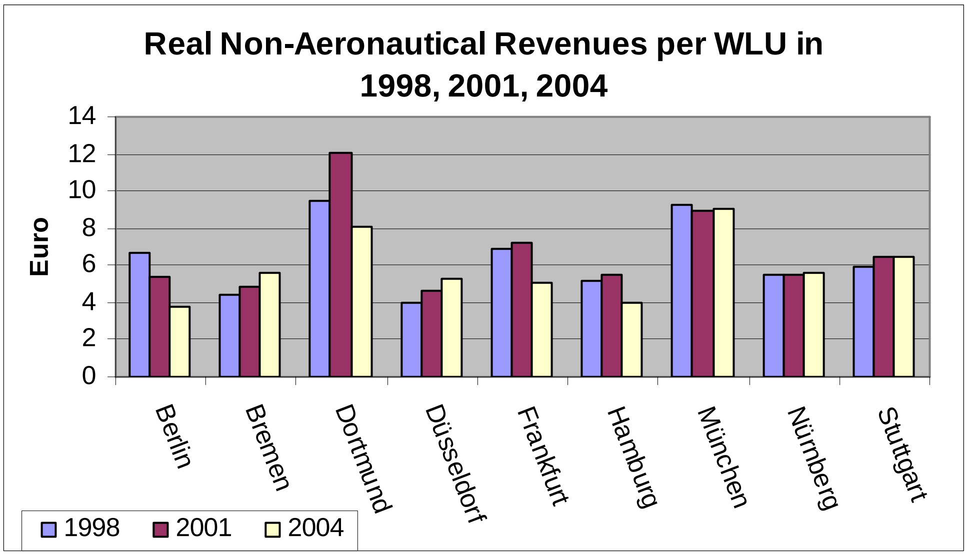

Figure 8: Real Non-Aeronautical Revenues per WLU in 1998, 2001, 2004

DTM is the surprising high performer, with MUC surpassing in 2004 in non aeronautical performance. Fraport's decline in non aeronautical performance is due to terminal upgrades associated with the fire code after the Düsseldorf fire. Large areas in the terminals were closed off for construction, dampening retail sales in the airport. HAM and Berlin Airports are the low performers in non aeronautical performance, both experiencing a decrease in 2004. This is due to the relatively small size of the airports (which hinders the availability of retail outlets) and the disproportionately high frequency of passengers which commute there. For example, at some gates in TXL, there is only about a 15 meter gap between the street and the gate.

d.) Labor Productivity

Labor efficiency does not seem to have a clear trend between different airport sizes according to Figure 7 underneath. For example, MUC has a relatively favorable efficiency score in relation to FRA, its closest competitor. STR and TXL seem to be clear winners in this category, although STR is more highly vertically integrated. Other German airports, such as BRE, DUS, and LEJ are close behind; however, improvements in efficiency at BRE and LEJ are mainly due to layoffs in 2002, and 2001, respectively.

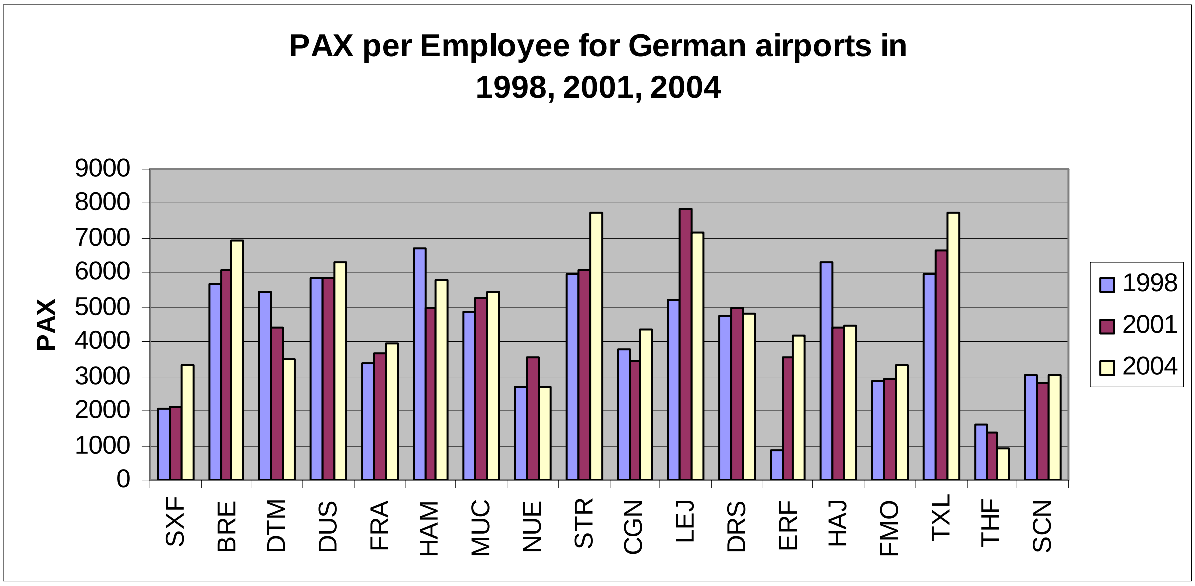

Figure 9: PAX per Employee for German Airports in 1998, 2001, 2004

Similar results can be observed in movements per employee. DTM is the clear winner though, due to the presence of merely 112 workers and total movements of 44,221 in 1998, yielding an impressive efficiency of 394.83 movements per worker. Fraport scores again very low in this category, with only 33.04 movements per worker in 1998 decreasing to 19.75 in 2004. Bremen, Stuttgart, and Leipzig again score very well.

Figure 10: Movements per Employee for German Airports in 1998, 2001, 2004

e.) Capital Productivity

German Airports have been expanding heavily in terminal capacity during the period from 1998 to 2004. In 2000 and 2001, terminal expansions were completed in CGN, DRS, DTM, DUS, FMO, SCN, and STR. MUC's introduction of its Terminal 2 in 2003 was also a notable expansion. Since these expansions were so recent and long term capacity levels have not been reached, a relative decrease in terminal capacity is to be expected, and is also observed. The only airport to conduct an expansion in runway capacity was LEJ, which opened a new runway in 2000.

1.) Runway Capacity

FRA, MUC, and STR are clear winners in runway capacity, with 3, 2, and 1 runway respectively. In 2004, MUC handled over 191,000 movements per runway while FRA achieved an average capacity of 159,000.

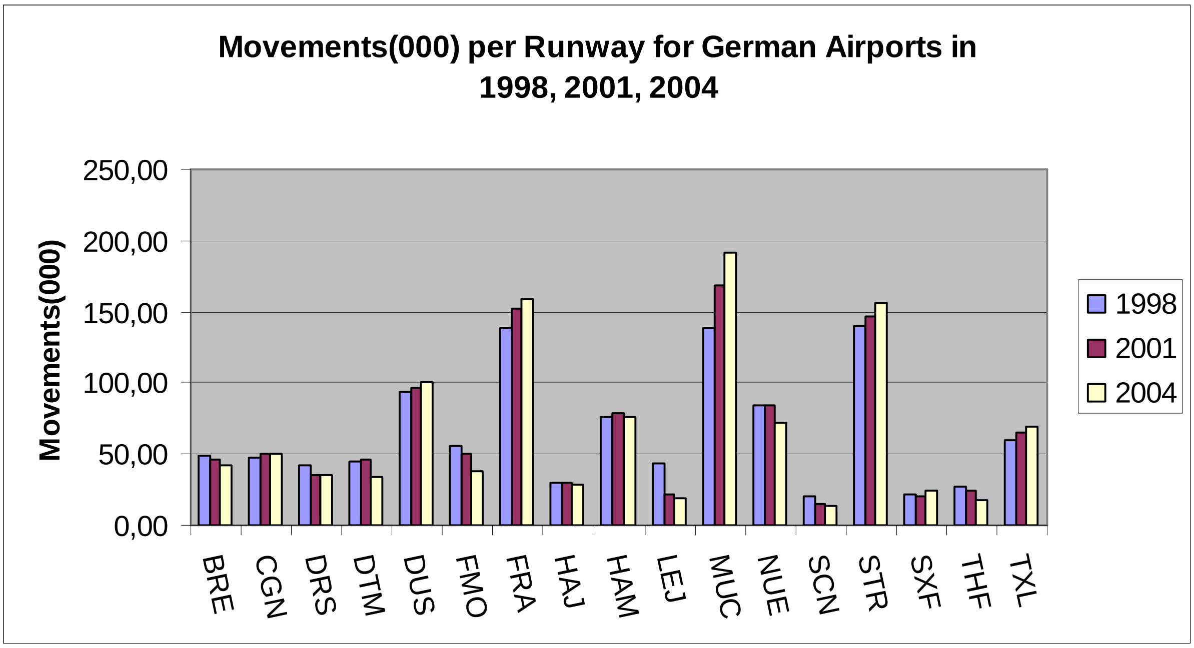

Figure 11: Movements (000) per Runway for German Airports in 1998, 2001, 2004

In terms of growth percentages (Figure 10), movements per runway at MUC, FRA, STR along with TXL have improved more favorably when compared to other German airports. Leipzig, the lone airport with a capacity expansion, bottoms out the group with -12.48% compounded growth from 1998 to 2004, with other notably bad performances by SCN (-6.66%), THF (-6.64%) and FMO (-6.01%).

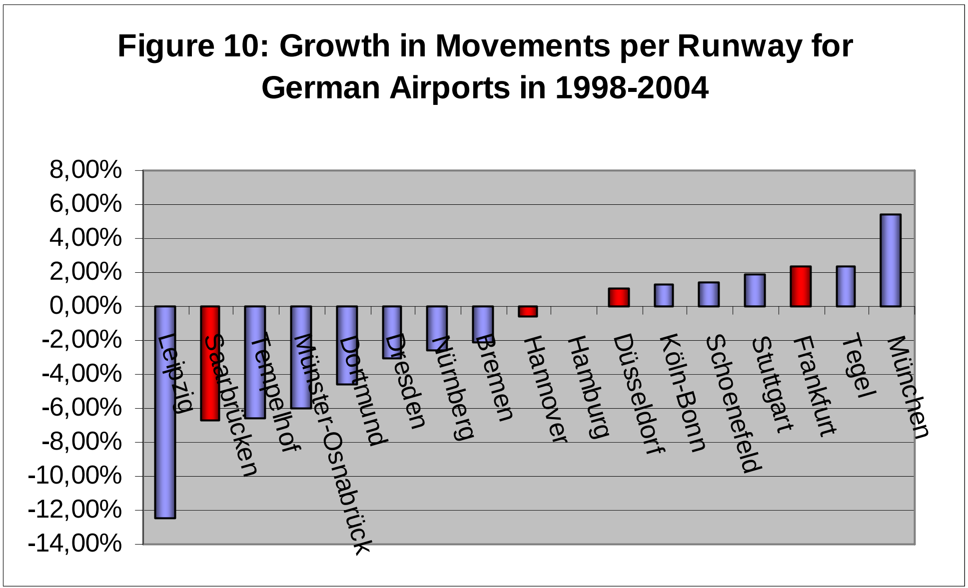

Figure 12: Growth in Movements per Runway for German Airports from 1998 to 2004

2.) Terminal Capacity

PAX per M^2 (terminal side) and PAX per gate were calculated to determine the efficiency of terminal usage. TXL is the clear winner for both categories, with its relatively small terminal and number of gates (18) but impressively large number of passengers (11,014,062 in 2004). It should be noted that the result for PAX per gate is somewhat misleading, since TXL also has 24 remote stands which were not included in the measurement. Inclusion still yields a very favorable efficiency score, and TXL also had the best result in PAX per M^2 (terminal side), with over 400 in 2004.

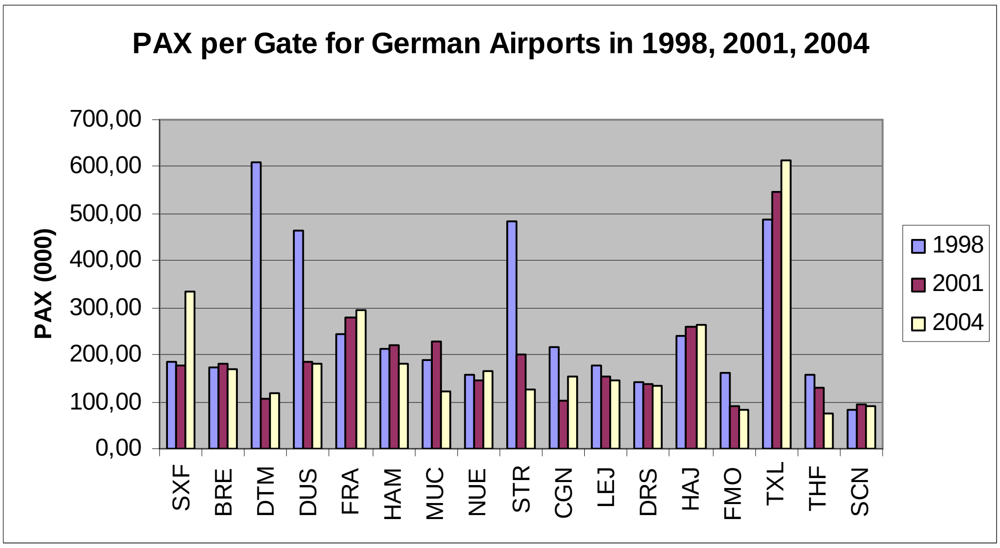

Figure 13: PAX per Gate for German Airports in 1998, 2001, 2004

In terms of PAX per gate, other high performers were SXF, FRA; and HAJ. Clear losers are FMO, THF, and DTM, where a decline in terminal capacity of 23.97% from 1998 to 2004 is apparent in the latter. The strongest growth was seen by SXF with an increase of 10.25% in PAX per gate, largely attributable to the emergence of LCCs such as Easyjet, Ryanair and Germanwings in Berlin in 2004.

A similar story can be told when referring to PAX per M^2 (terminal side), where TXL is again the clear winner, and large differences from the PAX per gate comparison are not present. The only notable observation is FRA's performance, which received 8th place after reaching 3rd for PAX per gate. Large decreases in PAX per M^2 can also be seen from 1998 to 2004. Twelve of eighteen airports showed a decrease in terminal capacity in this respect.

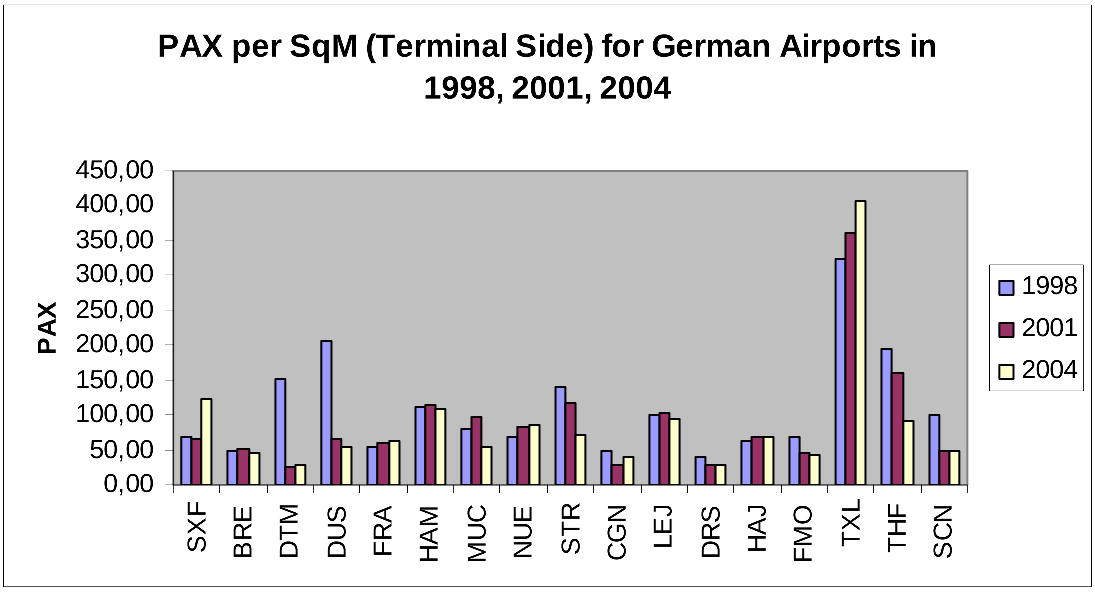

Figure 14: PAX per m^2 (Terminal Side) for German Airports in 1998, 2001, 2004

Section V: Empirical Results - Data Envelopment Analysis

The following analysis is divided into two broad sections. In the first section the technical efficiency of the terminal services of the German airports, consisting of six inputs, was measured(number of runways, number of gates, terminal area, number of employees, number of baggage collection bells, number of public parking spots) and two outputs (number of passengers, and pounds of cargo (approximated by WLU)). Subsequently, the technical efficiency with regards to airport movements including the use of one output was determined (air carrier movements) and 4 inputs (airport area, number of runways, runway area (approximated by length of runway) and number of employees). Unfortunately, DEA is only a method which depicts the inefficiencies of firms in the sample set. It does not give explanations as to why. Therefore, only the relative positions of firms will be presented, and explanations given where available. Further research is required to provide clarification as to the nature of the inefficiencies. The empirical results are presented in the following figures; the individual technical efficiency score under the different assumptions as well as the scale efficiency and returns to scale are summarized in Appendices B and C.

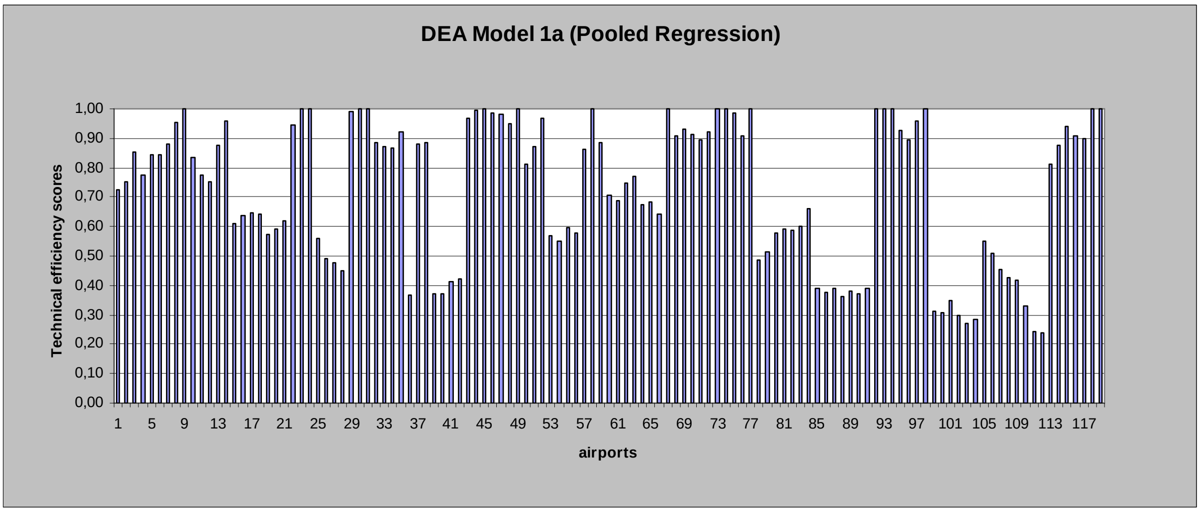

Figure 15: DEA Model 1a (Pooled DEA) – Terminal Services

Calculation of the Pearson Correlation Coefficient (0.711) shows a positive and significant relationship between the two models, which means that airports featuring a high efficiency score in terminal services also had relatively high performance measures with regard to aircraft movements, as one can see in Appendices B and C. The average efficiency for Model

1a is 72.4%. If one used the VRS specification of Model 1a instead, the efficiency scores would rise significantly, which can be explained by the fact that now airports of similar size are compared with each other, and not with the best ones in the sample. With VRS, the average efficiency increases to 83.3%. For individual firms, this improvement is significantly higher, in particular for the smaller airports. Under a CRS assumption for Model 1b, average technical efficiency equates 64%, as opposed to an average of 83% with a VRS postulation.

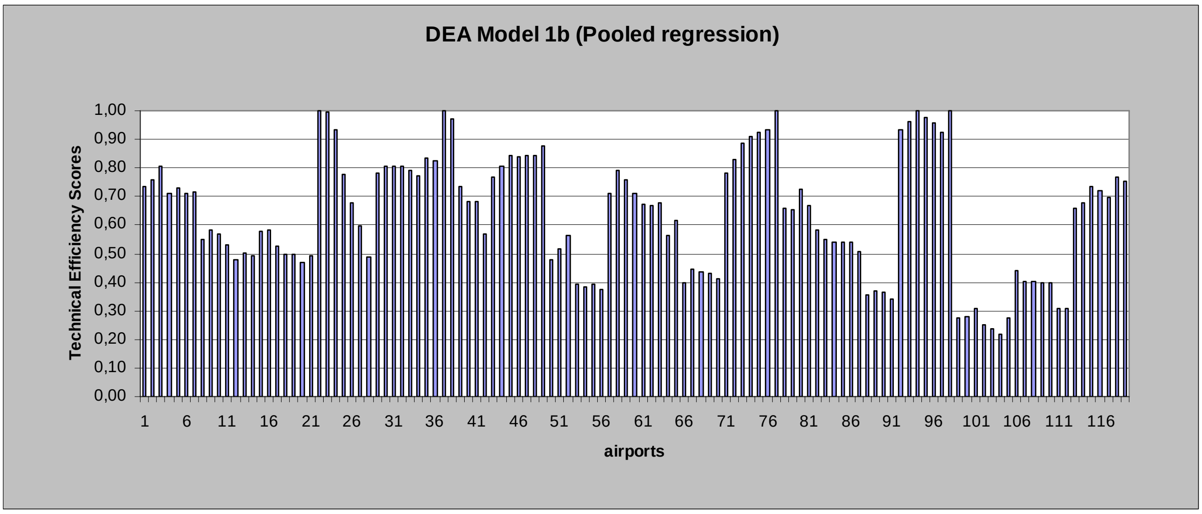

Figure 16: DEA Model 1b (Pooled DEA) – Aircraft Movements

a.) Terminal Services

Technical efficiency for terminal services increased at BRE, LEJ, NUE, SXF, and TXL between 1998 and 2004. The only airport of the four with an expansion in infrastructure was LEJ (runway), but the large increase in efficiency there is due to a decrease in employees in 2001 (from 459 to 277), subsequently improving labor productivity. BRE, LEJ, and NUE are operating under increasing returns to scale[12], which means they could increase their scale to achieve a higher amount of output per input. SXF is the only airport which has improved its technical efficiency (31% to 55%) but is operating on decreasing returns to scale. TXL has achieved 100% efficiency and lies on the CRS line. FRA, DUS, TXL and MUC are the most efficient airports in terms of terminal services in the sample, each of which showing a consistently high efficiency score for every year. Efficiency scores at THF, SCN, SXF and FMO have been consistently low.

[12] Please refer to Appendix B for a more detailed layout of DEA inefficiency scores and returns to scale in regards to terminal services

It appears that most German airports are operating under increasing returns to scale. CGN, DUS, HAM and SXF are operating under decreasing returns to scale, which is interesting because these airports have relatively different sizes and passenger structures. This makes the relationship between relative size and returns to scale still somewhat unclear.

b.) Air Traffic Movements

The technical efficiency of German airports with regards to air traffic movements behave slightly different when compared to terminal services. Only MUC and TXL have shown significant increases in technical efficiencies over the time period[13]. When analyzing returns to scale for MUC, one can see a convergence to the optimum productive scale size; a priori to its DRS rating in 2002, an IRS rating in 2003, and a scale efficiency of 1 in 2004. TXL has consistently run under IRS over the sample period, but differs different from MUC in terms of the relative size of the airports, again disallowing any conclusions based on returns to scale and relative size.

FRA and STR have shown a degree of growth in efficiency, but a more modest one when compared to MUC and TXL. FRA, however, shows a lower efficiency score in movements when compared to its results in terminal services (88% and 100%, respectively, in 2004), whereas STR's scores are more consistent with each other. FRA is also operating under decreasing returns to scale, while STR can increase its scale in order to reach its optimal productive scale size.

HAJ, LEJ, SCN, SXF and THF are the worst performers in the German airport industry with this output, achieving inefficiency scores consistently fewer than 50%. Each of these airports except for HAJ shows increasing returns to scale.

[13] Please refer to Appendix C for a more detailed layout of DEA inefficiency scores and returns to scale in regards to air traffic movements

Section VI: Conclusion

As mentioned earlier in the introduction, this analysis was meant to be the initial phase in partial factor calculation and comparison in the context of the German airport industry. Initial results verified with frontier comparisons have shown that FRA, MUC, STR, and TXL are the most technically efficient German airports. In terms of financial health, most of the airports in the sample performed poorly, many of which just barely managed to cover operating costs. However, it is important to remember that partial factor methodology and DEA are only relative measures, and do not provide conclusions based on absolute efficiency.[14]

Since the larger German airports included in benchmarking studies of ATRS and TRL received unfavorable efficiency scores, and these same airports operated more efficiently in the German context, then by the transitive property are German international airports indeed inefficient when compared to other airport industries.

a.) Future Considerations

First, in order to pursue more concise research in the area of German airport efficiency, disaggregated financial data and comprehensive information on airport activities is needed in order to identify core airport activities and to construct relevant criteria for data comparison. This would in turn allow for comparison of airports at the same level, subsequently increasing the credibility of the conclusions. Also, detailed analysis will allow a finer scope to be calibrated, whereby problem areas could perhaps be identified and best practices integrated.

Second, inclusion of non-German international airports (large and small) in the sample should also be considered. This will allow the efficient frontier to reflect a.) a more accurate depiction of German airport inefficiency through comparison with their European counterparts, and b.) a ranking of German airports in a European context. Also, an analysis of relatively efficient airports with similarly structured inefficient competitors could perhaps allow best practices to be pinpointed.

[14] Partial measures based on output/input comparisons are considered relative measures, however, measures such as the Revenues/Expenses ratio allow for absolute comparisons. In this case, R/E = 1 is the break-even point for firms when interest and tax obligations are not considered.

In terms of methodological considerations, airport cost function estimation will be attempted and Stochastic Frontier Analysis will be applied in order to determine the specific impact of input factors. This isolation will help explain the behavior of airport inefficiencies in contrast to the non-parametric DEA approach. Distance function estimation is also a consideration and may follow as a parametric approach with multiple dependent variables.

This analysis is merely the tip of the iceberg in terms of understanding the inefficiencies and poor performance of German airports. Further research is necessary in order to identify reasons *why* German airports have performed so poorly.

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Appendix A: Partial Indicators – Financial Performance

Airport	IATA and Year	Real Costs Per WLU	Real Revenues per WLU	Real Aeronautical Revenues per WLU	Real Commercial Revenues per WLU	Aeronautical/Total Revenue (%)	Revenue/Expenses Ratio
Bremen	BRE-1998	15.562	20.273	15.056	4.464	74.27%	1.303
	BRE-1999	16.613	20.421	15.182	4.457	74.35%	1.229
	BRE-2000	16.041	20.106	15.024	4.276	74.72%	1.253
	BRE-2001	15.497	20.043	14.288	4.800	71.29%	1.293
	BRE-2002	16.443	21.096	14.911	5.181	70.68%	1.283
	BRE-2003	18.426	21.746	14.579	5.855	67.04%	1.180
	BRE-2004	16.327	19.736	13.422	5.633	68.01%	1.209
Köln Bonn	CGN-1999	14.843	17.751	13.359	3.746	75.26%	1.196
	CGN-2000	14.994	17.088	12.973	3.623	75.92%	1.140
	CGN-2001	14.466	17.555	13.042	3.940	74.29%	1.214
	CGN-2002	13.769	16.678	12.327	3.825	73.91%	1.211
	CGN-2003	13.238	15.844	11.991	3.489	75.68%	1.197
	CGN-2004	12.124	14.931	11.177	3.364	74.86%	1.232
Dortmund	DTM-1998	20.132	17.951	7.026	9.467	39.14%	0.892
	DTM-1999	23.826	20.204	7.142	9.622	35.35%	0.848
	DTM-2000	28.945	20.665	7.336	10.532	35.50%	0.714
	DTM-2001	30.941	23.017	8.547	12.042	37.13%	0.744
	DTM-2002	38.281	23.087	8.287	11.988	35.89%	0.603
	DTM-2003	38.949	21.942	8.040	11.190	36.64%	0.563
	DTM-2004	39.040	16.487	5.503	8.086	33.38%	0.422
Düsseldorf	DUS-1998	14.858	17.697	12.508	4.025	70.68%	1.191
	DUS-1999	13.997	17.933	12.897	3.924	71.92%	1.281
	DUS-2000	13.852	18.009	12.979	3.895	72.07%	1.300
	DUS-2001	14.630	18.502	13.176	4.663	71.21%	1.265
	DUS-2002	15.254	18.795	12.945	5.240	68.87%	1.232
	DUS-2003	16.189	18.887	12.908	5.414	68.35%	1.167
	DUS-2004	12.575	14.808	8.749	5.293	59.08%	1.178
Fraport	FRA -1998	19.734	24.087	15.711	6.942	65.23%	1.221
	FRA -1999	18.907	23.442	17.621	5.580	75.17%	1.240
	FRA -2000	19.491	24.558	17.920	5.932	72.97%	1.260
	FRA -2001	21.450	26.160	18.229	7.165	69.68%	1.220
	FRA -2002	24.060	28.585	20.996	6.448	73.45%	1.188
	FRA -2003	25.111	28.277	16.623	5.465	58.79%	1.126
	FRA -2004	23.998	27.826	16.805	5.091	60.40%	1.159
Hamburg	HAM-1998	12.839	20.128	14.386	5.146	71.48%	1.568
	HAM-1999	12.234	19.507	13.825	5.009	70.87%	1.595
	HAM-2000	13.280	19.202	13.222	5.002	68.86%	1.446
	HAM-2001	14.451	19.218	12.668	5.485	65.92%	1.330
	HAM-2002	13.770	19.323	12.502	5.760	64.70%	1.403
	HAM-2003	12.676	18.267	11.752	4.285	64.34%	1.441
	HAM-2004	11.961	18.363	11.895	4.037	64.77%	1.535

Airport	IATA and Year	Real Costs Per WLU	Real Revenues per WLU	Real Aeronautical Revenues per WLU	Real Commercial Revenues per WLU	Aeronautical/Total Revenue (%)	Revenue/Expenses Ratio
Leipzig	LEJ-1998	22.274	18.704	14.308	3.307	76.50%	0.840
	LEJ-1999	18.470	18.685	14.255	3.238	76.29%	1.012
	LEJ-2000	35.733	19.143	14.310	3.706	74.75%	0.536
	LEJ-2001	29.725	19.714	13.582	4.718	68.90%	0.663
	LEJ-2002	29.691	16.031	14.050	0.528	87.65%	0.540
München	MUC-1998	20.439	23.627	13.751	9.220	58.20%	1.156
	MUC-1999	20.027	22.867	13.443	8.959	58.79%	1.142
	MUC-2000	19.786	22.103	13.075	8.679	59.16%	1.117
	MUC-2001	19.835	22.478	13.018	8.962	57.92%	1.133
	MUC-2002	20.516	22.599	12.907	8.979	57.11%	1.102
	MUC-2003	22.970	23.263	12.231	9.913	52.58%	1.013
	MUC-2004	21.033	21.579	11.699	8.999	54.22%	1.026
Nürnberg	NUE-1998	16.408	21.028	13.677	5.492	65.04%	1.282
	NUE-1999	16.965	21.520	13.595	5.994	63.17%	1.268
	NUE-2000	15.832	21.034	13.635	5.608	64.82%	1.329
	NUE-2001	15.998	20.145	12.692	5.499	63.00%	1.259
	NUE-2002	16.140	20.803	13.196	5.552	63.43%	1.289
	NUE-2003	16.752	20.739	12.858	5.711	62.00%	1.238
	NUE-2004	16.151	20.880	13.002	5.605	62.27%	1.293
Stuttgart	STR-1998	21.190	20.947	14.612	5.968	69.76%	0.989
	STR-1999	20.494	20.213	13.933	5.691	68.93%	0.986
	STR-2000	20.577	20.880	13.429	5.784	64.32%	1.015
	STR-2001	20.624	21.008	13.885	6.493	66.09%	1.019
	STR-2002	23.814	21.969	14.284	7.095	65.02%	0.923
	STR-2003	21.406	21.541	13.465	6.999	62.51%	1.006
	STR-2004	22.436	20.450	13.174	6.466	64.42%	0.912
Berlin Airports	BER-1998	12.620	14.097	6.792	6.640	48.18%	1.117
	BER-1999	10.148	13.083	7.655	5.312	58.51%	1.289
	BER-2000	10.217	12.750	7.763	4.866	60.89%	1.248
	BER-2001	10.991	14.293	7.698	5.346	53.86%	1.300
	BER-2002	11.135	15.597	7.939	5.720	50.90%	1.401
	BER-2003	11.235	12.971	7.257	5.102	55.95%	1.155
	BER-2004	19.425	11.619	7.385	3.780	63.56%	0.598
German Average	Avg-1998	17.606	19.854	12.783	6.067	63.85%	1.156
	Avg-1999	16.957	19.602	12.992	5.594	66.24%	1.190
	Avg-2000	18.977	19.594	12.879	5.628	65.82%	1.123
	Avg-2001	18.964	20.194	12.802	6.283	63.57%	1.131
	Avg-2002	20.261	20.415	13.122	6.029	64.69%	1.107
	Avg-2003	19.695	20.348	12.170	6.342	60.39%	1.109
	Avg-2004	19.507	18.668	11.281	5.635	60.50%	1.056

Appendix B: DEA Model 1a

Airport	Year	DMU	Technical Efficiency Score (CRS)	Technical Efficiency Score (VRS)	Scale Efficiency	Returns to Scale
Bremen	BRE-1998	1	0,72	0,85	0,85	irs
	BRE-1999	2	0,75	0,89	0,85	irs
	BRE-2000	3	0,85	1,00	0,86	irs
	BRE-2001	4	0,78	0,91	0,85	irs
	BRE-2002	5	0,84	0,97	0,87	irs
	BRE-2003	6	0,85	0,96	0,88	irs
	BRE-2004	7	0,88	1,00	0,88	irs
Köln-Bonn	CGN-1998	8	0,95	1,00	0,96	irs
	CGN-1999	9	1,00	1,00	1,00	-
	CGN-2000	10	0,84	0,86	0,98	drs
	CGN-2001	11	0,77	0,80	0,97	drs
	CGN-2002	12	0,75	0,78	0,97	drs
	CGN-2003	13	0,87	0,91	0,96	drs
	CGN-2004	14	0,96	1,00	0,96	drs
Dresden	DRS-1998	15	0,61	0,98	0,62	irs
	DRS-1999	16	0,64	1,00	0,64	irs
	DRS-2000	17	0,65	1,00	0,65	irs
	DRS-2001	18	0,64	0,86	0,75	irs
	DRS-2002	19	0,58	0,78	0,74	irs
	DRS-2003	20	0,59	0,80	0,74	irs
	DRS-2004	21	0,62	0,84	0,74	irs
Dortmund	DTM-1998	22	0,94	1,00	0,94	irs
	DTM-1999	23	1,00	1,00	1,00	-
	DTM-2000	24	1,00	1,00	1,00	-
	DTM-2001	25	0,56	0,64	0,87	irs
	DTM-2002	26	0,49	0,56	0,87	irs
	DTM-2003	27	0,48	0,55	0,86	irs
	DTM-2004	28	0,45	0,54	0,84	irs
Düsseldorf	DUS-1998	29	0,99	0,99	1,00	-
	DUS-1999	30	1,00	1,00	1,00	-
	DUS-2000	31	1,00	1,00	1,00	-
	DUS-2001	32	0,89	0,93	0,96	drs
	DUS-2002	33	0,87	0,92	0,95	drs
	DUS-2003	34	0,87	0,92	0,94	drs
	DUS-2004	35	0,92	0,98	0,94	drs
Münster-Osnabrück	FMO-1998	36	0,37	0,46	0,80	irs
	FMO-1999	37	0,88	1,00	0,88	irs
	FMO-2000	38	0,88	1,00	0,88	irs
	FMO-2001	39	0,37	0,43	0,87	irs
	FMO-2002	40	0,37	0,42	0,88	irs
	FMO-2003	41	0,41	0,46	0,90	irs
	FMO-2004	42	0,42	0,47	0,90	irs
Frankfurt	FRA -1998	43	0,97	0,98	0,99	drs
	FRA -1999	44	0,99	1,00	0,99	drs
	FRA -2000	45	1,00	1,00	1,00	-
	FRA -2001	46	0,98	0,98	1,00	-
	FRA -2002	47	0,98	0,98	1,00	-
	FRA -2003	48	0,95	0,95	1,00	-
	FRA -2004	49	1,00	1,00	1,00	-
Hannover	HAJ-1998	50	0,81	0,81	1,00	irs
	HAJ-1999	51	0,87	0,88	1,00	irs
	HAJ-2000	52	0,97	0,97	1,00	irs
	HAJ-2001	53	0,57	0,57	1,00	-
	HAJ-2002	54	0,55	0,55	1,00	-
	HAJ-2003	55	0,60	0,60	1,00	-
	HAJ-2004	56	0,58	0,58	1,00	-
Hamburg	HAM-1998	57	0,86	0,87	0,99	drs
	HAM-1999	58	1,00	1,00	1,00	-
	HAM-2000	59	0,89	0,90	0,98	drs
	HAM-2001	60	0,71	0,72	0,98	drs
	HAM-2002	61	0,69	0,71	0,97	drs
	HAM-2003	62	0,75	0,77	0,97	drs
	HAM-2004	63	0,77	0,80	0,96	drs

Airport	Year	DMU	Technical Efficiency Score (CRS)	Technical Efficiency Score (VRS)	Scale Efficiency	Returns to Scale
Leipzig	LEJ-1998	64	0,67	1,00	0,67	irs
	LEJ-1999	65	0,68	1,00	0,68	irs
	LEJ-2000	66	0,64	0,81	0,79	irs
	LEJ-2001	67	1,00	1,00	1,00	-
	LEJ-2002	68	0,91	0,91	1,00	irs
	LEJ-2003	69	0,93	0,96	0,97	irs
	LEJ-2004	70	0,91	0,92	0,99	irs
München	MUC-1998	71	0,90	0,90	0,99	irs
	MUC-1999	72	0,92	0,92	1,00	-
	MUC-2000	73	1,00	1,00	1,00	-
	MUC-2001	74	1,00	1,00	1,00	-
	MUC-2002	75	0,99	0,99	1,00	irs
	MUC-2003	76	0,91	0,91	1,00	drs
	MUC-2004	77	1,00	1,00	1,00	-
Nürnberg	NUE-1998	78	0,49	1,00	0,49	irs
	NUE-1999	79	0,51	1,00	0,51	irs
	NUE-2000	80	0,58	1,00	0,58	irs
	NUE-2001	81	0,59	0,97	0,61	irs
	NUE-2002	82	0,59	0,90	0,65	irs
	NUE-2003	83	0,60	0,92	0,65	irs
	NUE-2004	84	0,66	1,00	0,66	irs
Saarbrücken	SCN-1998	85	0,39	1,00	0,39	irs
	SCN-1999	86	0,37	0,82	0,45	irs
	SCN-2000	87	0,39	0,71	0,55	irs
	SCN-2001	88	0,36	0,61	0,59	irs
	SCN-2002	89	0,38	0,62	0,61	irs
	SCN-2003	90	0,37	0,61	0,61	irs
	SCN-2004	91	0,39	0,64	0,61	irs
Stuttgart	STR-1998	92	1,00	1,00	1,00	-
	STR-1999	93	1,00	1,00	1,00	-
	STR-2000	94	1,00	1,00	1,00	-
	STR-2001	95	0,93	0,94	0,99	irs
	STR-2002	96	0,90	0,90	1,00	-
	STR-2003	97	0,96	0,98	0,98	irs
	STR-2004	98	1,00	1,00	1,00	-
Schönefeld	SXF-1998	99	0,31	0,32	0,99	drs
	SXF-1999	100	0,31	0,31	1,00	-
	SXF-2000	101	0,35	0,35	1,00	-
	SXF-2001	102	0,30	0,30	1,00	drs
	SXF-2002	103	0,27	0,27	1,00	-
	SXF-2003	104	0,29	0,29	0,99	drs
	SXF-2004	105	0,55	0,55	0,99	drs
Tempelhof	THF-1998	106	0,51	1,00	0,51	irs
	THF-1999	107	0,45	0,90	0,50	irs
	THF-2000	108	0,43	0,86	0,50	irs
	THF-2001	109	0,42	0,85	0,49	irs
	THF-2002	110	0,33	0,69	0,48	irs
	THF-2003	111	0,25	0,52	0,47	irs
	THF-2004	112	0,24	0,53	0,45	irs
Tegel	TXL-1998	113	0,81	0,81	1,00	-
	TXL-1999	114	0,88	0,88	1,00	-
	TXL-2000	115	0,94	0,94	1,00	-
	TXL-2001	116	0,91	0,91	1,00	-
	TXL-2002	117	0,90	0,90	1,00	-
	TXL-2003	118	1,00	1,00	1,00	-
	TXL-2004	119	1,00	1,00	1,00	-
		mean	0,72	0,83	0,87	

Appendix C: DEA Model 1b

Airport	Year	DMU	Technical Efficiency Score (CRS)	Technical Efficiency Score (VRS)	Scale Efficiency	Returns to Scale
Bremen	BRE-1998	1	0,73	1,00	0,73	irs
	BRE-1999	2	0,76	1,00	0,76	irs
	BRE-2000	3	0,80	1,00	0,80	irs
	BRE-2001	4	0,71	1,00	0,71	irs
	BRE-2002	5	0,73	1,00	0,73	irs
	BRE-2003	6	0,71	1,00	0,71	irs
	BRE-2004	7	0,72	1,00	0,72	irs
Köln-Bonn	CGN-1998	8	0,55	0,70	0,79	drs
	CGN-1999	9	0,58	0,75	0,78	drs
	CGN-2000	10	0,57	0,71	0,80	drs
	CGN-2001	11	0,53	0,65	0,82	drs
	CGN-2002	12	0,48	0,56	0,86	drs
	CGN-2003	13	0,50	0,59	0,86	drs
	CGN-2004	14	0,49	0,57	0,86	drs
Dresden	DRS-1998	15	0,58	1,00	0,58	irs
	DRS-1999	16	0,58	1,00	0,58	irs
	DRS-2000	17	0,53	1,00	0,53	irs
	DRS-2001	18	0,50	1,00	0,50	irs
	DRS-2002	19	0,50	1,00	0,50	irs
	DRS-2003	20	0,47	1,00	0,47	irs
	DRS-2004	21	0,49	1,00	0,49	irs
Dortmund	DTM-1998	22	1,00	1,00	1,00	-
	DTM-1999	23	1,00	1,00	1,00	irs
	DTM-2000	24	0,93	1,00	0,93	irs
	DTM-2001	25	0,78	1,00	0,78	irs
	DTM-2002	26	0,68	1,00	0,68	irs
	DTM-2003	27	0,60	1,00	0,60	irs
	DTM-2004	28	0,49	1,00	0,49	irs
Düsseldorf	DUS-1998	29	0,78	0,90	0,87	drs
	DUS-1999	30	0,81	0,95	0,85	drs
	DUS-2000	31	0,81	0,95	0,85	drs
	DUS-2001	32	0,81	0,94	0,85	drs
	DUS-2002	33	0,79	0,92	0,86	drs
	DUS-2003	34	0,77	0,89	0,88	drs
	DUS-2004	35	0,83	1,00	0,83	drs
Münster-Osnabrück	FMO-1998	36	0,83	1,00	0,83	irs
	FMO-1999	37	1,00	1,00	1,00	-
	FMO-2000	38	0,97	1,00	0,97	irs
	FMO-2001	39	0,74	1,00	0,74	irs
	FMO-2002	40	0,68	1,00	0,68	irs
	FMO-2003	41	0,68	1,00	0,68	irs
	FMO-2004	42	0,57	1,00	0,57	irs
Frankfurt	FRA -1998	43	0,77	0,86	0,89	drs
	FRA -1999	44	0,81	0,94	0,86	drs
	FRA -2000	45	0,84	1,00	0,84	drs
	FRA -2001	46	0,84	0,99	0,85	drs
	FRA -2002	47	0,84	0,96	0,88	drs
	FRA -2003	48	0,84	0,95	0,88	drs
	FRA -2004	49	0,88	1,00	0,88	drs
Hannover	HAJ-1998	50	0,48	0,66	0,73	drs
	HAJ-1999	51	0,52	0,75	0,69	drs
	HAJ-2000	52	0,56	0,86	0,65	drs
	HAJ-2001	53	0,39	0,44	0,89	drs
	HAJ-2002	54	0,39	0,43	0,90	drs
	HAJ-2003	55	0,39	0,45	0,89	drs
	HAJ-2004	56	0,38	0,41	0,92	drs
Hamburg	HAM-1998	57	0,71	0,80	0,89	drs
	HAM-1999	58	0,79	0,94	0,84	drs
	HAM-2000	59	0,76	0,87	0,87	drs
	HAM-2001	60	0,71	0,72	0,99	drs
	HAM-2002	61	0,67	0,68	1,00	irs
	HAM-2003	62	0,67	0,67	1,00	irs
	HAM-2004	63	0,68	0,68	1,00	irs

Airport	Year	DMU	Technical Efficiency Score (CRS)	Technical Efficiency Score (VRS)	Scale Efficiency	Returns to Scale
Leipzig	LEJ-1998	64	0,57	1,00	0,57	irs
	LEJ-1999	65	0,61	1,00	0,61	irs
	LEJ-2000	66	0,40	0,50	0,80	irs
	LEJ-2001	67	0,45	0,50	0,89	irs
	LEJ-2002	68	0,43	0,50	0,87	irs
	LEJ-2003	69	0,43	0,50	0,86	irs
	LEJ-2004	70	0,41	0,50	0,82	irs
München	MUC-1998	71	0,78	0,81	0,97	drs
	MUC-1999	72	0,83	0,87	0,96	drs
	MUC-2000	73	0,89	0,96	0,93	drs
	MUC-2001	74	0,91	0,94	0,97	drs
	MUC-2002	75	0,92	0,94	0,98	drs
	MUC-2003	76	0,93	0,94	0,99	irs
	MUC-2004	77	1,00	1,00	1,00	-
Nürnberg	NUE-1998	78	0,66	1,00	0,66	irs
	NUE-1999	79	0,65	1,00	0,65	irs
	NUE-2000	80	0,72	1,00	0,72	irs
	NUE-2001	81	0,67	1,00	0,67	irs
	NUE-2002	82	0,58	1,00	0,58	irs
	NUE-2003	83	0,55	1,00	0,55	irs
	NUE-2004	84	0,54	1,00	0,54	irs
Saarbrücken	SCN-1998	85	0,54	1,00	0,54	irs
	SCN-1999	86	0,54	1,00	0,54	irs
	SCN-2000	87	0,51	1,00	0,51	irs
	SCN-2001	88	0,36	1,00	0,36	irs
	SCN-2002	89	0,37	1,00	0,37	irs
	SCN-2003	90	0,37	1,00	0,37	irs
	SCN-2004	91	0,34	1,00	0,34	irs
Stuttgart	STR-1998	92	0,93	1,00	0,93	irs
	STR-1999	93	0,96	1,00	0,96	irs
	STR-2000	94	1,00	1,00	1,00	-
	STR-2001	95	0,98	1,00	0,98	irs
	STR-2002	96	0,96	1,00	0,96	irs
	STR-2003	97	0,92	1,00	0,92	irs
	STR-2004	98	1,00	1,00	1,00	-
Schönefeld	SXF-1998	99	0,27	0,50	0,55	irs
	SXF-1999	100	0,28	0,50	0,56	irs
	SXF-2000	101	0,31	0,50	0,61	irs
	SXF-2001	102	0,25	0,50	0,51	irs
	SXF-2002	103	0,24	0,50	0,47	irs
	SXF-2003	104	0,22	0,50	0,44	irs
	SXF-2004	105	0,28	0,50	0,55	irs
Tempelhof	THF-1998	106	0,44	0,50	0,89	irs
	THF-1999	107	0,40	0,50	0,81	irs
	THF-2000	108	0,41	0,50	0,81	irs
	THF-2001	109	0,40	0,50	0,80	irs
	THF-2002	110	0,40	0,50	0,80	irs
	THF-2003	111	0,31	0,50	0,62	irs
	THF-2004	112	0,31	0,50	0,62	irs
Tegel	TXL-1998	113	0,66	0,68	0,97	irs
	TXL-1999	114	0,68	0,70	0,97	irs
	TXL-2000	115	0,74	0,75	0,98	irs
	TXL-2001	116	0,72	0,73	0,98	irs
	TXL-2002	117	0,70	0,71	0,98	irs
	TXL-2003	118	0,77	0,78	0,99	irs
	TXL-2004	119	0,76	0,77	0,99	irs
		mean	0,64	0,83	0,77	