ECONOMIES OF SCALE AND SCOPE OF AIRPORTS – A CRITICAL SURVEY

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ABSTRACT

The question whether airports are natural monopolies has increasingly become an issue in studies on regulation, deregulation and privatization of airports. In particular it was questioned whether airports have market power at all and if this is due to economies of scale and scope. This paper provides an overview of studies on economies of scale and scope. It critically evaluates the method of data gathering during the studies and the resulting information uncovers some drawbacks of the studies and the data gathering process. It reaches the conclusion that the most studies on economies of scale are problematic in regard to the definition of "output", the treatment of capital and the exclusion of land side activities. Economies of scope have only been researched in the most recent studies. The study illustrates that the non-aviation business should be considered in more detail.

Keywords: Economies of scale and scope, DEA, econometric estimations cost functions, natural monopoly

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1. INTRODUCTION

The nature and breadth of economies of scale and scope are essential for airport economics, management and policy. Are airports public utilities because economies of scale and scope lead to a natural monopoly which needs to be publicly owned or regulated? Should airports (of which size) be subsidized to cover their high fixed costs? How many airports should there be in a region on narrow economic ground abstracting from environmental externalities? Will a region like Berlin gain if it closes two of its three airports and concentrate its traffic on one? Will new airports enter the market or does this not happen because of scale economies or because of planning restrictions? Is terminal competition feasible because economies of scope are limited? Can freight be separated from passenger traffic and the latter are split up in national and international traffic without any economic costs? Is the tendency to develop commercial activities only driven by demand complementarities or are there cost complementarities to be reaped as well? This list of questions can easily be extended, but it is already obvious that the nature and scope of economies of scale and scope are essential for all important problems of governance, regulation, planning, pricing and management of airports.

The importance is, however, negatively related to what textbooks and even a number of benchmarking studies say about these economies. The standard view (Button and Stough, 2000, Graham, 2008, Oum et. al. 2006, Doganis, 1992) has been that economies of scale run out at a level of three or five million passengers. This is surprisingly low as it would imply that there are hardly any barriers to entry other than legal and planning restrictions. Market entry could occur at regions serving six to ten million passengers so that, for example, most European airports face potential competition. Given the expected growth rates we would expect in the near future a wave of new entrants leading to a situation that in most cities and regions two or more airports will compete intensively making regulation obsolete. The EU directive on charges should then revert its threshold, that is, instead of regulating airports of more than five million it should regulate small regional airports in rural areas.

In this paper we challenge the standard view by critically reviewing the existing literature. We ask at what output level run out economies of scale? Do diseconomies occur at all? Do economies of scope exist and if so between which activities?

In reviewing the literature we will analyze how the studies model the airport. This is particularly important as the production process has changed over the period of research which begins in 1973. Researchers such as Graham (2008) have argued that the business focus of the airport has changed in the last decades. The non-aviation business including shopping centers and the use of the airport facilities for conferences etc. has grown to such a scale that today for many airports commercial revenues make up to 50 percent of the total revenue.

This paper is organized as follows: the first section we will concisely explain the concept of economies of scale and scope. In section two, we will describe the airport production process highlighting structural changes and inspect the deriving key processes which studies show should be accounted for in each case. In section 3, we will analyze several studies dedicated to the measurement of economies of scale and scope at the operational level of an airport. We will highlight potential drawbacks, differences and similarities concerning the definition of output, input, and costs of an airport. Finally, in the concluding section, we will sum up our findings and suggest areas of further research.

2. ECONOMIES OF SCALE AND SCOPE

Right from the outset it is important to distinguish between short run and long run economies of scale and scope as the paper is about the latter. In the short run at least one factor is fixed so that the firm cannot adjust as perfectly its production to changes in demand and other factors as the firm can in the long run. In the short run increasing demand might lead to economies of density, which is to decreasing average costs due to more intense capacity utilization. These have been estimated for airports by Gillen and Lall (1997) and by Pels et.al. (2010). Also, diseconomies resulting from airport congestion belong to the short-run theory of production (Janic and Stough, 2003). Thus short run decreasing average costs are caused by sharing fixed costs while long run costs are caused by indivisibilities.Economies of scope, on the other hand, can be obtained when the joint production of two or more goods saves cost compared to a separated production.

The differentiation between short-run and long-run is not linked to a certain time period but related to the existence of fixed input factors. In the short-run some kind of input factor is fixed and thus cannot easily be changed without investment. In the long-run every input factor is variable and no fixed factors exist (Nicholson and Snyder, 2007). Viner (1932) investigated the relationship between short-run and long-run average cost curves and showed that the long-run cost curve builds an envelope around several short-run cost curves. This indicates that the long-run average cost curve is tangential to the short-run average cost curves. Doganis (1992) applied this concept to the airport industry. Terminals and runways are in the short-run fixed input factors, thus cannot easily be changed. Increasing the number of runways the short-run cost curve shifts to the right, indicating lower average cost. In the long-run, when all factors are variable Doganis (op.cit.) predicted that in the case of an L-shaped cost curve the long-run cost curve is always tangential at the minimum of the short-run cost curve.

2.1 Indivisibility and its Results

The theory of perfect competition implies the existence of an atomistic market structure, with many suppliers and demanders who each have a relatively small market share. This includes a functioning market with infinite divisibility of input factors. However, many markets are marked by a concentration on the supply side, sometimes even in its extreme form as a monopoly (Fritsch et al., 2003). This can lead to market failure and welfare losses. The market failure can result from so called indivisibilities of input-factors. The indivisibility can result from resources whose characteristics and functions can be varied only in limited steps. "A commodity is indivisible if it has a minimum size below which it is unavailable without a significant quality change" defines Baumol (1987, p.793). Runways might be an example of such an indivisibility and perhaps also terminals. Such indivisibilities might cause sub-additive cost-functions, decreasing average costs (economies of scale), and increasing returns to scale.

Returns to scale show the relation between a proportional change of all inputs and the related change in output. This means that the ratio between all input-factors remain constant. They can be differentiated into three types of returns to scale constant returns to scale, decreasing returns to scale and increasing returns to scale. Constant returns to scale imply that a change in the quantity of all input factors leads to an equal change in output, decreasing returns to scale lead to a under proportional change in output and increasing returns to scale mean an over proportional output change (Eatwell, 1987). If we consider constant input prices, an over proportional output change would also imply decreasing average costs. Therefore one can conclude that increasing returns to scale is a special case of economies of scale, decreasing average costs. The concept of economies of scale is broader since it as opposition to returns to scale also includes the possibility of a change in the ratio of input-factors (Fritsch et al., 2003).

Economies of scale exist, when the average total costs (ATC, fixed and variable costs per unit of output) decline over a certain range of increasing output (Silvestre, 1987). In the perfect competitive model the average total cost curve (the relationship between average total costs and output) is U-shaped at least in the short run, which indicates that the average total costs decline over a certain range of increasing output and increase again after they reached their minimum (Besanko et al., 2004). This minimum point of the average total cost is referred to as optimum point of scale (Pratten, 1971).

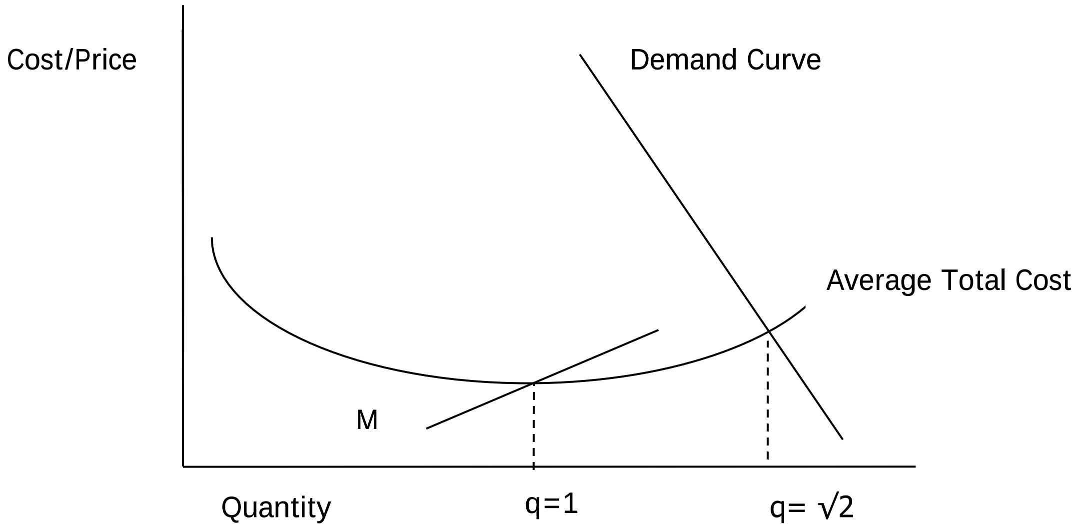
The downward sloping part of the short-run ATC curve can for example be explained by the fact that fixed costs, which are by nature unrelated to the output of the company are spread over a wider range of produced goods if output increases. These fixed costs can be related to airport terminals and facilities, insurance, costs for machinery like conveyer belts, stairways and so on. The upward sloping part of the short-run ATC curve is caused by the fact, e.g. that the company reaches its capacity limit and has to enlarge its production facilities like runways and terminals at an airport, to produce more goods. Congestion increases the short run costs and in addition the company "encounters bureaucratic and agency problems" (Besanko et al., 2004, p. 74). If we consider this U-shaped cost curve as given for each industry one would conclude that small and large firms have equally high average costs for producing one product.

A necessary condition for the existence of a natural monopoly is a *Sub-additive cost-function.* This relates to the fact that the production of the whole quantity of a good is lower than the sum of the total costs of a partial production of that quantity. In other words if TC (X^M) are the total costs of the whole quantity of good X, and X^m (m= 1, 2, 3…n) are the single quantities of a partial production (Baumol et al., 1982 and Frank, 1969). In this case sub-addivity of the cost-function indicates

$$TC\ (X^M) < TC\ (X^1) + TC(X^2) + \ldots + TC(X^n)$$

This can also imply the existence of decreasing average costs over the range of the expanding output. Although economies of scale in the range of the quantity demanded are a sufficient condition for a natural monopoly, it is not a necessary condition. Fig. 1 shows that a natural monopoly can exist even beyond the minimum efficient scale when average costs rise again. As long as the quantity demanded at the intersect of the demand curve and the average total cost curve is less than double the amount of the minimum efficient scale it would be less costly if the supply of the good would be produced by one firm (Joskow, 2007). Such a constellation is called weak natural monopoly to differentiate it from a strong natural monopoly with decreasing average costs (Church and Ware, 2000, p. 786). As airport investment is a relation specific investment fixed costs have the character of sunk costs so that a natural monopoly is not contestable (for a detailed discussion of sunk costs of airports see Wolf, 2005).

Figure 1 - Sub-Additive Cost Function and Increasing Average Cost



Source: Joskow, 2006, p. 10

The three concepts are interrelated, since they can partially explain the sources for indivisibility of input-factors, whereby they build upon each other. Increasing returns to scale are very strict in their assumption of a fixed proportion of input-factors, indicating a special case of economies of scale. Economies of scale relate to decreasing average cost over an increasing rang of output, whereby the combination of input-factors is allowed to change. The concept of sub-additivity of cost-functions offers a complete capture of all relevant cases of indivisibilities of commodities. It can explain these indivisibilities even if the average total cost are not declining over the complete range of increasing output (Fritsch et al., 2003).

2.2 Economies of Scope

While economies of scale are linked to decreasing costs over a range of increasing output, economies of scope describe the situation where it is feasible for the company to produce a variety of products, since this will reduce its total costs. This implies that it is cheaper to produce these products in a single company instead of producing each one separately (Panzar and Willig, 1981):

$$TC(Q_1,Q_2) < TC(Q_1) + TC(Q_2)$$

Whereby TC (Q_1, Q_2) is equal to the total cost of a conjoint production of products Q_1 and product Q_2. TC (Q_1) and TC (Q_2) are the total cost for each product in a separated production process.

There can be two reasons for economies of scope. First use of a sharable input or second the production of a by-product. If we consider a two-product case, there can be the possibility that these two products use a common input, like production/research facility or heating and electricity generators (Fritsch et al., 2003). Examples at an airport would be a terminal used for domestic passengers and international passengers or a conveyer belt for luggage and cargo. Also human-capital e.g. workers who are able to carry out several working steps in the production process of more than one product can be a reason for the existence of economies of scope.

The second possibility is the appearance of a by-product in the production process of the main product, whereby the most common examples are mutton and wool (Panzar and Willig, 1981). Transferred to the airport business, one could say that the passenger handling is the main product and as a by-product the airport provides cargo and luggage handling, while handling the passenger traffic.

3. THE AIRPORT BUSINESS

Since the 1970 ties the production process of airports has changed substantially. The range of airport business has broadened. Doganis (1992) differentiates between "essential operational services and facilities, traffic-handling services and commercial activities (p.7)". While the basic inputs like runway and outputs (passenger, movements and freight) of the airport barely changed over the last decades, other inputs and outputs have changed indeed. Especially the non-aviation business has increased its importance for the airport business from 41 % in 1983 and has reached at some airports already up to 50 percent of the revenue (Graham, 2008). The focus shifted to the commercialization of the airport business and the expansion of commercial non-aviation activities (Freathy, 2004). Fuerst et al., (2011) argue that today's airports are multiproduct companies serving as consumer temples and wellness oases for the wealthy business travelers as well as service providers for the airlines.

Outsourcing and technological progress, e.g. online check-in, self-baggage handling and other forms of self-service has transformed the airport business (Chang and Yang, 2008).

Airports are characterized by different degrees of outsourcing. While for example German airports offer ground handling services, UK airports have relied on third party providers. Although EU liberalized ground handling German airports have not changed their business model, but airports in a number of other countries have (Templin, 2010).

Estimating costs of airports with different models involves the use of models. These models reduce the complexity of real business. It is not necessary and sensible to capture all the details and complexities of the airport business, but the changing nature and the increased complexity can lead to problems. Focusing exclusively on the so called core business of airports by abstracting from commercial activities involves allocating common costs between separate business areas which is difficult to obtain. It is self-evident that in a multi-product firm the processes are interrelated and that the overall efficiency depends on how the processes are managed.

4. SURVEYING THE APPLICATION OF ECONOMIES OF SCALE AND SCOPE TO THE AIRPORT INDUSTRY

We have now analyzed the basic concept of economies of scale, thus giving us the knowledge to evaluate the application to the airport industry. We have seen that the airport business has expanded from a "field" for landing and departure of an airplane to a diversified multi-business; including ramp and traffic handling, management of events and other commercial activities not directly related to the aviation business. It can be expected, that the studies analyzed include some factors concerning the different business activities of the airports and thus the diversification.

There have been several studies concerning the examination of economies of scale in the airport industry. Although these studies are concerned with the same industry they come to very different conclusions. The results range from no economies of scale at all, up to the existence of economies of scale until a traffic volume of 3, 20 or even 90 million passengers or that they do not exhaust at any number of passengers or work load unit[1] (WLU). The next section will look at several studies by examining the data they used e.g. which airports, how many airports and over which period they did observe. A further criterion will be the

[1] A work load unit (WLU) is equal to one passenger or 100kg of freight

methodology they used in their study, which will be explored. Under these premises the results of the studies will be evaluated. Due to this it will be possible to assess the strength and weaknesses of each and maybe give advice for improvements.

4.1 Application of DEA on the Economic Performance of Airports

Gillen and Lall (1997) started to use DEA to measure the productivity of airports, whereby they focused on the economies of density. Thus not strictly concerned with economies of scale it is a good starting point for the analysis of the airport economics. They separated between airside activities e.g. the gate capacity and the terminal side. Through this they aimed to analyze the strategic options for airport managers to increase the efficiency in the short run. Thereby they indicated that several parameters, e.g. the increase of number of gates including the management of them, in the reach of the airports management can have a substantial impact on the airports efficiency.

Similar results concerning the short-run costs can be found in Pels et al. (2010). Like Gillen and Lall their study used DEA as a method to depict the occurrence of economies of density of 36 international airports. Hereby is the most significant cost driver the number of handled passengers whereby the concluded a strong influence of the fraction of international passenger.

The Gillen and Lall study indicated that economies of density exist at the operation of an airport thus leading to the question whether or not decreasing average costs remain in the long term and thus economies of scale exist. As seen in Table 1 there have been several studies concerned with the application of Data Envelopment Analysis[2]on the airport industry.

One of the first who applied this relative new methodology were Pels et al. (2003). Their sample consists of 33 European airports and they used a data set containing two years of observation. Pels et al. (op.cit.) used the airport's surface area (ha), number of aircraft parking positions at the terminal, number of remote aircraft parking positions, number of runways and number of runway crossings as input factors to measure air traffic movements

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[2]DEA is a non-parametric estimation method introduced by Charnes et al. (1978), which estimates on the basis of empirical data the practical feasible terms of efficiency. In contrast to econometric estimations it only considers realizable solutions and needs no specification of the production or cost function. Banker et al. (1984) developed this methodology further to incorporate the possibility of varying returns to scale.

(ATM). ATM served also as an indirect input for air passenger movements (APM), whereby the further input factors for APM were number of check-in desks and number of baggage claim units. With their estimations Pels et al. (op.cit.) reached the conclusion that an average airport (12,5 Milion PAX[3] and 150.000 ATM) exhibit constant returns to scale in ATM and increasing returns to scale in APM. This indicates that there are no economies of scale in the operation of a runway but that they can be realized in the terminal operation. Although the study is consistent, it has some major drawbacks. It does not include the labor inputs of the airport even though they make up a high proportion of the total inputs of airport operations.
Bazargan and Vasigh (2003) analyzed 45 US airports, whereby they used a data set for the period of 1996-2000. As output measures they used PAX, annual air carrier movements as well as other air traffic movements. Thereby they employed operating expenses, non-operating expenses, number of runways and number of gates as input factors. As an outcome of their study they reach the conclusion that small airports are more efficient than large airports, whereby they differentiate the airports according to the percentage of national enplaned passengers[4].

Vogel (2005) investigated the financial performance of airport thus using different input and output factors than other related studies. He applied DEA by using total revenue as output and total expenses including depreciation as input of the airport. Although no further information is given, and even though he is just concerned with the financial aspects of the operation of an airport, he comes to the conclusion, that economies of scale exist up to four million PAX and that beyond this point diseconomies of scale set in. Additional information would be helpful in order to evaluate his calculations and to compare them with other studies.

One of the latest studies dealing with this issue is from Ablanedo-Rosas and Gemoets (2010). They analyzed the Mexican airport industry with a data set of 37 airports. As output they used Aircraft Movement, PAX and tons of cargo and number of passengers per hour and number of operations per hour as input factors. Although the study is more concerned with the economic efficiency of Mexican airports it also tested via a Wilcoxon (1945) test[5] the existence of economies of scale. Thereby, their estimations reach the conclusion that there

[3] PAX – Number of Passengers
[4] large > 1 %, medium= 0.25 – 0.99 %, small = 0.05-0.24%
[5]The Wilcoxon Test is a non-parametric test on the comparison of two related observation samples

are differences between the economic efficiency of large[6] and small airport, thus indicating the existence of economies of scale. The largest airport in the sample has an output of 12 million PAX.

All DEA studies have in common that they draw conclusions about economies of scale from the estimation of returns to scale. Although not per se false this indication is incomplete. What as Fritsch et al (2003) has described in his study are increasing returns to scale, a special case of, and not, the same as economies of scale. This implies that there is the possibility that economies of scale exist although there are no increasing returns to scale. This would indicate that estimations of economies of scale based on returns to scale are incomplete.

4.2 Application of Econometric Estimations on the Airport Industry

Two of the first who applied econometric estimations for calculating the cost structure of airports were Doganis and Thompson (1974). Doganis and Thompson analyzed the data of 18 UK airports over a two year period from 1969-1970. They assumed a Cobb-Douglas cost curve, using WLU as output measure. To account for different activities of airport operation they categorized the cost into total, capital, maintenance, labor, administrative and operating cost. In the process, they also investigated the influence of a recent development program introduced by the British Government and the operation of air traffic control on airport costs. The study concluded that economies of scale exist up to three million WLU. Due to the drawbacks of a Cobb-Douglas Cost function their assumptions were very restrictive and thus not very meaningful. In addition, as indicated by Tolofari et al. (1990), their separation of different cost types can lead to estimation disruptions and as a result to a false cost curve.

Tolofari et al. (1990) criticized Doganis and Thompson (1973) and eliminated their faults. They applied a translog cost function to account for more flexibility. Like Doganis and Thompson (1973) they used WLU as an output measure, whereby they indicated labor, equipment, residual factors and capital stock as the inputs of an airport. Further variables include PAX per ATM, fraction of international passengers from overall passengers, percentage of used terminal capacity, and trends over time. They analyzed the data from seven BAA airports for the period from 1975-1987.

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[6] Large= more than 1 million Pax or Cargo tons

Table 1 - Compilation of Studies using DEA for analyzing Economies of scale

Author	TimeFrame	Sample size	Output measure	Input measure	Economies of scale
Pels et al. (2003)	1995-1997	33 European Airports	APM, ATM	Inputs for ATM: Airport's surface area (ha), No. of aircraft parking positions at the terminal. No. of remote aircraft parking positions. Nr of runways, No. of runway crossing Inputs for APM: ATM, number of check-in desks and number of baggage claim units	constant returns to scale in ATM and increasing returns to scale in APM up to 12.5 million PAX
Bazargan and Vasigh (2003)	1996-2000	45 US Commercial Airports	PAX, Air Carriers annual operation, Other aircraft movements	Operating expenses, non-operating expenses, No. of runways, No. of gates	Small airports(0,05 – 0,24% of national enplaned passengers) are more efficient than large airports(>1% of national enplaned passengers)
Vogel (2005)	1990-1999	35 European Airports	Total revenue	Total cost including depreciation	Economies of scale up to four million PAX and diseconomies of scale beyond
Ablanedo-Rosas and Gemoets (2010)	Not published	37 Mexican Airports	Aircraft Movement, PAX, tons of cargo	No. of passengers per hour, No. of operations per hour	Only four airports are scale efficient; testing for economies of scale via Wilcoxon test, which rejected the hypothesis, that large airports (>one million PAX or Cargo tons) are equally efficient than small airports. The largest airport has 12 million PAX

Source: Own research and investigation

This small sample of airports is also the major drawback of the study. They estimated that economies of scale exist up to 20.3 million WLU, but London Heathrow, with the highest volume of 38.2 Mio WLU over the observed period was the only airport in their sample which reached this size. The second biggest airport included in their sample, Gatwick reached only a volume of 18.5 million WLU. This leaves room for discussion about the range of the cost curve beyond this point and thus their result cannot be generalized.

In 1995 Doganis et al. analyzed the data of 25 European Airports from 1993. They chose, like the studies mentioned above, WLU as physical output measure and in addition value added[9] as a financial output measure. To account for different cost for domestic respectively international passengers, they differentiated between them. They divided their measured input factors in labor and capital, whereby the input factor labor consists of full-time equivalent, employee wages and salaries, and capital of capital charges including depreciation and interest rates and asset values. In their study Doganis et al. (1995) differentiated between three different regions where the airport was located, Northern Europe, Southern Europe and United Kingdom(UK)/Ireland. They found that at Southern European airports as well as UK/Irish airports Economies of Scale exist up to five million WLU and that they are not relevant at Northern European airports.

Main et al. (2003) included two different data sets in their study and thus reached two different conclusions. For both data sets they applied a Cobb-Douglas cost function. The first data set was provided by the Centre for Regulated Industries (CRI) and consisted of 27 UK airports for the period of 1988-1989. Since some airport data were incomplete they only included 25 airports in their measurement of WLU and 26 airports in measuring PAX. As input factors the study used price of staff, price of other costs, passengers per ATM, the percentage of international passengers and total assets. Concerning the operating costs Main et al. (op.cit.) differentiate between including and excluding of depreciation. They first calculated the short run cost curve and then derived the long run average cost curve by including operating cost, staff cost, depreciation and eight percent of the total assets as opportunity costs for capital. The study reached the conclusion that economies of scale are highly relevant up to four million PAX and five Million WLU and exist up to 64 Million PAX and 80 Million WLU.

[9] Value added= total revenue – costs of intermediate inputs, thus it excludes costs which cannot influenced by management

As Table 2 shows the information consisted of the second data set used by Main et al. (2003), which was provided by the Transport Research Laboratory (TRL) of 44 international airports for a period from 1998-2001. Though not all variables were included for every airport they excluded all “airport groups and Hong Kong, which was a clear outlier” (Main et al, 2003, p.46). To account for the internationality of the data set, the currencies were converted into SDR[10]. They used the same input for the CRI data set but measured only the WLU as output. As for the CRI study, they first calculated the short run total cost curve. To reach the long run average cost they added operating costs with an eight percent interest rate and divided the sum by WLU. Thereby they estimated that clear economies of scale exist up to 90 million WLU. Main et al. (op.cit., p.47) admit that their study has some limitations, in particular the assumptions that “all airports operate with the optimal amount of capital with no economies of density available. This is unlikely to be true and so the true LAC curve may be lower than the estimated curve”.

In 2005, Jeong composed a study of the operating costs of an airport, whereby he applied a translog cost function[11], which was proposed by Tolofari et al.(1990). He analyzed the 2003 data of 94 US airports and found that economies of scale exist up to 2.5 Million PAX or three Million WLU. The study indicates PAX and WLU as the output of an airport but also creates a so called output index. This output index consists of PAX, number of aircraft movements and non-aviation revenue. Labor and other expenditures like operating and soft costs which, for example, includes contractual services. Jeong (2005) focused on US airports because “there is relative uniformity in the managerial and regulatory structure across most U.S. airports” (p.4) due to the fact, that they are all governed by the Department of Transportation and the Federal Aviation Administration. This implies one of the major drawbacks of international studies. They often do not take into consideration the differences in accounting practices across countries and thus created a false picture of the cost structure.

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[10] SDR - *Special Drawing Right*, a factitious currency implemented by the IMF in 1969 (Stock,1972)

[11] Transcendental logarithm (translog) cost functions in opposition to the commonly used Cobb-Douglas cost function which predicts an elasticity of input factor substitution of one (McCarthy, 2001), implies no fixed input factor relation at all. Thus the impeded restriction of the Cobb-Douglas function which can lead to statistical distortions in the estimations can be circumvented (Tolofari et al., 1990).

Table 2 - Compilation of studies using econometric estimation for the examination of Economies of scale

Author	Timeframe	Sample size	Output measure	Input measure	Economies of scale
Doganis and Thompson (1973)	1969-1970	18 UK Airports	WLU	Total, capital, maintenance, labor, administrative and operating cost	Economies of scale up to 3 million WLU
Tolofari et al. (1990)	1975-1987	7 BAA Airports	WLU	Labor, Equipment, residual factors, Capital	Economies of Scale exist up to 20.3 million WLU
Doganis et al. (1995)	1993	25 European Airports	WLU, Value added as financial measure	Labor Capital	Differentiation between Northern Europe(NE), Southern Europe(SE) and UK/Irish(UK) NE: No economies of scale exist SE & UK: Economies of scale up to5 million WLU
Main et al. (2003)	1988-1989	27 UK Airports	WLU and PAX	Operating costs, price of staff, total assets	Strong economies of scale up to 4 million PAX and 5 million WLU Mild economies of scale up to 64 Mio PAX and 80 million WLU
Main et al. (2003)	1998-2000	44International Airports	WLU and PAX	Operating costs, price of staff, total assets, excluding of non-core activities	Economies of scale up to 90 million WLU
Jeong (2005)	2003	94 US Airports	WLU,PAX and output index	Labor and other expenditures (operating and soft cost incl. contractual services	Economies of scale up to 2.5 million PAX or 3 million WLU
Martin and Voltes-Dorta (2008)	1991-2005	41 International Airports	WLU and ATM	Prices of capital, labor and materials	Economies of scale are not exhausted at any level of output yet reached (83 million PAX)
Martin and Voltes-Dorta (2011)	1992-2008	161 International Airports	Domestic and international PAX, Commercial ATM, Commercial Revenue, Tons of cargo	labor, material and capital costs, terminal floor area, warehouse area, runway length, number of gates check-in desks and full-time equivalent employees	Economies of scale are not exhausted at any level of output yet reached (90 million PAX). Economies of scope between domestic and international traffic and aviation and non-aviation business activities

Source: Own research and investigation

One of the latest studies concerning the econometric estimation of economies of scale at airports is from Martin and Voltes-Dorta (2008). They analyzed the data of 41 international airports from North America, Europe, Asia and Australia for the period of 1991 to 2005.For their calculations they applied a single as well as a multi-product translog long-run cost function and used WLU and ATM as outputs. In addition the study material indicates capital and labor as inputs but exclude air traffic management cost. They transferred the prices of these three input factors into 2005 power purchasing parities (PPP). Martin and Voltes-Dorta (2008) come to the conclusion that economies of scale exist and are not exhausted at any level of output of their sample which includes airports up to the size of 83 million PAX.

The latest study related to the econometric estimation of airports cost function is provided by Martin and Voltes-Dorta (2011). It is one of the few studies including the diversification of the airport business. In their multi-product translog long-run cost function they constructed an output-index, which included the differentiation between domestic and international passengers, commercial ATM as well as tons of cargo and commercial non-aviation revenues. As their input factor they combined the financial factors of labor, material and capital costs with the physical inputs of terminal floor and warehouse area, runway length, number of gates as well as check-in desks and full-time equivalent employees and total landed MTOW[12]. With their data sample of 161 airports over the period of 1992 to 2008 they come to the conclusion that increasing returns to scale exist and are not exhausted at any level, even not at the level of the largest airport with 90 million PAX. They also found a strong indication of economies of scope between domestic and international passengers as well as between aviation and commercial non-aviation activities.

4.3 Measuring Economies of Scope

In Sec. 4.1 and 4.2 several studies dedicated to the measurement of economies of scale in the operation of an airport are shown. All of these studies leave out the fact that the airport business consists of several different operational activities and thus economies of scope can play a crucial role for the airport cost structure. The topic of economies of scope is rarely examined for the airport industry nevertheless some studies exist.

Tovar and Martin-Cejas (2009) analyzed the impact of outsourcing and diversified non-aeronautical activities on the efficiency airports. Their data sample consisted of 26 Spanish

[12]MTOW = Maximum take off weight

airports from 1993-1996. They indicated three different outputs of the airports operation, ATM, the relation between passenger volume and ATM and the percentage of non-aeronautical revenue of the total revenues of the airports activities. As inputs they chose the average number of employees, the surface area of the airport, and the number of gates. They applied a translog distance function and measured the influence of outsourcing by defining it “as the share of soft cost inputs in total cost (Tovar and Martin-Cejas, 2009, p.218)”.

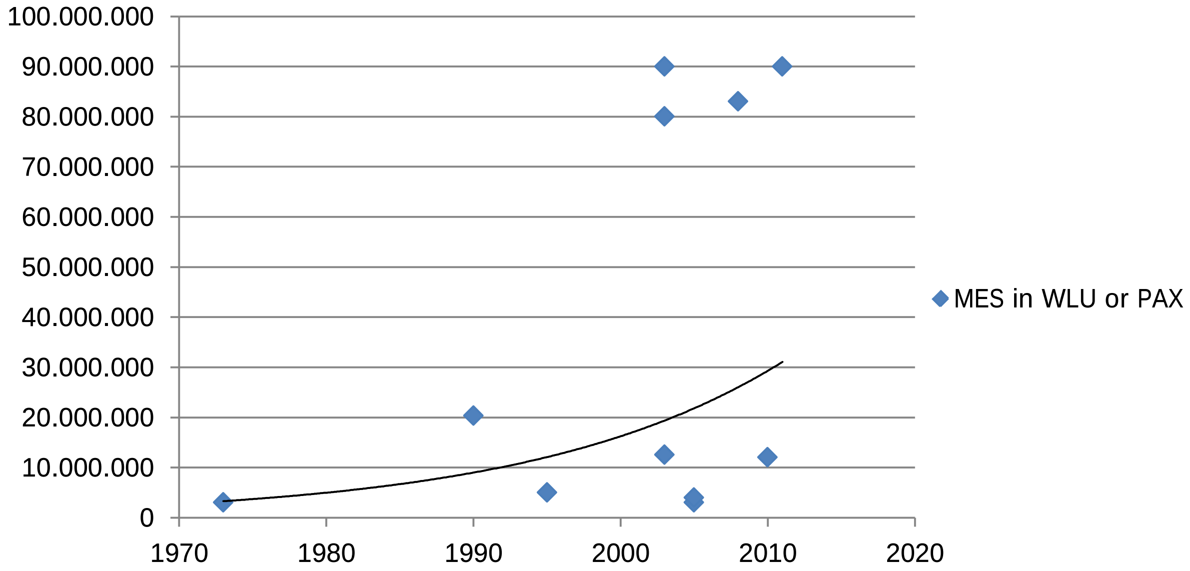
As a result of their estimations they found that outsourcing of certain activities as well as a higher volume of commercial activities revenue has a positive effect on the technical efficiency of the airports. This leads to the conclusion that there are economies of scope between the aeronautical and the non-aeronautical business of the airport. Further investigation should be made to identify the activities which have a positive effect on the airports efficiency and the ones which should be outsourced.

Chow and Fung (2009) analyzed the Chinese airport industry and investigated the possibility of economies of scope between air passenger movement (APM) and air cargo movement (ACM). Their dataset included 46 Chinese airports with data from 2000. In accordance with Pels et al. (2003) they used ATM as an input factor for the two outputs APM and ACM. ATM consisted of the inputs airport’s surface area, the length of the runways and number of parking positions for the aircrafts. As ATM served as input for both APM and ACM Chow and Fung (op.cit.) added the passenger terminal area and the car-park area as further inputs for APM and the cargo handling area for ACM. Other variables included in their estimations were regional effects and the fact if the airport serves as an operational base for a major airline. They compared the results of a single output stochastic production frontier for each output with a multi-output stochastic production frontier. In doing so they reached the conclusion that economies of scope exist and that these economies have a significant effect on the estimation of the airports technical efficiency.

5. CRITICAL DISCUSSION

The studies reach the conclusion that economies of scale exist, although the level at which these economies of scale are exhausted differs largely. While the early studies suggested that economics of scale run out at a level of 3 to 5 Million passengers later studies did not confirm. Jeong seems to be the exception (see. table. 2). In Figure 2 the points of minimum efficient scales[13] (MES) of the surveyed studies are plotted along a time scale.

Figure 2 - MES in WLU or PAX



Source: Own research

We would argue that the MES has shifted over time because the output has increased over time. The early studies of Doganis and others did not contain none or at least not many airports of the size of 50 or 80 million passengers. Furthermore the number of observations of airports with 5 and more million passengers has increased making these estimates more reliable. Another important factor is that the increased aircraft size and load factors systematically shift the MES. The average passenger load at the three airports (see Figure 2) which were studied in the early studies have tripled turning a 3 million threshold into a 9 million[14].

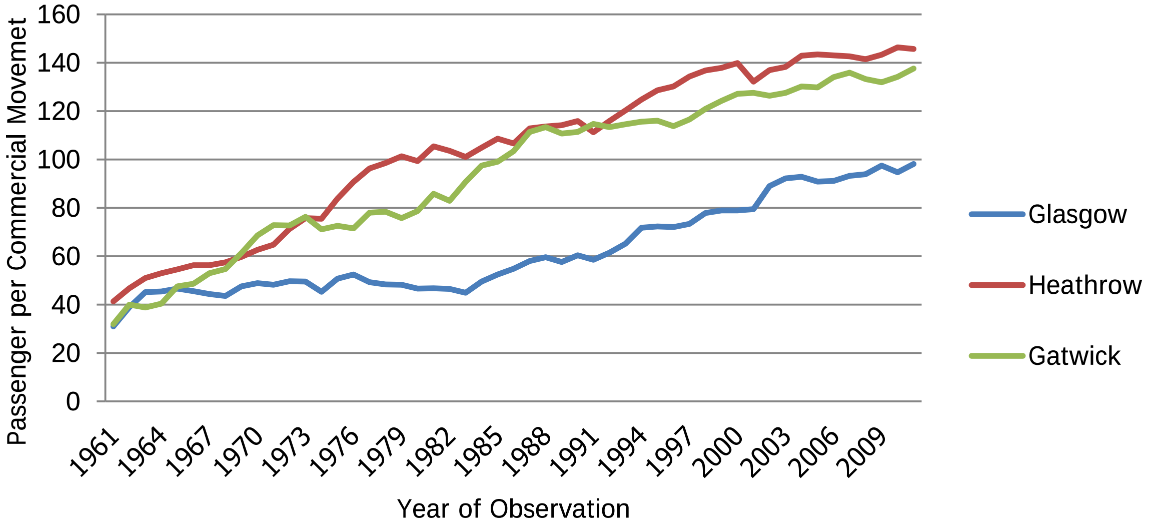
The increased airport size in the sample reflect that rising demand for the airport services leads to increases in economies of density and economies of scope. Early studies most probably have a larger share of airports with unrealized economies of scope and density.

[13] MES is the level at which economies of scale are exhausted. The results on MES are plotted irrespective of whether output is defined in WLU or passengers. This inaccuracy is acceptable as the values are rough estimations.

[14]We owe this hint to Mike Tretheway. Of course, this effect is not so strong at airports which have experienced less growth.

These airports have moved down the short run average cost curve and have lead to more observations with lower average costs. The estimations reflect this and lead to a higher MES. Another drawback of the studies is the definition of output. As shown in the analysis the most common output measure used is the so called WLU. This measure is introduced to incorporate the combination of passenger and cargo output. This is arbitrary since the production processes and machineries necessary for the handling of each differ substantially. So while useful for the output measurement of airline this output-factor is highly problematic measuring the output of airports (Doganis, 1992).

Figure 3 - Developement of Average Passenger Load



Source: Own research

Defining output as WLU also means that the output of commercial activities is neglected. By focusing on only one fraction of the airport business the authors of these studies leave out the influence of the diversification of the airport business. Chow and Fung (2009) have proven that the existence of economies of scope have a strong influence on the measurement of the airports efficiency, indicating that the results of the studies concerned with only one aspect of the airport business give a false picture.

A further critical point in the studies can be found when airports of different countries are compared. International studies often failed to account for different accounting practices, which allow some costs to be excluded from the balance sheets. This makes a comparison between these airports very difficult as accounting costs and arbitrary accounting rules do not reflect economic costs.

The DEA methods draw their conclusion concerning economies of scale from the measurement of scale efficiency. Thus, not directly measuring the cost structure gives a clear indication to the existence of economies of scale in the operation of an airport. But nevertheless they do have some drawbacks which can easily lead to misinterpretations[15].

Most studies of econometric estimations of the cost curve of the airport lag on the drawbacks of the Cobb-Douglas cost function. The estimations could increase their value if a translog cost function would have been applied as Tolofari et al. (1990) did. However he has chosen a sample size to small to draw generalized conclusions concerning the airport industry. Jeong (2005) who also chose a translog form of the cost function leaned his estimation on Tolofari et al.(op.cit.). Jeong admits that his picture is incomplete because he only focuses on output economies of scale but that this is due to a lack of data and information. Doganis et al. (1995) separated the airport's activities and only looked at the core competence to compare the different airports. This is the major drawback of all studies. They all leave out the fact that the airport business is much diversified and does not consist of airside activity only. By separating the different activities of airports the described studies leave out possible influences of other airports activities or entities on the performance of the analyzed airports.

The studies show no diseconomies of scale which is surprising given the complexities of large airports, scarcity of land at large airports in metropolitan areas and signs of bureaucratic management. In this respect it is important that the costs measured in these studies are only the private costs of airports which do not reflect costs for the users in from of longer taxi times for aircrafts or longer path for passenger to reach the gate. Other external cost caused by noise and emission are excluded as well as external benefits.

6. CONCLUSION

Our survey shows that the standard view that economies of scale run out at a level of three or five million passengers is not supported anymore by more recent research, especially the more sophisticated studies of Martin and Voltes-Dorta (2008 and 2011) confirm the view that in many local markets airports are strong or at least weak natural monopolies. These barriers

[15]Pels et al. (2003) leave out the labor inputs of airport operation although according to Doganis (1992) they make up a high proportion of overall inputs cost. Vogel (2005) gives only very limited information about his calculation.

to entry need to be further studied in analyzing airport competition and regulation (Forsyth et al. 2010).

Just a few studies try to analyze the economies of scope. They clearly show that economies of scope exist and that they play an important role in the measurement of the airports efficiency. If not included in the estimation, the results of the estimations will be incomplete and thus might lead to wrong conclusions.

In a nutshell, the literature on economies of scale and scope seems currently to suggest that airports are at least weak natural monopolies, but given the renewed interest in airport competition and regulation further studies need to be conducted capturing the multi-product nature of the capital intensive airport industry.

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