CAUSAL RELATIONSHIPS BETWEEN AIRPORT PROVISION, AIR TRAFFIC AND ECONOMIC GROWTH: AN ECONOMETRIC ANALYSIS

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ABSTRACT

As globalization progresses, air transport as a means of rapid transportation over long distances, is becoming more important to the development of economies. Thus, the availability of air transportation should exert positive effects on economic growth in the vicinity of an airport. In this paper, we present evidence of such positive economic effects and reveal the causal relationships, by using a production-function approach. The econometric estimation is based on a panel data set of major German airports.

Keywords: airports, economic effects

INTRODUCTION

Airports are the essential link between air and surface transport. In an increasingly globalized world, rapid transportation over long distances is becoming progressively more important to the development of economies. Air transport facilitates fast and intercontinental traffic, thus contributing to economic competitiveness. Consequently, the availability of air transport in the vicinity of airports might exert positive effects on economic output.

The impact of airports on productivity and long-run economic growth are, in fact, not their only economic effects. Private individuals benefit from the availability of airports in the vicinity of their homes, through, for example, being able to reach a wide variety of holiday destinations. Of course, these effects of leisure traffic are economic benefits which one has to take into account in order to study the full economic benefits of airports. But as these

private benefits are not measurable in the output of an airport catchment area, they are not incorporated in the following analysis. Thus, the scope of the study is limited in this respect. Furthermore, the provision of an airport infrastructure and its operations also impact on aggregate demand. These effects are usually identified by employing input–output analysis, based on the national accounts system. Although these effects on aggregate demand cause substantial value-added and employment, they do not include the positive effects which arise due to the macroeconomic input of airport capital stock and increased air traffic services. This analysis focuses on the latter effects. These positive long-run effects are caused mainly by enhanced productivity in the airport region. Due to fast air-traffic connections for business passengers and cargo, as well as reduced travel expenses and connections to distant destinations, enterprises are able to boost their competitiveness through cost reduction and market development. These effects are regional, as they are only generated as far from an airport as their efficient use permits.
Macroeconomic regression analysis is often used to research the productivity of public capital, such as airports, streets and railways. Although the capital stock of German airports is not completely public, the production function approach provides a valuable framework for discussing the positive output effects of infrastructure, irrespective of ownership.
In this paper, we first consider the research on the productivity effects of public capital and on the growth effects of air traffic. Based on the main issues emerging from this overview, we develop a model for quantifying the assumed positive effects of airports and estimate the model parameters by employing econometric methods. The results of the study are presented and discussed.

PRODUCTIVITY OF PUBLIC CAPITAL AND ECONOMIC EFFECTS OF AIR TRAFFIC

Looking at the literature on the impact of infrastructure and air transport we can distinguish between two main approaches: The first one tries to analyse the effects caused by the provision of infrastructure without explicitly taking into account traffic and traffic patterns on the infrastructure. The second one analyses the impact due to traffic developments at a given level of infrastructure capital. Hence, this analysis does not account for the effects of infrastructure provision.

Growth effects caused by the provision of the infrastructure

Since *Aschauer's* (1989) work on the productivity of public capital, a broad discussion on econometric methods, measurement of public capital and the economic plausibility of the results has emerged.[1] *Aschauer's* study is based on a production function approach, linking macroeconomic inputs like labour, private capital and public capital to macroeconomic output. *Aschauer* found that the output elasticity of core infrastructure such as highways, airports, electrical and gas facilities, water and sewers in the USA is 0.24.[2] This result soon

[1] For a comprehensive survey of different approaches see *Romp / de Haan* (2007).
[2] *Aschauer* (1989), pp.193 f.

became the subject of controversy, as it implies a rate of return on public capital investments higher than 100% in the first year after investment. This result is considered to be implausibly high.[3]

The criticism of *Aschauer's* results focuses mainly on the methods employed to estimate the output effects of public capital. The alleged problem is that inappropriate methods might lead to upward bias. Parameter endogeneity, non-stationary, but potentially cointegrated time series and measurement errors relating to the public capital stock are the main points of discussion:[4]

Endogenous regressors in a regression analysis arise from reverse causality. If correlation between public capital and economic output is influenced by causal links in both directions, simple regression analysis (OLS methods) yields biased estimates.[5] Because economic growth increases national budgets, the additional funding can be spent on new public investments. Hence, public investment may foster economic growth, and conversely, economic growth may foster public investments. Thus, reverse causality is a relevant source of estimation bias. More recent research uses various different methods to overcome these problems. Some researchers use simultaneous equations[6], while others include instrument variables in their analysis.[7] As an alternative means of overcoming the reverse causality issue, some studies use vector autoregressions (VAR) or vector autoregression error correction models (VECM), which do not assume any form of causal relationship between the variables.[8]

The growth effects of public capital have been analyzed mainly on the basis of time-series data. If these time series are non-stationary, the estimates might reflect spurious regression. Hence, the estimates could indicate a causal relationship which does not exist. Thus, a test for unit roots in the data is necessary. If there is evidence that the data is non-stationary, the estimation must be conducted in differences or using methods of de-trending.[9] Nevertheless, the non-stationary time series may also be cointegrated. In this case, error correction models can be used in order to develop the model. In contrast to methods of de-trending or applying an estimation in differences, this approach is superior in identifying long-run relationships between the level of public capital and economic output.[10]

A third concern about the analysis is the measurement of public capital. Because public capital is provided by the state, there are no market prices to determine its value. Furthermore, a cost-related valuation of the public capital stock does not provide an unbiased quantification, as the historic costs of producing public infrastructure do not reflect the economic costs, due to inefficiencies in the public sector.[11] Thus, in many investigations, the public capital stock is overvalued. In the context of transportation infrastructure, the loose relationship between the monetary value of public infrastructure and its performance becomes even more problematic, due to different country characteristics. For instance, a certain capital expenditure on highways for a flat region of a country creates a larger highway

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3 *Gramlich* (1994), pp.1185 f.
4 *Romp / de Haan* (2007), pp. 7 f and 12 f.
5 *Gramlich* (1994), pp.1188f.
6 See for instance *Esfahani/Ramirez* (2003) or *Cadot* et al. (2006). The latter models the political-economy process in which decisions about public infrastructure investments are reached.
7 *Ai / Cassou* (1995), *Boarnet* (1997) or *Calderón / Servén* (2002)
8 *Romp / de Haan* (2007), pp.46ff for a detailed survey of these studies.
9 *Aaron* (1990), p.53.
10 *Munnell* (1992), p.193.
11 *Sanchez-Robles* (1998), p.100.

network than the same capital investment in a mountainous region, because highways need more expensive engineering work for tunnels or bridges in the latter case.[12]
In a comprehensive meta-analysis of 76 studies, based on the production function approach, *Bom* and *Lighthart* find an output elasticity of 0.086 for public capital, taking into account some of the flaws mentioned above. Moreover, they provide evidence that neglecting cointegration or spurious regressions from non-stationary time series, are an important source of estimation bias.[13] Attempts to quantify the productivity of transportation infrastructure have been conducted particularly with regard to highways. Recent research by *Ozbay et al.* quantifies the output elasticity of highway capital at 0.171.[14]

Growth effects caused by the utilization of the infrastructure

The economic effects of air traffic are mainly discussed with regard to the utilization of airport infrastructure instead of focussing on the mere infrastructure provision. For instance, a study by *Brueckner* provides evidence that airline traffic positively effects employment in metropolitan areas in the USA. He finds that a 10 percent increase in airline traffic, which is defined as the number of boardings, raises service-related employment by 1.1 percent. Furthermore, he finds that these effects arise in the service-related sector but not in goods-related sectors. Thus, the positive effects of airline services on economic growth are explained with the theory of intercity agglomeration, because high quality airline services facilitate easy face-to-face contact with business partners in other cities. From a methodological point of view, this study is mainly concerned with the problem of endogenous traffic measures. Thus, instrument variable estimation is introduced and tested against ordinary least squares procedures. However, *Brueckner* does not find evidence that traffic figures are not exogenous.[15] Further research by *Green* confirms the positive effects of airline traffic on employment growth. Moreover, it provides a more disaggregated view on air traffic. Also accounting for possible reverse causality with the help of two stage least squares estimation procedures, *Green* reveals that the effects of airline traffic, measured as boardings or originations per capita, on employment is positive. Moreover, he finds that the effects are larger in hub cities and do not exist in case of air cargo.[16]
In addition to the literature on air traffic, which is explicitly focussed on the utilization of the airport infrastructure, some research on the economic effects of highways accounts for the effects of the utilization of the highways as well. *Fernald* points out that sectors with high vehicle intensities benefit more from highway investment than sectors with low vehicle intensities.[17] In addition to this result, *Boarnet* introduces variables of highway congestion into the analysis. He finds that congestion of highways is an important obstacle to economic growth.[18]

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[12] *Di Palma / Mazziotta* (2003), p.369.
[13] *Bom / Lighthard* (2008), p.32.
[14] *Ozbay et al.* (2007), p.327.
[15] *Brueckner* (2003).
[16] *Green* (2007).
[17] *Fernald* (1999).
[18] *Boarnet* (1997).

The analysis presented in this paper focuses on assessing the positive output effects of airports and air traffic. In addition to the empirical studies mentioned, both effects are included explicitly in the estimation. We use monetary values of airport infrastructure in our analysis instead of physical measures or performance indicators as proposed in the literature. This is due to two reasons: First, contrary to road and rail infrastructure, airports are usually not built at unfavourable and therefore costly locations. Hence, 1 EUR of airport infrastructure can, in principle, represent the same amount of physical infrastructure. Second, all German airports are run as private businesses and some airports are even at least partly privatized.[19] As a consequence, the likelihood of biased capital stocks of German airports is low.

As the connectivity of an airport is determined by scheduled traffic and not by individual general aviation flights, we explicitly include air traffic conducted by airlines into our analytical framework. The studies by *Brueckner* and *Green* use boardings and originations in order to measure the quality of air traffic services. In our analysis we employ the number of commercial aircraft movements as a measure of quality and quantity of air traffic supply. In contrast to the indicators, which are used by *Brueckner* and *Green,* aircraft movements is a supply-side indicator which does not reflect specific demand patterns or the size of aircraft which are used at an airport.

THE MODEL

Macroeconomic production functions model the technical relationship between macroeconomic inputs and macroeconomic output in a given production system. Thus, it is necessary to identify the relevant determinants of macroeconomic output that are correlated to other relevant variables included in our analysis. According to basic macroeconomic theory, we include labor L and capital K. Given that we wish to study the impact of airport capital expenditure on economic output, we also include the capital stock of airports $AIRPORTCAP$. Furthermore, we need to include a measure of the quantity of air traffic at an airport, so as to avoid omitted variable bias, as shown above. The connectivity of an airport is determined by the number of routes and by the operative frequency of these routes at the airport. Hence, we use the aircraft movements $MOVEMENTS$ in our analysis. Additionally, we include the performance of other surface transportation infrastructure $INFRA$ into our analysis, in order to avoid further omitted variable bias.

The basis of the model is a Cobb-Douglas production function. Using the parameters set out above, we formulate the basic model as follows:

$$Y = A \cdot L^{\alpha} K^{\beta} \tag{1a}$$

$$\Leftrightarrow \ln(Y) = \ln(A) + \alpha \cdot \ln(L) + \beta \cdot \ln(K). \tag{1b}$$

According to *Romp* and *de Haan,* public capital can be included in the analysis as a macroeconomic input factor or as a determinant of multifactor productivity.[20] As the capital stock K in our data already includes public capital and specifically airport capital, we only

[19] Almost 50% of the important German airports of Frankfurt, Düsseldorf and Hamburg are privately owned according to data from the German Airport Association.

[20] *Romp / de Haan* (2007), pp.10ff.

model the effect of airport capital and other infrastructure on the multifactor productivity measure. In a general model, this yields:

$$Y = A(AIRPORTCAP, MOVEMENTS, INFRA) \cdot L^{\alpha} K^{\beta} \tag{2}$$

In accordance with the transformed model, we use the logarithmic multifactor productivity $\ln(A)$ for further modeling. We employ a second-order trans-log function to specify the multifactor productivity. This methodology is analogous to the modeling of *Boarnet,* who comparably includes highway capital and congestion measures of highways to quantify the effects of highway investments.[21] Taking into account entity fixed effects and period fixed effects, we can specify the multifactor productivity. Substituting the multifactor productivity into the basic Cobb Douglas production function yields:

$$\begin{aligned}\ln(Y) = {} & \big[\varepsilon_2 \ln(AIRPORTCAP)^2 + \varepsilon_1 \ln(AIRPORTCAP) + \zeta_2 \ln(MOVEMENTS)^2 + \zeta_1 \ln(MOVEMENTS) + \\ & \iota_2 \ln(INFRA)^2 + \iota_1 \ln(INFRA) + \kappa_{A,I} \ln(AIRPORTCAP) \ln(INFRA) + \\ & \kappa_{A,W} \ln(AIRPORTCAP) \ln(MOVEMENTS) + \kappa_{I,W} \ln(INFRA) \ln(MOVEMENTS) + \textstyle\sum_{i=1}^{N} \gamma_i D_i + \\ & \textstyle\sum_{t=1}^{T} \delta_t T_t\big] + \alpha \ln(L) + \beta \ln(K).\end{aligned} \tag{3}$$

This modeling includes some universal properties. Thus, our model does not impose restrictive assumptions on the way airports and other transportation infrastructure influence economic output. Exemplarily, the output elasticity of airport capital reveals the possible economic implications which can be considered in our model:

$$\begin{aligned}& \frac{\Delta Y / Y}{\Delta AIRPORTCAP / AIRPORTCAP} \approx \frac{\partial \ln(Y)}{\partial \ln(AIRPORTCAP)} \\ & = 2\varepsilon_2 \ln(AIRPORTCAP) + \varepsilon_1 + \kappa_{A,W} \ln(MOVEMENTS) + \kappa_{A,I} \ln(INFRA).\end{aligned} \tag{4}$$

The output effects of investments in airports may depend on their capital stock. It is possible that the effects of investments rise ($\varepsilon_2 > 0$) or decline ($\varepsilon_2 < 0$) as the capital stock of an airport increases. The latter implication may be plausible, due to rising opportunity costs of capital. The initial implication may be caused by network effects, which can be generated at a larger airport with a greater capital stock.

A constant level of the output elasticity of the airport capital stock ε_1 is also considered in the model.

The output effects of airport capital can be studied, subject to aircraft movements at the airport and the quality of surface transportation infrastructure in the catchment area of the airport. For instance $\kappa_{A,I} > 0$ implies that a less competitive surface transportation infrastructure[22] might lead to greater positive output effects of airport investments. The reason might be that airports and air traffic constitute a fast link to economic centers, which is even more necessary than within regions with a competitive surface transportation infrastructure. Furthermore, the coefficient $\kappa_{A,W}$ models the interdependencies between

[21] *Boarnet* (1997), p.44.
[22] Because $INFRA$ is a measure of access times in an airport catchment area, a high value of $INFRA$ implies a less competitive infrastructure.

airport investments and aircraft movements. As an example, $\kappa_{A,W} < 0$ might reveal that the output effects of airport capital can decline, as air transportation connectivity is enhanced.
In short, the model does not contain restrictive economic a priori assumptions on the effects of airports on economic output. Due to the variety of different airports in our sample, which includes first-tier hub airports like Frankfurt as well as third-tier airports like Bremen, a flexible functional form, which can reflect different causal relationships, is necessary for this analysis. Although our economic reasoning confirms the plausibility of the model, we must test the functional specification of the model on the basis of our data set, so as to avoid misspecification.[23]

ECONOMETRIC ESTIMATION

Definition of "Influenced Areas"

As said before, the positive effects of airports on economic output are generally regarded as being regional. Hence, they are only generated in areas adjacent to the airport, in which people use the airport. We call these areas "influenced areas". These areas differ from the catchment area of an airport or its air traffic market because the influenced area only reaches as far as competitive advantage in comparison to the utilization of other airports arises for the passengers at this airport. Although there are further passengers from outside the influenced areas, the use by these people does not cause economic growth as there is no competitive advantage due to the existence of the airport. Thus, the catchment areas are supposed to be larger than the influenced areas.
Influenced areas can be calculated based on different criteria. As an example, they are visualized for Munich Airport in *Figure 1*:

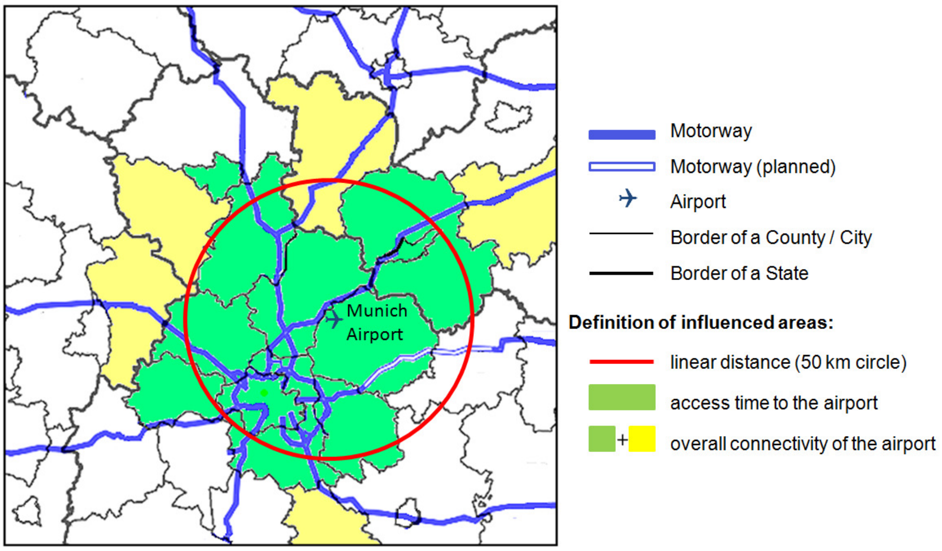

Figure 1 – Definition of influenced areas: the example of Munich Airport

[23] See Estimation Section.

1. Definition based on linear distance

As the growth effects of airports and air traffic are believed to be regional, they are generated at locations which are situated "near" the airport. Therefore, we define an influenced area based on linear distance to the airport. In *Figure 1* "near" is defined as a circle with a 50 km radius around Munich airport.

2. Definition based on access time to the airport

Although it is reasonable to have a basic definition of influenced areas with the help of linear distance to the airport, this definition does not account for access conditions to the airport. Thus, the definition of influenced areas should rather be based on access time than linear distance to the airport. In *Figure 1* all regions and counties are allocated to the influenced area, if the average access time to the airport does not exceed 45 minutes.[24] Not surprisingly, good transport links to the airport, e.g. due to fast motorway connections, lead to an expansion of the influenced area beyond the scope of the definition based on 50 km linear distance.

3. Definition based on the overall connectivity by using the airport

Mode and route choice of passengers usually includes total travel time. Therefore, we have to account for total travel time as well when defining the influenced area of an airport. Assuming a threshold of reaching destinations within Europe within one working day,[25] we find that the influenced areas of hub airports like Munich are expanded even beyond the scope based on access time. This is due to the fact that direct connections at larger airports provide short travel times compared to smaller airports where most connections require feeder flights to hubs and, thus, have longer overall travel time. However, employing this overall connectivity criterion to smaller airports would, however, lead to implausibly small influenced areas.

Concluding from the evaluation of the criteria we use a combination of the first and the third criterion. It is not necessary to explicitly use criterion two as well, because its indicator (access time) is already part of the third criterion. Thus, we first calculate influenced areas for each German airport based on a maximum linear distance to the airport of 50 km. Because larger airports with high air-traffic connectivity and high intermodal connectivity may affect larger regions, due to their easy access and fast air connections without further transfer times, we expand the airport influenced area of an airport where necessary, by using connectivity measures for the influenced areas. Due to high spatial concentrations of airports in some German regions, the influenced areas of certain airports overlap. As it is not possible to allocate growth effects in regions within the influence area of more than one airport to a specific airport, we cluster airports with overlapping influenced areas. We calculate a common influenced area for the airport cluster and allocate the growth effects to this cluster. Of course, there might be positive or negative spill-over effects to other regions outside the influenced area. However, they cannot be accounted for in our framework.[26]

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[24] See *BBSR* (2010) for data source.
[25] See *ECAD* (2008) for further elaboration on the enlargement of catchment areas.
[26] See for instance *Ozbay et al.* (2007), p. 325.

The Data

The econometric estimation of our model is based on a panel dataset containing 11 airports or airport clusters and a time dimension extending from 1997 to 2006. We choose a rather short time dimension in order to avoid the introduction of structural breaks into our model which might exist due to the reunification in Germany. The influenced areas of the airports are defined as described above.

Because the influenced areas of the airports are based on German counties and towns, the relevant data for the estimation of our model can be found in the national accounts. The real gross domestic product in the influenced areas is used as an output measure. The labor input is that of the labor force in the airport region. Given that the labor force is based on the number of individuals not on work input, we standardize the work force in the different counties, using the volume of working hours per work force unit. The macroeconomic capital stock of German counties is not available. The most disaggregated level of the data is available for the German Federal States, divided into six sectors of economic activity. We use the capital intensities for these sectors of the relevant Federal States to approximate the capital stock of the counties in the airport regions.[27] Because the defined capital stock includes the entire capital stock of the influenced area, including public capital and the airport capital stock, we quantify the effects of the airport capital stock on output, taking into account the average opportunity costs of capital appropriation in the economy.[28]

Moreover, the model also includes data about aircraft movements and the airport capital stock. As the macroeconomic capital stock in the German national accounts is defined as the gross capital stock, we use the acquisition and production costs in order to measure the capital stock of an airport. Data for the capital stock of German airports and the number of scheduled flight movements were provided by the German Airports Association.

Furthermore, an indicator of the quality of surface transportation infrastructure is included in our model. As explained in the literature overview, performance indicators based on accessibility times for road and rail, rather than monetary valuations of the surface transportation infrastructure are considered.[29] Using weighted averages, the indicators are aggregated into one indicator and to the level of the influenced areas. Given that this indicator is based on accessibility times, a decline in the indicator value reveals a higher infrastructure quality.

Estimation Methods

Based on our panel data set, we perform a two-stage least squares (TSLS) estimation. Thus, we need to identify a valid set of instruments which are strictly exogenous, but relevant. In particular, the aircraft movements at an airport and the quality of public infrastructure are endogenous variables. We use the population in the catchment area of an airport and lagged values of the infrastructure performance indicator as valid instruments. These instruments are considered to be exogenous, as the population in an airport catchment area is not

[27] *Deitmer* (1993), p.35.
[28] *Canning* (1999).
[29] We use two indicators for road and two indicators for rail. These indicators are generated by the *Federal Office for Building and Regional Planning* for all German counties and towns.

influenced by variations in economic output[30] and lagged values of infrastructure performance cannot be influenced by output variations in a certain period. Furthermore, we add an exogenous measure of airport competitiveness, compared to other German airports.[31] Finally, the airport capital stock is included only as a lagged measure, which eliminates potential endogeneity. The lagged inclusion of the airport capital stock[32] is necessary, as the causal effects of airport investments can only arise after the infrastructure becomes operational and when it is actually used by the airlines. Because our definition of capital stock also includes infrastructure under construction, and there is a need for airlines to adapt to new infrastructure, we use lagged values of the airport capital stock in our analysis.

Performing panel unit root tests, we find evidence of non-stationary time series in our data. This result is robust with respect to the inclusion of trend variables in the test setup. Furthermore, the first differences of the time series are stationary. [33] Hence, these time series are integrated of order one. As there is no significant evidence of long-run cointegration, we do not construct an error-correction model.[34] However, this implication may also arise from the short time dimension of our panel. Consequently, we apply the TSLS method to the data in first differences, which might ignore a positive long-run relationship in the levels of airport capital and economic output.[35] Using the first differences in our model, we add out the entity fixed effects. They are only included implicitly in the first differences of the model. Furthermore, the period fixed effects will be used as period fixed growth effects, rather than period fixed effects, in order to simplify the model.

Because we use a panel data set, we have to consider cross-sectional and serial autocorrelation. Serial autocorrelation is tested with a panel version of the Durbin Watson test statistic. Cross sectional dependence is researched by means of a cross-sectional dependence test by *Pesaran* (2004).[36] As the tests for autocorrelation require residuals, autocorrelation is considered in the process of model validation. If we find evidence of cross-sectional or serial correlation, panel corrected standard errors (PCSE) are used to ensure the econometric validity of the statistical inference in the model.

Estimation

The estimation of the specified model is conducted with the aid of the software package *eViews 6*. *Table 1* shows the results of the regression analysis.

Model 1 is similar to *Aschauer's* approach of introducing public capital as a macroeconomic input factor. This model contains neither quadratic summands[37] nor cross products. We find that the non-quadratic inputs are insignificant, except for the inputs of labor and capital. In contrast to these results, we show *Model 2,* which contains all cross products and quadratic terms, but no non-quadratic expressions. The results become more significant, but, due to some insignificant summands, the model fit is not ameliorated. *Model 4* does not contain

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30 Nevertheless, output changes are caused by a change in the work force.
31 The measure is constructed as the share of the airport's WLU to the total German WLU.
32 The lag used is 6 periods.
33 Test for panel unit roots are based on ADF Fisher tests for individual unit root processes.
34 Cointegration testing is based on Pedroni's residual cointegration test.
35 *Munnell* (1992), p.193.
36 *Pesaran* (2004).
37 Except for $INFRA$, which does not yield any plausible results without using its squared form.

these insignificant regressors, which we treat as irrelevant, so that the model fit rises. Furthermore, the results of the regression analysis do not change considerably, thus confirming the robustness of the model. Finally, we use the non-quadratic expressions combined with cross products in *Model 3,* in order to check for further misspecifications of *Model 4*. As we find a significant decline in the adjusted fit measure $\overline{R^2}$, we choose *Model 4* for our further analysis.

Table 1 - Estimation results

$\Delta[\boldsymbol{ln}(\boldsymbol{BIP})]$	**Specification**			
	1	**2**	**3**	**4**
	TSLS, PCSE	**TSLS, PCSE**	**TSLS, PCSE**	**TSLS, PCSE**
Period Fixed	X	X	X	X
$\Delta[\ln(labour)]$	0.697755** (0.316833)	0.576832* (0.316417)	0.635272** (0.311362)	0.649489** (0.310780)
$\Delta[\ln(capital)]$	0.430475** (0.196412)	0.321206 (0.228018)	0.475933** (0.216874)	0.355760* (0.181499)
$\Delta[\ln(movements)^2]$		0.054637** (0.022835)		0.050612** (0.020900)
$\Delta[\ln(movements)]$	-0.021662 (0.089194)		-0.154330 (0.342204)	
$\Delta[\ln(infra)^2]$	-0.433538** (0.216920)	0.211635 (1.485116)		-0.411429* (0.229000)
$\Delta[\ln(infra)]$			1.260259 (3.044495)	
$\Delta[\ln(airportcap)^2]$		0.018481** (0.007174)		0.015469** (0.005917)
$\Delta[\ln(airportcap)]$	-0.006778 (0.021624)		-0.022011 (0.167689)	
$\Delta[\ln(movements) \cdot \ln(infra)]$		-0.246746 (0.181654)	-0.204759 (0.255780)	
$\Delta[\ln(airportcap) \cdot \ln(infra)]$		0.164587 (0.136280)	0.074800 (0.094829)	
$\Delta[\ln(airportcap) \cdot \ln(movements)]$		-0.063717* (0.024773)	0.003860 (0.016841)	-0.056850** (0.021825)
F	5.135239	4.439324	3.971102	5.158973
R^2	0.440398	0.451228	0.443393	0.449490
$\overline{R^2}$	0.350862	0.336900	0.327434	0.352779
Durbin Watson	1.954480	1.940127	2.000412	1.959283
CD-Test (p-value)	0.055819	0.053575	0.053141	0.054571

* Significant at the 10% level
** Significant at the 5% level

A misspecification of the model was analyzed with regard to a lower order of the trans-log specification. Using the *RESET* method, we also elaborate on other functional forms of the model. The functional form of the analysis cannot be rejected up to a specification of order 5.[38]

We thus use *Model 4* as the basis for our analysis. We find some important features of the model which highlight its credibility:

1. The model yields almost constant returns to scale, although we did not use this constraint as an explicit assumption. Hence, our results are mainly in line with other studies which use constant returns to scale as an economic assumption[39] or which yield comparable results. [40] The constant returns to scale are calculated as the sum of the coefficients of labor and capital, as we use the full capital stock in the analysis.

2. In a Cobb-Douglas production function, the output elasticity of labor input should be roughly the same size as the wage share.[41] The adjusted wage share in Germany for 2007 was 64.6%, which is almost the same size as the coefficient of labor 0.649 in our model.

As shown in *Table 1,* we also tested for cross-sectional dependence and serial correlation. A value of about two for the Durbin Watson Statistic implies that serial correlation is not considered a relevant problem. The test for cross-sectional dependence reveals econometric evidence of cross-sectional dependence. Therefore, we use panel-corrected standard errors and covariances (PCSE) to estimate the standard errors of the estimators.[42] Because we find comparable results for all models, this method is employed for all presented models.

Furthermore, we have already discussed which relevant, but exogenous instruments are included into our analysis. Given that the exogenous instruments are crucial to the validity of the estimation, we apply the overidentifying restrictions test.[43] The test yields $J \sim \chi_2^2$ with $J = 3.6548$, such that the null hypotheses of parameter exogeneity cannot be rejected, even at a level of significance of $\alpha = 10\%$. Thus, we find signs of exogenity of the instruments.

RESULTS

The results of the regression analysis yield insight into the various causal economic relationships that generate the economic effects of airports. On the basis of the estimates, it is possible to distinguish between those capital effects which arise from the provision of airports and the air traffic effects resulting from the connectivity provided by an airport to its influenced area. Furthermore, we can discuss the output effects generated by airport expansion.

38 P-value $p = 0.4447$.
39 *Esfahani/Ramirez* (2003), p.447.
40 *Ozbay* (2007), p.324.
41 *Phelps-Brown* (1957).
42 The method is based on *Beck/Katz* (1995).
43 *Hansen* (1982).

Effects of Airport Provision

The capital effects of airports are caused by the existence of an airport and not by its air traffic. Two lines of economic arguments justify these effects:

1. Entrepreneurs interpret the existence of an airport as a signal of economic strength. The provision of an airport, which is often supported by public agencies, reveals that such agents facilitate economic growth by providing the necessary infrastructure and institutions. Entrepreneurs try to take advantage of these positive conditions in the influenced area. Thus, they locate their business in these regions, causing positive output effects.

2. For the airports which are included into our dataset, we find a strong correlation between the basic "supply" of destinations which are relevant to business travelers and the airport capital stock. Thus, we conclude that a larger airport ensures a higher connectivity for business travelers in the airport region, compared to an airport with a smaller capital stock. Thus, the provision of airports usually provides business travelers with basic air-traffic links. This includes at least hub airports and some direct flights to important commercial centers. Thus, the mere existence of an airport may already generate positive output effects.

The effect of airport provision is analyzed by differentiating the model in terms of logarithms, with respect to the airport capital stock in logarithms. This yields the output elasticity of the provision of airport capital:

$$\frac{\partial \ln(\widehat{BIP})}{\partial \ln(AIRPORTCAP_{t-6})} = 0{,}03094 \cdot \ln(AIRPORTCAP_{t-6}) - 0{,}05685 \cdot \ln(MOVEMENTS) > 0 \qquad (5a)$$

$$\Leftrightarrow \frac{\ln(MOVEMENTS)}{\ln(AIRPORTCAP_{t-6})} < 0{,}54421. \qquad (5b)$$

Interpreting this result, we conclude that the output elasticity of airport capital is only positive for third-tier airports. Thus, only the provision of these airports exerts significant effects on the regional output in their respective influenced area. Furthermore, there is no need for these airports to use the infrastructure to its full capacity. These airports generate their positive output effects by their very existence and through the related supply of basic air transportation services. In addition to this, the leisure traffic at these airports exerts positive economic effects. But as these effects are not part of this study they are not considered in our results. Of course, it is highly implausible that these effects are caused by the mere existence of a huge airport with a low air traffic connectivity. As we have already elaborated above, our data does not provide us with evidence of such a situation. Thus, it is the combination of basic air traffic services and the provision of the airport which creates the positive output effects of airport capital for third-tier airports. In this context, it is important to remember that the production function used for our analysis is substitutional. Thus, we do not have sunk costs in our model. Although this assumption is not realistic, it is also possible to evaluate the past capital expenditure.

Shifting the focus to first and second-tier airports, we conclude that the influenced areas of these airports do not benefit from the mere provision of these larger airports, although they benefit from the air traffic which is conducted at these airports.[44] Assuming a declining marginal productivity of capital and fixed capital resources, we find that the opportunity costs of providing these airports rises as the airport capital grows. Hence, it can be concluded that the provision of first and second-tier airports becomes too expensive in terms of opportunity cost to justify the capital effects, as shown above.

Effects of Air Traffic

The model provides evidence that the economic significance of airports cannot be justified solely by the provision of an airport. Furthermore, the economic effects of airports are also caused by the air traffic at the airport. These effects are analyzed by using the first derivation of the model in logarithms, with respect to the logarithmic aircraft movements on an airport:

$$\frac{\partial \ln(\widehat{BIP})}{\partial \ln(MOVEMENTS)} = 0{,}10122 \cdot \ln(MOVEMENTS) - 0{,}05685 \cdot \ln(AIRPORTCAP_{t-6}) > 0 \qquad (6a)$$

$$\Leftrightarrow \frac{\ln{(MOVEMENTS)}}{\ln{(AIRPORTCAP_{t-6})}} > 0{,}56162. \qquad (6b)$$

Based on this result, we conclude that first-tier and second-tier airports in our study yield positive output effects of enhanced traffic on the existing infrastructure. Thus, limiting the number of flights by administrative means, on an existing infrastructure at first and second-tier airports, comes at an economic cost, as it reduces the connectivity of the influenced area of an airport with regard to air traffic. Furthermore, we reveal that larger airports cause positive output effects through facilitating additional air services.

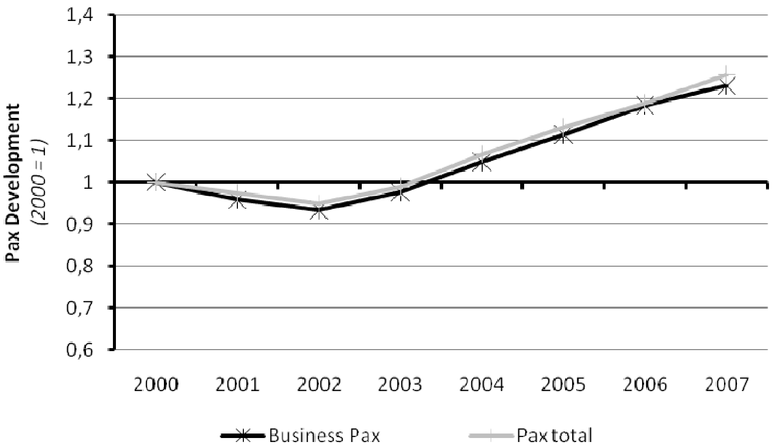

Figure 2 – Traffic development at German first- and second-tier airports

Traffic figures show that additional traffic at first and second tier airports is mostly traffic which is relevant to business travellers. This conclusion can be drawn from *Figure 2* as the development of the sum of business travellers at German first- and second-tier airports nearly matches the development of the sum of the total passenger number at German first- and second-tier airports. Thus, additional flights at first- and second-tier airports are usually

44 See next section.

direct connections, which are highly attractive to business travellers. These additional flights generate positive effects both on productivity and on economic output.

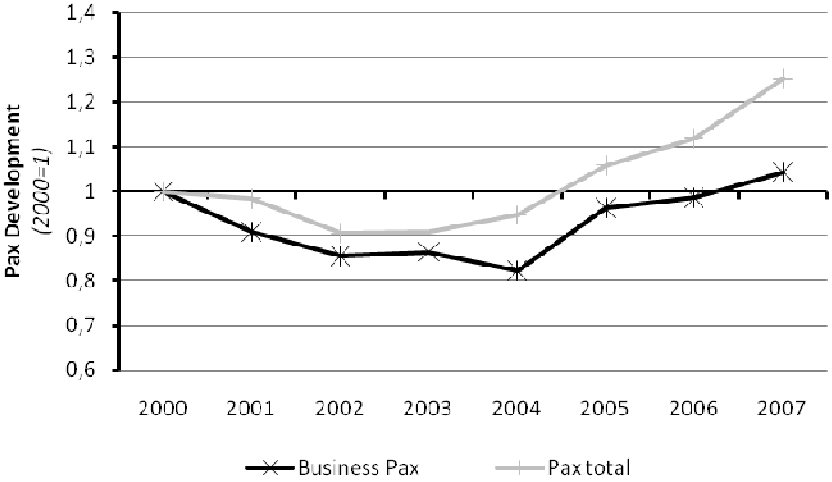

Figure 3 – Traffic development at German third-tier airports

In contrast to this, additional traffic at third-tier airports is mostly leisure traffic. *Figure 3* reveals that the development of the sum of business passengers at German airports is lower than the development of the sum of total passengers at German third-tier airports. Hence, additional traffic at third tier airports is generally focused on leisure traffic. As a consequence, it is not surprising that we do not find the positive effects of additional air traffic for third-tier airports. Third-tier airports offer basic air traffic services to hub airports, some direct flights to main European cities and holiday services. Although additional leisure flights at third-tier airports cause positive effects for the inhabitants of the influenced area as they reach their holiday destination at lower time costs, they do not generate economic growth as it is defined in this analysis.

Combining the results of capital and air traffic effects, we find that there are airports which do not yield positive effects of airport capital or of air traffic. These are some second-tier airports that yield:

$$0{,}54421 < \frac{\ln(MOVEMENTS)}{\ln(AIRPORTCAP_{t-6})} < 0{,}56162. \qquad (7)$$

According to our economic analysis of airport capital and air traffic effects, we can conclude that these airports are too large to generate positive capital effects, due to the high opportunity cost of capital appropriation. On the other hand, they do not have sufficient traffic to provide a high connectivity for business travellers. Because we have to take into account the high sunk costs of these airports, it is important for them to attract further routes which are attractive to business travellers.

Expansion of Airports

Airport expansions often focus on removing infrastructural capacity constraints. Thus, we have to consider simultaneous variations in aircraft movements and the airport capital stock, in order to evaluate the economic effects of airport expansions. These effects are only relevant to first and second-tier airports, as other airports usually do not have capacity bottlenecks. We use the total differential in order to simulate these effects. This yields:

$$\frac{d(Y)}{Y} = \frac{\partial \ln(Y)}{\partial \ln(AIRPORTCAP)} \cdot \frac{dAIRPORTCAP}{AIRPORTCAP} + \frac{\partial \ln(Y)}{\partial \ln(MOVEMENTS)} \cdot \frac{dMovements}{Movements}. \quad (8)$$

As explained above, we find $\frac{\partial \ln(BIP)}{\partial \ln(AIRPORTCAP)} < 0$ and $\frac{\partial \ln(BIP)}{\partial \ln(MOVEMENTS)} > 0$ for first and second-tier airports. Hence, we conclude that positive output effects of airport expansions for first and second-tier airports are only possible, if the positive effects on air traffic movements exceed the negative opportunity costs of providing further airport infrastructure. Thus, it is possible to calculate a critical “break-even” air traffic development for the airports that enable positive output effects of airport expansions. As we do not verify constant output elasticities in our model, it is not possible to calculate a general relationship. Simulations show that expansions tailored to fit market needs usually generate positive expansion effects at German first and most second-tier airports. The air traffic growth rates which are necessary to ensure the positive effects of airport expansions increase, as soon as the airport capital grows and there is no commensurate growth in air traffic. Thus, positive output effects diminish for larger airports that are not used sufficiently.

CONCLUSIONS

Based on a dataset of German airports and their corresponding influenced areas, we find that German airports generate positive effects on economic output. For third-tier airports, these positive effects are caused by their very existence, due to signalling of site-specific quality and the provision of basic air services, which mainly includes connections to hub airports and some direct flights to economic centres. By contrast, the influenced areas of first-tier and second-tier airports benefit from air traffic which facilitates potential for cost reductions and productivity growth in the economy of an influenced area. We also conclude from our analysis that necessary airport expansions tailored to market needs, yield positive output effects. However, it is necessary to bear in mind the efficient level of capital appropriation for these expansion projects, as high opportunity costs for the airport capital stock may outweigh these positive effects.

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