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SPATIAL COMPETITION FOR PASSENGERS AND ITS INFLUENCE ON EFFICIENCY OF EUROPEAN AIRPORTS

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ABSTRACT

This study deals with estimation of European airports' efficiency values and their interrelation with a level of competition pressure for passengers among airports.
In this paper we present a new adaptive definition of airport's catchment area. Using this definition we develop an indicator of a level of competition pressure, based on overlapping of airport's potential catchment areas.
We apply a stochastic frontier model to estimate efficiencies of airports. The method includes the construction of a production frontier for a sample of airports and estimation of individual airports' efficiency values as distances from this frontier. We use a classic production approach to airport activities, where an airport enterprise uses labour resources (a number of employees) and infrastructure (a number of runways, gates, check-ins and parking spaces) for transportation of passengers. Also we use a re-sampling jack-knife technique to test the reliability of airports' efficiencies estimates.
We investigate a relationship between a level of competition pressure and airports' operation efficiencies in case of imperfect spatial competition for passengers.

Keywords: stochastic frontier, efficiency, airport, spatial competition

Introduction

A relationship between a level of market competition pressure and efficiency of economic units' activities is one of the foundation stones of the economic theory. The market of air carriage is not an exception, and the common rules should work there, but the competition pressure has some specifics.

There are two main competition areas for a company – competition for suppliers and competition for customers. For airport companies suppliers are a set of service providers, the main of which are airlines, and customers are potential air passengers. Competition for airlines is very important for airports, but it can be considered as a standard one from a theoretical point of view. In this area we can consider conditions for landing/maintenance, contact agreements, discounts, etc. – the usual set for competition for suppliers. But the competition for passengers has some features, and the main of them is related with a location of airports. The spatial nature of competition for passengers makes it interesting for researches.

The theory of airport competition for passengers is based on a conception of airport catchment areas (or hinterlands). A catchment area is "a geographical zone containing the potential users and passengers for the airport" [1]. The main reason for competition in this approach is unalterable locations of airports. Usually airport's catchment area is calculated on the base of a distance from the airport (for example, 100 kilometres area around the airport). A better approach uses a travel time instead of a distance (for example, a zone where a travel to the airport takes less than 2 hours) [2].

Overlapping of airports' catchment areas is a considered source of competition pressure [3]. The conception is presented on the Figure 1. Airport A and B compete for passengers living in the overlapping area (a shaded area on the Figure 1.A), and bigger overlapping area (relatively to airport's catchment area) means higher competition pressure. The situation B on the Fig.1 (labelled "No competition") is also frequently considered in literature, but looks as non-natural from our point of view. The nature of competition is based on availability of a number of alternatives, and if a passenger has no other alternatives, but he needs for airport services – he will have to travel to the nearest airport even if he is not living in airport's catchment area (the "Passenger" point on the Fig.1) and will spend 3-4 (or even more) hours to reach it. So the classical approach to catchment areas as a circle with a predefined radius is not working in this case, and in this research we suggest a correction for catchment area definition.

Situation A. Competition for passengers in the overlapping area

Situation B. No competition

Figure 1. Spatial competition among airports

Another complication of catchment areas is related with services provided by airports. Each airport has its own "range of goods" – flights to different destination points with different frequencies. If one airport provides flights to a selected destination, and another one does not – the catchment area for this destination of the first airport will be enlarged, the catchment area of the second airport will be joined to the first. Destination points as usual goods have an interchangeability property, for example, in some cases flights to Munich can be replaced with flights to Frankfurt. A frequency of flights also makes a difference.

In this research we suggest a method to calculate a level of competition pressure on the base of catchment areas overlapping subject to all listed complexities.

One of the main economic advantages of the competition is increasing of efficiency of activity of economic units. We use a stochastic frontier model [4] to estimate efficiencies of European airports and its interrelation with a level of competition pressure. The conception of a stochastic frontier is widely used in modern researches of efficiencies; the model allows constructing a "best performance" frontier and estimating a relative efficiency score for each airport.

There are a sufficient number of researches devoted to estimation of efficiency levels of European airports on the base of frontier methods [5][6]. The most of researchers ascertain a relationship between airport's efficiency and characteristics of its organization structure like ownership, contacts with air carriers, managerial factors. The present paper innovates in this context by analyzing the relationship between levels of a competition pressure and airport's efficiency scores.

Methodology

There are two main methodical points in this research:

- calculation of a level of the spatial competition pressure on airports, and
- calculation of airport's efficiency scores and their relation with the competition pressure.

The method of calculation of competition pressure is developed and described in details in this research, and efficiency scores are calculated on the base of a standard stochastic frontier model.

The level of the competition pressure: a calculation procedure

As we have noticed in the introduction, a level of competition pressure can be considered as a proportion of population living in the overlapping regions to the whole population of airport's catchment areas.

We have developed a method to calculate this proportion using the information about population of each geographical "point" (a region 5x5 kilometres in our calculations), distances from this point to nearest airports and available flights destinations and frequencies.

Let consider a particular geographical place and a particular destination point required. The population of this place needs to choose one of the nearest airports for their trips. Let we have two characteristics for each airport:

- $Flights_{airport,\ time,\ destination}$ – a number of flights executed from a particular airport during a particular time interval to a selected destination. We will use this number as an indicator of "service availability", a frequency of flights to a selected destination.

  We assume that a law of diminishing returns is present here – each additional flight is more important if there are only a few flights a week than if there is a flight every hour already. To include this assumption into the calculation we use the logarithm of the number – $\ln(1+Flights_{airport,\ time,\ destination})$

- $Distance_{airport,point}$ – a distance from a particular place to a selected airport. A distance can be measured in kilometres or in travel times. In this research we use a distance in kilometres for simplicity reasons.
  Usually the probability of a trip as a function of a distance to services is considered as sigma-shaped function (called distance decay function) (Fig.2). Some first kilometres don't make a difference, and after that we have a steep grade, and then kilometres don't make a big difference again.
  For this research we selected a log-logistic distance-decay function:
  $$F(Distance) = \frac{1}{1+\exp(a+b\ln(Distance))},$$
  where $a = -11.13, b = 2.72$

  Values of a and b parameter where selected following the [7] to reflect a travel time behaviour of people with a low value of time.

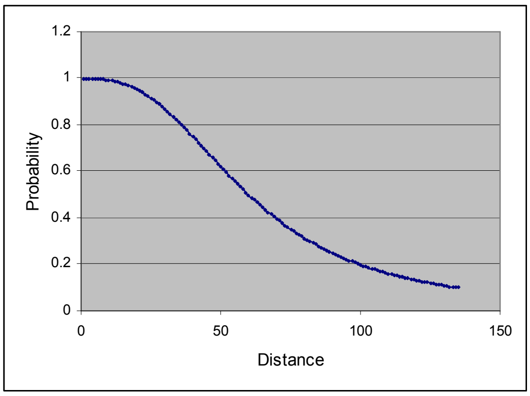

Figure 2. A distance decay function

The product of these two characteristics gives us a measurement of airport's availability for a particular point:

$$AirportAvailability_{airport,time,destination,pont} = \frac{\ln(1+Flights_{airport,time,destination})}{1+\exp(a+b\ln(Distance_{airport,point}))}$$

Higher value of calculated AirportAvailability means better availability. If an airport doesn't provide flights to a selected destination, the AirportAvailability equals to 0.

Similarly we compute availabilities of all nearest airports, and after that calculate availability shares:

$$AirportShare_{airport,time,country,point} \frac{AirportAvailability_{airport,time,country,point}}{\sum_{airport \in AREA} AirportAvailability_{airport,time,country,point}}$$

The AREA which includes nearest airports is defined for calculation reasons only. Theoretically, we can calculate values for all airports, but the assigned shares for airports located far from the geographical point will be negligibly small. In this research we used a circle area with the 300-kilometers radius to limit the AREA.

The *AirportShare* value can be considered as a probability of a trip using a particular airport from a particular geographical point. If only one airport is available for this point – it will have AirportShare = 1.

On the base of this probability we can calculate a share of population of this point which will choose a particular airport as $Popul_{point} * AirportShare_{airport,time,direction,point}$.

After that we can summarize this indicator for all geographical points and calculate the share of population which chooses a particular airport.

$$AreaPop = \sum_{point \in AREA} Popul_{point}$$

$$CatchedPopulationShare_{airport,time,direction} = \frac{\sum_{point \in AREA} \left(Popul_{point} \cdot AirportShare_{airport,time,direction,point} \right)}{AreaPop}$$

Higher values of the CatchedPopulationShare mean less competition pressure for this direction for a particular airport. The 1 value means that the population has no choice and the nearest airport is a locational natural monopoly [8].

The next point of the method to discuss is an importance of a particular direction. This point is highly related with a level of competition pressure, because it makes a difference if an airport is under high competition pressure for a very important direction or if the direction is a rare one and not important. For example, if we consider two airports, an international (flights to the domestic and other countries) and a national (flights inside the domestic country only), the competition for domestic flights is more important for the national airport and less important for the international one.

In this research we assume that the importance of the directions can be calculated as a share of flights to this direction from a selected airport:

$$DirectionImportance_{airport,time,direction} = \frac{Flights_{airport,time,direction}}{\sum_{direction=1}^{DIRECTIONS} Flights_{airport,time,direction}}$$

After that we join competition pressure for passenger to all directions using the importance of directions as weights.

$$CompetitionPressure_{airport,time} = \sum_{direction=1}^{DIRECTIONS} \left(\begin{array}{l} DirectionImportance_{airport,time,direction} \cdot \\ \cdot \left(1 - CatchedPopulationShare_{airport,time,direction}\right) \end{array} \right)$$

So we constructed a metric of the competition pressure on an airport based on its spatial position. The metric also uses number of flights to different directions, and that's why it can vary over time. The metric doesn't utilize a quality of airport's services like check-in queuing, registration facilities, parking spaces, etc.

The suggested method has some limitations:

1. An economic activity level in the geographical point is not included into consideration. Without this correction we assume the uniform distribution of businesses and other features which can have an influence on airport necessity. Usually the businesses are concentrated around an airport (or an airport is constructed near to country business centres), so the calculated values of competition pressure will be overestimated. The method can be improved by using a product of population and an index of economic activity in region instead of the $Popul_{point}$ variable.
2. An importance of directions for an airport is calculated on the base of a share of flights to this direction. In practice an airport can have higher profit margins for some relatively rare directions, and can consider them as more important.
3. As we mentioned in the introduction, the direction can be interchangeable, that's why the competition pressure can be underestimated. The correct way is to use a metric of interchangeability between each pair directions (based, for example, on

a distance between them). In this research we used destination countries instead of direction themselves, which is an equivalent of an interchangeability metric, which is 0 for different countries (no interchangeability) and 1 for the same country (an absolute interchangeability).

Stochastic Frontier Model

For estimating airports' efficiency levels we applied a stochastic frontier model. The model can be formalised as:

$$y = f(x, \beta) + \varepsilon,$$
$$\varepsilon = v - u, v \sim N(0, \sigma_v^2), u \geq 0,$$

where

y – an output;

x – a vector of resources/inputs;

f – a production/cost function;

β – a vector of unknown coefficients;

ε – a composite error term.

The first component of composite error term, v, shows the random variation of the efficiency frontier, and the second one, u, shows the technical inefficiency of airports. The individual efficiency of the airport i can be estimated as [9]:

$$TE_i = e^{-E(u_i|\varepsilon_i)},$$

where $E(u_i|\varepsilon_i)$ – conditional expectation of u_i given estimated ε_i.

For estimating unknown parameters of the model we need to make some assumptions about distributions of error terms and a functional form of the production function. The usual assumption in the stochastic frontier model is the normal distribution of the random component v_i with zero mean. We used the truncated normal distribution for the second error term component u_i with a conditional mean (the first distribution parameter depends on the set of factors z, the most important of which is a level of the competition pressure):

$$u_i \sim N^+(\delta_0 + \sum_{i=1}^{m} \delta_i z_{it}, \sigma_u^2)$$

Also we considered a Cobb-Douglass function with time parameters as a functional form of the frontier:

$$\ln(y_{it}) = \beta_0 + \sum_{i=1}^{k} \beta_i \ln(x_{it}) + \sum_{i=1}^{k} \tau_i \ln(x_{it}) t + \nu_i - u_i$$

Data

The data set includes characteristics of European airports' activities from 2003 to 2007 (data for 2008 is not filled enough for this moment) and airports' geographical locations. Also we used a world population grid for calculation of a level of competition pressure.

There are four main data sources used:

1. The Eurostat (the Statistical Office of the European Communities) database is a source of information about airport activities. The information about each airport includes:
    a. a number of passengers carried. All passengers on a particular flight counted once only and not repeatedly on each individual stage of that flight; direct transit passengers are excluded. This indicator is used as the main output of airport's activity. Using the value without transit passengers allows reducing specifics of hub airports and should be related with competition for passengers more closely;
    b. a number of direct flights by country. Eurostat provides information about a number of flights to European countries, and also flights outside the European Union. The information is used for calculations of airport's flights to destination frequencies, and also for computing airport's destination importance.
    c. a number of employees of airports. Only employees hired directly in airports are included; we keep out all other organizations located on a site of an airport.

d. airports' infrastructure. We collected the information about a number of check-in facilities, gates, runways, and parking spaces as input resources of airports' activity.

2. The Atlas of Airports for 2005 from the Ruimtelijk Planbureau, Netherlands, is also used as a source of airport information as an addition to the Eurostat database.
3. The Gridded Population of the World database from the Centre for International Earth Science Information Network (CIESIN) includes population counts in 2005, adjusted to match UN totals. The raster data contains information about Europe population with 2.5 arc-minutes (~5 kilometres) resolution.
4. Digital Aeronautical Flight Information File (DAFIF) database is a complete database of up-to-date aeronautical data, including information on airports. The database is used together with the Google Earth software as a source of European airports geographical coordinates.

Stochastic Frontier Model Specification

Specification of the stochastic frontier model requires three groups of indicators – airport outputs, airport inputs and airport or external indicators related with airports' efficiency levels.

There are two main outputs of an airport – passengers carried and mail/cargo loaded/unloaded. As we study the relationship between a level of efficiency and competition for passengers, we can use passengers as the main output of the airport. So in this research we use the term "airport's efficiency level" as "airport's passenger carriage efficiency level". It was done to make the model simpler, because spatial competitions for passengers and for cargo are significantly different things. The simplification will lead to lower levels of passenger service efficiency for airports oriented to cargo carriage. We selected a number of passengers carried (*PassengersCarried*) as an output, although some researches used a number of flights executed, a potential number of passengers seats carried for the same purposes. A number of passengers carried is an indicator of actual airport's economic output, when other indicators are related with potential output which is possibly not fully utilised by the public.

We considered a number of airport infrastructure and labour resources as model inputs. Numbers of check-ins (*CheckIns*), gates (*Gates*), runways (*Runways*), parking spaces (*ParkingSpaces*), and a number of employees (*Employees*) were initially included into the model, but high level of correlation between inputs led to multicolleniarity problems. We made a decision to exclude number of check-ins and gates due to high correlation with a number of runways. Another explanation of the exclusion can be formulated in terms of resource manageability. Numbers of gates and, especially, check-ins are more flexible and manageable, than a location and a number of runways, so it can be considered not as resources, but as management efficiency components.

The final model component is parameters related with airport's efficiency. As the main goal of this research is to investigate the relationship between airport's efficiency and the level of the competition pressure, we used only one parameter (*CompetitionPressure*) calculated by formulas presented in the Methodology section.

As a functional form of the production function we initially chose the Cobb-Douglass function with time components. Time components included to reflect changes of the production frontier during the selected time interval (from 2003 to 2007). Usually changes of the frontier form are related with some innovations in the production process, and it is possibly that there are no significant changes during this short time interval. To test this hypothesis we used the likelihood ratio test, and the observed value is:

$$\chi^2_{obs}(r) = 2(Ln(H_1) - Ln(H_0)) = 2(-252.698 - (-253.384)) = 1.372,$$

where

$Ln(H_1)$ – log-likelihood function value for the model with time components,

$Ln(H_0)$ – log-likelihood function value for the model without time components,

r=3 – a number of time components (restrictions).

So we rejected a hypothesis about a significant advantage of the model with time components, and used the model without time components in our research.

The final stochastic frontier model is:

$$\ln(PassengersCarried_{it}) = \beta_0 + \beta_1 \ln(Runways_{it}) + \beta_2 \ln(ParkingSpaces_{it}) + \\ + \beta_3 \ln(Employees_{it}) + v_{it} - u_{it},$$

$$u_{it} \sim N^+(\delta_0 + \delta_1 CompetitionPressure_{it}, \sigma_u^2),\ v_{it} \sim N(0, \sigma_v^2)$$

Results

Using the formulas presented in the Methodology section we calculated levels of competition pressure for all airports in the sample for each time point. Results for selected airports are presented in the Table 1.

Literally the level of competition pressure shows the part of the population of airport's catchment area which can choose other airports for their trips on the base of distances to airports and flights frequencies. For example, a value for London Heathrow for 2007 is 0.917, which mean that 91.7% of people living in 300 kilometres from the airport will choose other airports (London Gatwick) for their travel if they take into account distances and flights availability, but don't consider other airports' features. Another example is Riga International Airport, 67.0% of population of which potential catchment area will choose another airport (and other 33.0% will choose Riga airport).

Higher (closer to 1) values of the indicator means higher competition pressure (1 means that 100% of people have alternatives with better characteristics of distance and flights availability), lower values means lower level (0 mean that the whole population of the catchment area have no choice and should use the selected airport). The first margin is unreachable in the real situation; the second is a usual position for islands with one airport only.

The average value of the indicator equals to 0.872 and shows that the overall competition pressure is high for European airports.

Another observation is the increasing of the competition pressure level for many airports during the time interval, which is related with the growth of an available number of flights/directions.

Table 1. Levels of competition pressure of some European airports

ICAO Code	Airport Name	Average number of passengers carried, mln.	Level of competition pressure				
			2003	2004	2005	2006	2007
EGLL	London Heathrow	66.68	0.905	0.909	0.912	0.915	0.917
LFPG	Paris - Charles De Gaulle	54.81	0.875	0.871	0.879	0.885	0.886
EDDF	Frankfurt/Main	51.66	0.918	0.932	0.933	0.934	0.935
EHAM	Amsterdam/Schiphol	44.01	0.923	0.932	0.935	0.941	0.943
LEMD	Madrid/Barajas	43.65	0.589	0.597	0.597	0.601	0.602
EGKK	London Gatwick	32.90	0.918	0.919	0.922	0.923	0.925
EDDM	Munchen	29.64	0.913	0.919	0.919	0.919	0.918
LIRF	Roma/Fiumicino	28.35	0.846	0.863	0.862	0.864	0.866
LEBL	Barcelona	27.81	0.778	0.784	0.786	0.790	0.793
LFPO	Paris/Orly	24.93	0.887	0.877	0.886	0.892	0.887
EPWA	Warszawa/Okecie	7.63				0.646	0.659
EVRA	Riga International Airport	2.45			0.669	0.669	0.670
EETN	Tallinn/Ulemiste	1.49	0.607	0.721	0.715	0.716	0.708
EYVI	Vilnius	1.23			0.451	0.458	0.459

Next we grouped airports' levels of competition pressure by country. The Table 2 contains values of competition pressure for European countries. We don't use any weights for grouping airports, but included airports with more than 1 million passengers carried only into the grouping.

For many European countries there are 1-2 main airports only, which service the lion's share of population and have competition pressure from airport in neighbour countries only.

Table 2. Levels of competition pressure by countries

Country	Airports (with more than 1 mln. passengers)	Average Level of Competition Pressure		Country	Airports (with more than 1 mln. passengers)	Average Level of Competition Pressure
Austria	2	0.892		Lithuania	1	0.456
Belgium	2	0.942		Luxemburg	1	0.965
Bulgaria	3	0.653		Malta	1	0.747
Cyprus	2	0.452		Netherlands	3	0.947
Czech Republic	1	0.874		Norway	7	0.877
Denmark	2	0.901		Poland	5	0.784
Estonia	1	0.713		Portugal	5	0.714
Finland	1	0.652		Romania	1	0.602
France	18	0.929		Slovakia	1	0.893
Germany	19	0.936		Slovenia	1	0.899
Greece	8	0.834		Spain	26	0.826
Hungary	1	0.650		Sweden	5	0.833
Ireland	3	0.882		Switzerland	3	0.938
Italy	21	0.878		UK	23	0.940
Latvia	1	0.670				

Another main result of this research is construction of airport's catchment areas with the next improvements:

1. Airport's catchment area should be built with information about nearest airports and their flights availability.
2. Airport's catchment area can vary for different destinations.

The example of the first improvement is presented on the Figure 3.A, catchment areas for airports in Estonia, Latvia, and Lithuania for flights to Germany. The catchment area of the Vilnius airport is restricted by flights provided by Kaunas and Palanga airports, when the catchment area of the Riga airport is not restricted by other domestic airports.

If we compare catchment areas for flights to Germany (Fig. 3A) and to Austria (Fig. 3B) we can see the second improvement – the difference is significant. As Kaunas and Palanga airports don't provide (in 2007) a significant number of flights to Austria, the Riga and Vilnius airports captured their catchment areas for this direction.

One of shortcoming of the method (and a direction for future researches) is a catchment of passengers from outside the European Union (Russia and Byelorussia for considered Baltic countries). Actually Riga, Vilnius, Tallinn airports also catch passengers from Russia, so the calculated catchment area and relatively a level of competition pressure is less than it is in reality. Additional statistics can be used to improve this shortcoming.

We also placed international borders on the Fig.3. Some researches uses them as borders of catchment areas, but no there is material reasons to use them for this purposes. Cultural reasons (like languages, for example) are still play the roles, as well as habits of people.

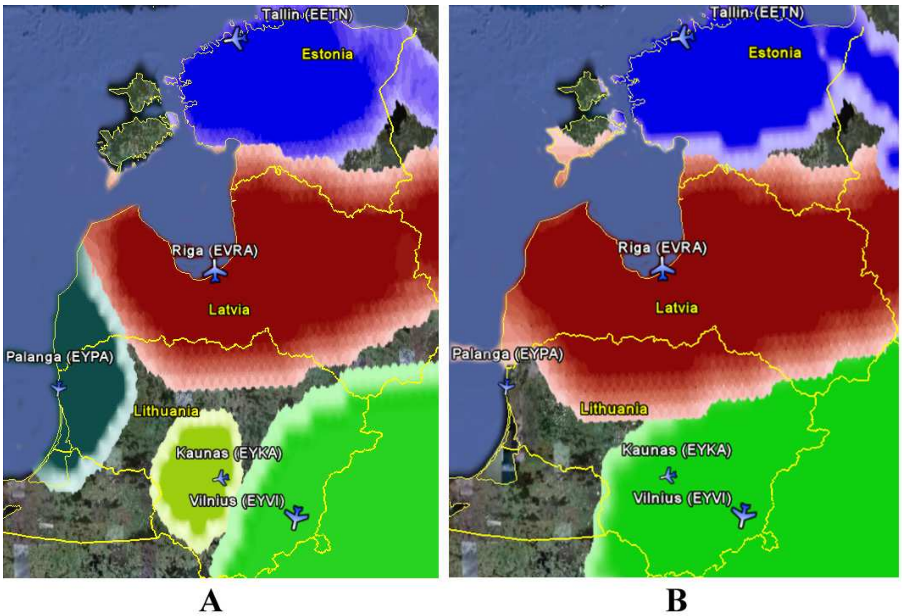

Figure 3. The Catchment Areas of Baltic Airports (A – flights to Germany, B - flights to Austria)

The next step of the research was estimating of parameters of the stochastic frontier model. The model allows us ascertaining the possible relationship between a level of competition pressure and airport's efficiency.

Usually the maximum likelihood method is used to estimate the stochastic frontier model. A well-known problem for the model is high outlier sensitivity. In this research we selected a Cobb-Douglass function which is not flexible enough, and the problem's consequences can be arisen. To reduce the problem we used the jack-knife bootstrapping procedure for estimation standard errors of coefficients. We run two different versions of the jack-knife procedure:

- with excluding a particular airport-time observation, and
- with excluding all observations for an airport.

Both procedures give the similar results, so we selected the first one for further analysis. The estimates are presented in the Table 3.

Table 3. Stochastic frontier model estimation results

	Coefficients	**Jackknife Std. Err.**	**P-value**	**90% conf. interval**	
Dependent variable					
ln(PassengersCarried)					
Frontier					
ln(Runways)	1.131	0.089	0.000	0.985	1.277
ln(ParkingSpaces)	0.070	0.036	0.053	0.011	0.129
ln(Employees)	0.365	0.049	0.000	0.285	0.446
Constant	12.670	0.298	0.000	12.178	13.161
Inefficiency					
CompetitionPressure	**-0.962**	**0.557**	**0.085**	**-1.882**	**-0.042**
Constant	1.241	0.552	0.025	0.330	2.152
Sigma_u2	0.285				
Sigma_v2	0.218				
Gamma	0.567				
Log likelihood	-253.384				

We don't pay special attention in the article to the form of the stochastic frontier (just say that signs of all estimates are expected). The main attention was oriented on the coefficient for the *CompetitionPressure* indicator (in bold in the Table 3).

The value (-0.982) is significant; the negative sign shows that higher values of *CompetitionPressure* lead to lower values of airport's inefficiency, and, obviously, higher values of airport's efficiency. So we ascertain the positive relationship between the level of competition pressure and airport's efficiency, which match our expectations based on the economic theory.

One of advantages of the stochastic frontier model is a possibility to calculate individual values of efficiency. Efficiency values of some selected airports are presented in the Table 4 (please note that the values show the efficiency of passenger carriage as described before).

Table 4. Estimated efficiency levels of European airports

ICAO Code	Airport Name	Country	Efficiency
LEMG	Malaga	Spain	83.3%
EGLL	London Heathrow	UK	78.9%
EGKK	London Gatwick	UK	78.8%
LPFR	Faro	Portugal	76.3%
EKCH	Kobenhavn/Kastrup	Denmark	75.2%
EDDS	Stuttgart	Germany	75.0%
LGIR	Irakleion	Greece	74.7%
EDDM	Munchen	Germany	72.4%
ENGM	Oslo/Gardermoen	Norway	71.7%
LEZL	Sevilla	Spain	71.5%
LFPG	Paris-Charles De Gaulle	France	69.8%
EBBR	Bruxelles/National	Belgium	64.9%
EDDF	Frankfurt/Main	Germany	64.7%
EVRA	Riga International Airport	Latvia	47.3%
EETN	Tallinn/Ulemiste	Estonia	45.2%
EYVI	Vilnius	Lithuania	34.7%
	Minimum		*24.1%*
	Maximum		*83.9%*
	Mean		*57.9%*

Conclusions

In this research we presented a new definition of airport's catchment area. The proposed definition is based on the competition ground, instead of classical direct distance or transit time measures. We consider all possible airport alternatives (for a particular direction) for population of a geographical point to calculate a share of population potentially captured by an airport. Similar calculations for each geographical point give us airport's catchment area. The competition base of our approach reflect the real situation more closely – a person has to spend a significant time for trip to an airport and should be included into airport's catchment area if he has no other alternatives. Another improvement is construction of different catchment areas for different destination points.

The next innovation of the research was the calculation procedure for the level of the competition pressure. We suggested formulas based on the new catchment area definition and the concept of overlapping catchment areas.

In the practical part of the research we calculated catchment areas for European airports and levels of the competition pressure. Some examples of calculations are presented as tables and figures in the research, but all results are omitted due to space limitations.

The main goal of the research was investigating of relationship between the level of the competition pressure and airport's efficiency level. We used the stochastic frontier model for estimating efficiency levels and found out the statistically significant positive relationship between the indicators.

Finally we can note that the methods developed and suggested in this article have a high application area and could be useful by researchers of airport's competition and efficiency.

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