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APPLICATION OF THE SPATIAL STOCHASTIC FRONTIER MODEL FOR ANALYSIS OF A REGIONAL TOURISM SECTOR

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This research is devoted to an econometric analysis of competition and cooperation on the regional tourism market between regions within the Baltic States (Estonia, Latvia, Lithuania). We estimate the relative regional efficiency levels of tourists' attraction and discovered factors affecting them. We propose an econometric approach called Spatial Stochastic Frontier, which corresponds to a spatial modification of a stochastic frontier model. The study includes three alternative specifications of the spatial stochastic frontier model: distance-based, travel-time based, and border-based. It is intended to identify the influence of existing transport networks on research results.

On the base of the models' estimation results we analyse region-specific factors (tourism infrastructure, employment, geographical position and natural attractions) which affect the numbers of visitors and estimate regions' efficiency values.

We discover a significant level of inefficiency of tourists' attraction in Baltic States region and propose some ways to improve the situation.

Keywords: spatial stochastic frontier, efficiency, competition, cooperation, regional tourism, transport network

1. Introduction

The growing importance of the tourist industry and its influence on the overall development of destination countries and regions mean that tourism policy is now strategically very important. The European Community has no direct tourism competence, but its policies in some areas have a considerable impact on tourism. The EU Commission funds sustainable tourism-related projects through the European Regional Development Fund (ERDF) in support of social and economic development. Objectives of the ERSF include a support of sustainable patterns of tourism to enhance cultural and natural heritage, develop accessibility and mobility of the related infrastructure. Environment and transport infrastructures, both of utmost importance for tourism, are also financed. All these financial instruments require an approach to regional efficiency estimation and comparison of regions' in respect of tourist's attraction.

There are many economic studies devoted to the positive effects of competition between companies in markets. Recently researchers have applied the same approach to competition between countries, administrative regions, and cities. Over the last decade tourism has increasingly become an area of competition [1, 2] between countries or regions for visitors. Competition forces regions to be more attractive for tourists and to use their resources more efficiently. Now regions can be examined not as a geographical areas with natural or heritage attractions, but as businesses, which should use all possible resources to beat their competitors and attract more tourists.

The completion between regions for tourists is growing, firstly because of increasing mobility of the population. Significant part of the population (at least in the EU) has a free choice of where to travel and spend their savings. Also the integration of the EU countries as well as EU border politics are significantly improved during last years, so the market of tourist destinations is partly in the making stage and quite flexible and mobile.

When we consider regions within a country (or several adjacent countries) as competitors, indicators of efficiency should be brought to the forefront. Being the economic units in a competitive environment, regions should be examined in terms of the efficiency of their use of resources and how this can be improved. There is very little analysis of region efficiency in the tourist literature. The majority of research in this area is at the microeconomic level, and contains efficiency analyses of hotels, restaurants, and other business units. There is little research designed to analyse efficiency at a regional level. One of the few studies in this area, that can be referred to, is the analysis of Italian tourist destinations [3], conducted by means of DEA and the Malmquist Index.

This research is intended to analyse the competitiveness and efficiency of regions within the Baltic States (Estonia, Latvia, and Lithuania). Tourism is one of the most important industries for these

countries, but there is no research, known to us, which analyses the competition between regions in this area. In all three Baltic countries the pattern of tourism is quite conservative – the capital cities (Tallinn, Riga, and Vilnius) attract the majority of tourists, and leave a small part of tourist flows for regional destinations. But the mild climate, relatively good level of service and transport network support the potential of regional tourism and provide a good source of regions' development.

One of the most important sources for development of regional tourism attractiveness is a transport network, so modelling of regional competition and efficiency requires consideration of regional spatial structure and existing transport networks. In this research we provide a spatial modification of the standard stochastic frontier model for efficiency estimation. The proposed models are based on the well-known stochastic frontier approach, frequently used for estimation of unit's relative efficiency levels, and amend it by adding a spatial component, reflecting dependencies between neighbour regions. We have applied the proposed approach to the Baltic state regional data and carried out empirical analysis of estimated results to provide some recommendations.

2. Spatial Stochastic Frontier Model

Stochastic Frontier Model

The well-known stochastic frontier model is usually presented as (in the matrix form) [4]:

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

where
y – an output;
x – a vector of resources;
f – a production function;
β – a vector of unknown coefficients;
ε – a composite error term.

The first component of a composite error term, v, shows the random variation of the efficiency frontier. The second one, u, shows the technical inefficiency of regions (as a distance from the efficiency frontier). An efficiency level of a given region i can be estimated as [5]:

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

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

Selection between the classical regression and the stochastic model is based on variances of u and v error terms. If the variance of u is significantly large relative to the total variance of the error term, then inefficiency presents in data. A γ statistic is used to check this hypothesis:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$$

If a value of γ statistics is far from 0, we accept the hypothesis about the presence of inefficiency in the data and the preference for the stochastic frontier model.

There are some different approaches to estimation of stochastic frontier model parameters, and the maximum likelihood estimator is one, which is used frequently. The classical maximum likelihood approach requires an exact distribution law for the composite error term, inherited from the stochastic model. In this research we assume a truncated normal distribution law of the inefficiency term u:

$$u \sim N^+(\delta z, \sigma_u^2)$$

The error term distribution function for the normal-truncated normal specification of the stochastic frontier model is presented in [4]:

$$f(\varepsilon)=\frac{2}{\sigma}\varphi\left(\frac{\varepsilon+\delta z}{\sigma}\right)\frac{\Phi\left(\frac{\delta z}{\sigma\lambda}-\frac{\varepsilon\lambda}{\sigma}\right)}{\Phi\left(\frac{\delta z}{\sigma_u}\right)},$$

where

$$\sigma=\sqrt{\sigma_u^2+\sigma_v^2},\lambda=\frac{\sigma_u}{\sigma_v},$$

φ and Φ are standard normal probability density and distribution functions accordingly.

Spatial Modification of the Stochastic Frontier Model

Spatial econometrics considers the possibility of geographic interaction between the economies of neighbouring regions. The general spatial autoregressive model is specified [6, 7] as:

$$y=\rho Wy+\beta X+\varepsilon,$$
$$\varepsilon=\lambda W\varepsilon+\upsilon,\upsilon\sim N\left(0,\sigma^2\right)$$

where
y – a vector of dependent variable values;
x – a matrix of explanatory variables' values;
ε – a vector of residuals;
W – a matrix of contiguity.

The feature of the model is designed in the components with the contiguity matrix W. This square matrix contains the information about inverse distances between data points, so a higher value means closer points, and zero values on the main diagonal (to exclude y values self-dependence). The authors assume that a value of the dependent variable y at a given data point depends on its own neighbour values, and closer neighbours have stronger influence. The same assumption is specified for the residuals ε.

One possible spatial modification of the stochastic frontier model [8] with the Cobb-Douglass form of the efficiency frontier and the truncated normal inefficiency component is:

$$\ln(y)=\rho W\ln(y)+\beta\ln(X)+\nu-u,$$
$$u\sim N^{+}(\lambda Wy+\delta z,\sigma_u^2),$$
$$\nu\sim N(0,\sigma_v^2)$$

The definition of the W contiguity matrix can be different and vary between research studies. Usually distances are specified as geometrical Euclidean distances, or as great-circle distances (in the case of significant geographical remoteness of data points). This specification is the most popular, but not the only one. In some researches (including this paper) it is necessary to include real journeys within the model, so the matrix with inverse travel time or cost values matches the real situation better. In our research we have used and compared both approaches. The dDetailed analysis is presented in the Model Specification section.

One of the main points of the research is the values of ρ and λ parameters. Parameter ρ shows the influence of model output values (the number of tourists) in neighbouring regions on the output in a given region. Our reasoning states that this influence can be regarded as positive (cooperation of regions), or as negative (competition between regions) [9]. The analysis of the ρ value will answer this major research question.

Parameter λ shows the influence of output values in neighbouring regions on efficiency in a given region. We expect a positive influence here, because both cooperation and competition should improve an economic unit's efficiency in a healthy economy.

3. Data

Panel data used in the research includes information about regions of Latvia, Estonia and Lithuania between 2005 and 2008 (data for 2009 are not yet completely available).

The division of these countries into regions is not well-defined and can cause some problems. We used the Nomenclature of Units for Territorial Statistics level 3 (NUTS 3) approach to define regions in Estonia and Lithuania (15 and 10 regions respectively), but not for Latvia. In NUTS3 Latvia comprised only 4 regions, which are significantly larger than the regions in Estonia and Lithuania, and appear to bevery heterogeneous. For this reason we used the same approach as the National Statistical Office of Latvia to divide the regions. 26 regions of Latvia correspond in terms of size and population with NUTS3 regions of Estonia. The regions of Lithuania are significantly larger (approximately twice the size, see Table 1), but their separation was impossible due to a shortage of information. Statistical data about smaller Lithuanian regions (municipalities) were provided by the National Statistical Office starting from 2009 only. We think that this discrepancy is a matter of scale only and is not a matter of 'production' differences (which are critically important for a frontier model) and that the discrepancy does not affect the received results significantly. We have incorporated dummy variables into the model to capture a possible effect of the difference in Lithuanian regions' definition.

The statistical information was collected from the following sources:

- National statistical offices of the Baltic states provided information about the number of tourists visiting a given region, the number of hotel beds, the number of enterprises in tourism-related sectors (according to NACE rev.2 classification), and also information about the area of the region, its population and road coverage. These parameters are described in detail in the Model Specification section.
- Schedules of railways and regional coach services are used for collecting data regarding travel time between regional centres.
- TomTom (a digital mapping and routing company) is used for information about road distances and travel time by car between regional centres.
- The Museums Associations of Latvia, Lithuania, and Estonia supplied information about the number of museums in each region.
- GIS system (Google Earth) is used for information about the geographical coordinates of regions and natural tourist attractors (sea-side, national parks).

Table 1. Descriptive statistics for used indicators

	Total	**Estonia**			**Latvia**			**Lithuania**		
Variable	*Mean*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
Tourists, people	73902	79276	8975	257930	23147	2043	97580	182576	13073	755013
Hotel beds	1609.8	1400.9	184	4752	516.2	71	1673	4766.5	263	16975
Labour, enterprise	1976.4	974.6	183	3019	618.6	177	2364	7009.3	1395	23987
Museums, count	15.9	16.5	4	38	4.8	1	14	43.8	22	86
Area, sq. km	3390	2895	1023	4806	2467	1628	3652	6530	4350	9731
Population, people	113713	62887	10118	170719	57613	24159	167774	335811	126717	848956
Roads/area ratio, km/sq.km	0.706	0.397	0.273	0.546	0.805	0.549	1.081	0.911	0.652	1.128

Capital cities (Riga, Tallinn, Vilnius) were excluded from the analysed data set as outlier – numbers of tourists, attracted in these cities, exceed number of tourists in all the other regions put together. Also Jurmala city was excluded using the same logic. The distribution of a number of visitors per capita is presented on Figure 1.

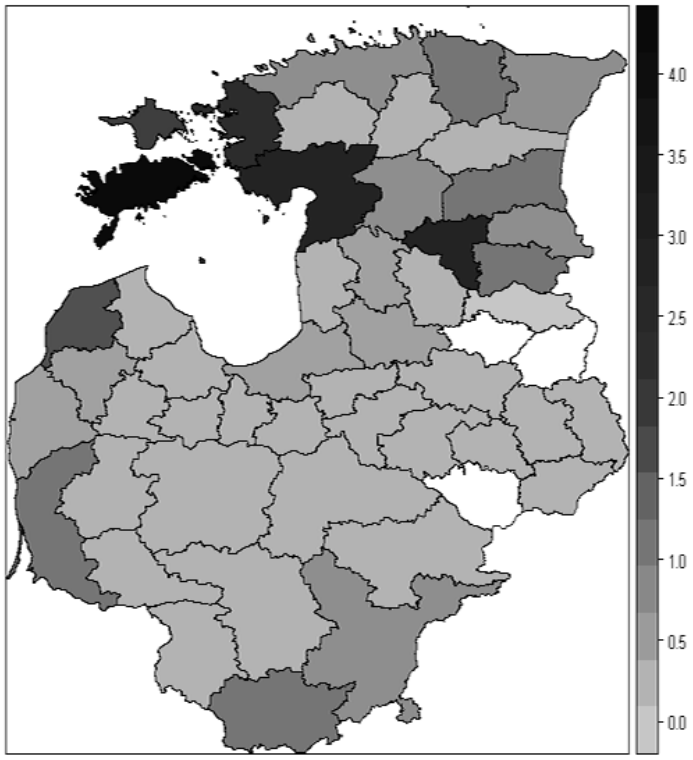

Figure 1. Number of tourists per capita in Baltic States regions

The distribution of tourists is not uniform – sea-side regions have expected larger values due to natural attractors for leisure and significant numbers of international businesses and volumes of passenger and cargo traffic (generally, via sea-ports).

4. Model Specification

The specification of the spatial stochastic frontier model includes output and resource parameter selection and definition of the contiguity matrix.

In this research we consider a region as an economic unit, which uses its own resources to attract and service tourists. The term 'tourists' can mean different things. It can refer to people who are accommodated in a region, but also to people who are just visiting the region; day-trip tourists or people in transit through the region. Tourists can be classified according to the purpose of their trip – business or private. We assume (and data collected by national statistical offices support this assumption) that the most important tourists for a region economy are those who are accommodated in the region. Usually a tourist who is accommodated in a given region spends a significant amount of time in that region and "supports" the region economy through spending money and using local services. For this reason, as a dependent variable, we chose the number of tourists (*tourists*) staying at least one night in a hotel, motel or any other kind of accommodation establishment. This definition of the dependent variable should add a value to the 'competition' scale pan of the 'competition-cooperation' scales.

The set of explanatory variables includes resources used in a given region to attract and service tourists. We include a region tourism infrastructure in the model in the form of a number of beds available in hotels and other types of accommodation (*beds*). This conforms to our definition of tourists. We also assume a strong relationship between the number of beds offered and other tourism facilities.

We have included the number of enterprises in tourist-related sectors as a service quality and labour force parameter. Generally, it is impossible to separate enterprises serving tourists and residents, therefore we have used the total number of enterprises in chosen sectors of the economy. We have used the NACE rev.2 classification and selected the following economic sectors as related to tourism: wholesale and retail trade; repair of motor vehicles and personal and household goods (class G); transportation and storage (H); accommodation and food services (I), information and communications (J). The final parameter used (named *services*) was calculated just as the total number of enterprises in the chosen sectors.

Transport infrastructure was included in the model in two different forms. The first one is related to the level of region accessibility for international tourists. We have considered the distance to the nearest airport/sea port (*nearestGate*) as an accessibility metric. The distance was measured in kilometres, travel time by car, train and coach. Usually regions in the Baltic countries have good connections of all types with the nearest airport, so all 4 parameters were highly correlated. We chose only one region's accessibility parameter (travel time by car) to avoid the multi-colleniarity problem. No distance decay functions were applied.

The second transport-related parameter was constructed to include local transport infrastructure in the model. We haveused a ratio of the total road lengths of a region and the regionarea as a metric (*road_coverage*), because usually all tourist movements within a region in the Baltic states are done by car or bus.

We have considered museums, castles and palaces as man-made tourist attractions. After data collection we have discovered a strong relationship between the numbers of this kind of attraction. Therefore, we have used only one of them (the number of *museums*) in the final model specification.

Natural attractions were included in the model in the form of a dummy variable for the sea-side (*sea*, yes/no) and the number of national nature parks (*natparks*) in a region.

An important parameter of the spatial stochastic frontier model is a contiguity matrix *W*. This matrix presents distances between regions in the model and can be defined in different ways [10].

The simplest method of defining the *W* matrix is as an inverse Euclidian distance between the regional centres. According to this approach we calculate the distances between regions in terms of kilometres between their main cities. The method can be modified by taking the spherical surface of the Earth into account (a great-circle distance). In this study we have filled this matrix with simple Euclidian distances between regional centres and restricted the distance with 1 (about 110 km). The model with this continuity matrix is called Model DIST.

The main disadvantage of this approach is obvious – being geographically close generally does not mean being accessible easily. There may be no road between two points or the road distance may be significantly longer than the direct distance. Matrix definition is a critical point for spatial models, so we have used an alternative approach to compare the estimation results. We have defined an alternative contiguity matrix on the basis of travel time between regional centres by car. This alternative model specification is noted as Model ROAD. Travel time reflects the real distance between regions more precisely and differs significantly from the geographical distance (see Figure 2). We calculate the coefficient of correlation between the models distance and travel time spatial components (*W·tourists*) and discovered an absence of a significant relationship (correlation = 0.06, p-value = 0.37).

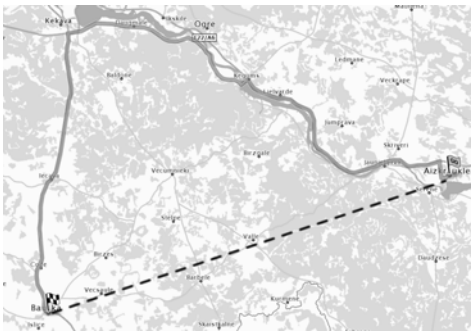

Figure 2. Geographical and road distances

The travel time-based contiguity matrix is adequate for use in cases of point-type economic units. Obviously, regions have areas, so the distance between the regional centres does not always reflects the distance between regions fairly.

Another possible approach is based on a binary contiguity matrix, which is constructed solely on the basis of direct borders between regions. There are two most frequently used border-based approaches – Rook and Queen. The names of approaches are derived from the chess terminology and are self-explaining – the Rook definition of contiguity is a direct edge-to-edge contact of units, and the Queen definition includes both edge-to-edge and vertex-to-vertex contact types. In this research we haveapplied a distance based modification of border-type contiguity. Two regions are considered as neighbours if the distance between their two nearest points is less than a predefined limit. The limit can be chosen in different ways, we have chosen a minimal distance, which provides at least one neighbour for all objects in the sample. The relevant model is called Model BORDER.

An efficiency frontier form can vary during the observable time interval (2005-2008). This variation can be caused by changes in the economies of the Baltic States and other general factors. We have included the time variable (*years*) in the specification of the efficiency frontier and as an explanatory variable for a regions inefficiency level. We have received insignificant values of the considered parameters in both cases and decided to exclude the time variable from the model. Therefore, we conclude that no significant changes in regional tourism efficiencies occurred during the period of the study.

Another model specification hypothesis was related to the different countries specifics. Estonia, Latvia, and Lithuania are significantly different in terms of economics and politics, and differences in regional tourism are also possible. We have included dummy variables for Estonia (*EE*) and Lithuania (*LT*) into the models to check for permanent differences of regional tourism efficiency frontiers between countries.

In addition to country-specific differences in the efficiency frontier position, we have investigated the possible differences in the main 'competition-cooperation' area. It is possible that the level of competition (or cooperation) between regions varies between countries. We have included cross dummy variables $EE \cdot \ln(W \cdot tourists)$ and $LT \cdot \ln(W \cdot tourists)$ to test this hypothesis.

The final model specification with the Cobb-Douglass form of the efficiency frontier and truncated normal distribution of the inefficiency component after removing insignificant explanatory variables is:

$$\begin{aligned}\ln(tourists) = {} & \rho W \ln(tourists) + \beta_1 \ln(beds) + \beta_2 \ln(services) + \beta_3 \ln(museums) + \\ & + \beta_4 \ln(nearestGate) + \beta_5 sea + \beta_6 EE + \beta_7 LT + \\ & + \beta_8 EE \cdot W \cdot \ln(tourists) + \beta_9 LT \cdot W \cdot \ln(tourists) + v - u,\end{aligned}$$

$$u \sim N^{+}(\lambda W \cdot \ln(tourists), \sigma_u^2), v \sim N(0, \sigma_v^2)$$

5. Empirical Results

Using the presented specification of a spatial stochastic frontier model we have constructed four alternative models:

1. Model NOSPAT – stochastic frontier model without spatial components;
2. Model DIST – spatial stochastic frontier model with distance-based contiguity matrix;
3. Model ROAD – spatial stochastic frontier model with travel time-based contiguity matrix;
4. Model BORDER – spatial stochastic frontier model with border-based contiguity matrix.

The Models' estimation results are presented in Table 2.

Table 2. Estimation results of three alternative models: Model NOSPAT (without spatial components), Model DIST (distance contiguity matrix), and Model ROAD (travel time contiguity matrix)

	Model NOSPAT		**Model DIST**		**Model ROAD**		**Model BORDER**	
Dependent variable	ln(*tourists*)		ln(*tourists*)		ln(*tourists*)		ln(*tourists*)	
Frontier Estimates	*Coefficient*	*p-value*	*Coefficient*	*p-value*	*Coefficient*	*p-value*	*Coefficient*	*p-value*
ln(*beds*)	0.878	0.000	0.890	0.000	0.843	0.000	0.885	0.000
ln(*nearestGate*)	0.003	0.896	0.043	0.027	0.028	0.307	0.341	0.009
ln(*services*)	0.300	0.000	0.387	0.000	0.306	0.000	0.018	0.700
ln(*museums*)	-0.107	0.094	-0.264	0.000	-0.214	0.002	-0.170	0.114
$W \cdot \ln(tourists)$, ρ			-0.091	0.002	-0.094	0.014	-0.002	0.981
Sea	0.163	0.043	0.099	0.078	0.271	0.000	0.320	0.019
EE	0.502	0.000	3.706	0.000	1.579	0.025	0.505	0.016
LT	-0.271	0.087	2.213	0.000	0.610	0.120	-0.031	0.914
$EE \cdot W \cdot \ln(tourists)$			-0.227	0.002	-0.114	0.132		
$LT \cdot W \cdot \ln(tourists)$			-0.174	0.000	-0.066	0.083		
Constant	2.841	0.000	3.682	0.000	4.161	0.000		
Inefficiency component								
$W \cdot \ln(tourists)$, λ			-0.491	0.000	-0.152	0.011		
Constant	-1.179	0.745	6.603	0.000	1.753	0.001		
Statistics								
Log likelihood	-78.393		-50.518		-59.226			
γ	0.921		0.983		1.000		1.000	

Firstly, we need to test the validity of the usage of the stochastic frontier and their dominance over the simple regression. The γ-statistic values for all models are near to 1 (significantly higher than 0), so we state the presence of inefficiency in the data, and prefer the stochastic frontier models.

We have used the likelihood-ratio test to compare spatial and non-spatial model specifications:

$$P\{LR > \chi^2_{crit}(4)\} = P\{2(Ln(H_1) - Ln(H_0)) > \chi^2_{crit}(4)\} =$$
$$= P\{2(-59.226 - (-78.393)) > \chi^2_{crit}(4)\} = P\{38.334 > \chi^2_{crit}(4)\} = 0.000$$

Therefore, we reject the model without the spatial components and accept the spatial stochastic frontier models. A difference in efficiency estimates between spatial and non-spatial models will be discussed later in this section.

The Model BORDER is the only model with the spatial component, which shows insignificant spatial effects in data. This result can be explained by incorrectness of the border-based approach for this data sample. The problem of a correct formulation of contiguity is well-known in spatial econometric literature. The comparison of two other alternative spatial model specifications (Model DIST and Model ROAD) is not only a statistical task, but also a matter of interpretation. The essence of these two models is different, and a researcher can choose one or the other depending on the goals of his research. We havechosen the model based on travel time (Model ROAD) for analysis in this research.

The majority of Model ROAD coefficient estimates are significant and match our expectations. The number of beds in hotels and the number of enterprises in tourism-related sectors have a significant positive influence on the number of tourists, so these predictably can be considered as important resources for regional tourism. This relationship is bidirectional; businesses adapt to the real economic situation and develop in regions with higher numbers of tourists.

The locational characteristics of regions also influence significantly the tourist numbers. The sea-side is one of the most powerful attractions in the Baltic States and has, as expected, a significant positive value. The influence of travel time from the nearest airport/port is significant in the Model DIST, but not significant in the Model ROAD. This can be easily explained using the fact that the travel time is already included in the Model ROAD for regions located near to main gates (in form of the contiguity matrix), and possibly there is no significant difference for other regions (due to the law of distance-decay).

The only unexpected parameter value is the negative influence of the number of museums in a region. The fact that having a large number of specialised museums may not act as a tourist attractor is predictable, but the negative sign is more difficult to explain. We do not make any assumptions or conclusions about this result in this study. It is a point that requires additional investigation.

The dummy variable *EE* (specifics of Estonia) has a significant positive sign, so we conclude that Estonian regions have a higher level of efficiency. This can be explained by the strong relationships between Estonia and Finland (including the tourism sector). More than 35% of tourists, visiting Estonia in 2008, arrived from Finland. In addition the lower crime rate and more stable political atmosphere can be considered as a reasons for the positive distinction in favour of Estonia (for example, according to Transparency International's Corruption Perception Index 2009, Estonia occupies 27th place while Lithuania and Latvia are 52nd and 56th respectively). The dummy variable for Lithuania also tends to be positive, but in the Model ROAD it is insignificant, so we do not distinguish between Latvia and Lithuania in terms of tourist attraction.

Analysis of competition and cooperation between regions in the Baltic states is one of the main points of this research. The spatial component $W\cdot\ln(tourists)$, included in the models, has a significant negative value (ρ) for both cases. This means that tourists accommodated in a neighbouring region cannot be considered as a resource for a given region, but quite the contrary. They have a negative influence on the region tourists numbers. So we state that **competition between regions for tourists is present in all Baltic states**.

This fact can be explained in different ways. Firstly, as we have used the number of accommodated tourists as a dependent variable, this conclusion shows that tourists prefer to stay in one particular region and visit neighbouring regions (if at all) as one-day trips.

The second reason for competition between regions is a shortage of organised tours in the Baltic States. Most of these tours are still country-oriented and usually have a base region where the tourists stay, several one-day trips to neighbouring regions. The development of tours, offering several nights stay in different regions, would improve the level of regional cooperation.

In addition we haveanalysed the cross-dummy variables to discover the differences in competition levels between the countries, but in our final model these effects are insignificant (though with a tendency to higher competition levels in Estonia and Lithuania).

As we have stated, for competition between regions for tourists we expect a relation between spatial component and regional efficiency levels. Economic theory postulates that a higher level of competition leads to a higher efficiency of economic units. In our case, we observe this effect via the value of λ coefficient. According to the stochastic frontier model specification, the negative sign of this coefficient decreases the value of region inefficiency u, and so has a positive influence on its efficiency. This can be stated as another very important conclusion of this research.

The stochastic frontier approach allows us to calculate efficiency level values for a given region for every time point. We have presented the average efficiency values (2005-2008 years) in Table 3 and their geographical distribution in Figure 3.

Table 3. Model ROAD and Model NOSPAT estimates of region efficiency levels

Latvia			**Estonia**			**Lithuania**		
Region	*Model ROAD, %*	*Model NOSPAT, %*	*Region*	*Model ROAD, %*	*Model NOSPAT, %*	*Region*	*Model ROAD, %*	*Model NOSPAT, %*
Ventspils	93	93	Laane	93	93	Taurage	87	92
Valmiera	89	89	Saare	82	81	Siauliai	84	87
Cesis	80	80	Viljandi	77	82	Alytus	79	82
Ogre	75	83	Parnu	73	78	Vilnius	79	80
Jekabpils	70	79	Polva	70	72	Marijampole	61	78
Preili	68	74	Voru	69	72	Kaunas	59	69
Bauska	68	79	Tartu	69	74	Klaipeda	41	56
Saldus	68	80	Jarva	67	78	Utena	38	61
Kuldiga	67	81	Jogeva	66	75	Telsiai	32	54
Riga region	64	67	Harju	65	67	Panevezys	27	39
Madona	58	73	Hiiu	64	77			
Jelgava	57	74	Laane-Viru	62	75			
Valga	56	62	Valka	48	64			
Liepaja	54	83	Rapla	40	53			
Limbazi	48	76	Ida-Viru	38	56			
Aizkraukle	46	62						
Daugavpils	46	63						
Talsi	45	65						
Kraslava	41	64						
Tukums	39	54						
Aluksne	34	50						
Ludza	30	49						
Rezekne	20	31						
Average	**59%**			**70%**			**60%**	

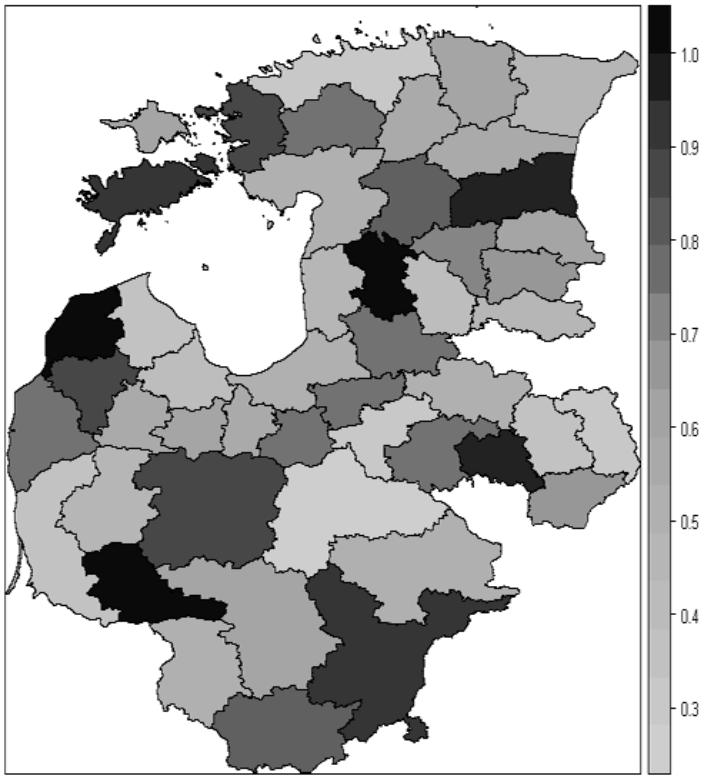

Figure 3. Map of regions' efficiency levels (Model ROAD)

The average value of the region efficiency levels is 63%, so regions have a significant internal potential and could attract 58.7% tourists more (37/63 = 0.587) using the available resources and increasing the efficiency of their utilization.

Estonian regions are relatively more efficient (70%) than the regions in Latvia and Lithuania (59% and 60% respectively), and there is no significant difference between Latvian and Lithuanian regions. Also it can be noted that Latvian and Lithuanian regions are more heterogeneous than regions in Estonia. A complete analysis of regions is beyond the scope of this research.

One of the main goals of this research is the comparison of spatial and non-spatial stochastic frontier models. Estimates of parameters (Table 2), included in both models, correlate to each other and the models look similar. Differences between the models efficiency estimates are presented in the Tables, but they should not be analysed directly, because generally efficiency estimates of different model specifications are non-comparable. Values, presented in the tables, allow conclusions about the patterns of the efficiency estimates to be made, not the numbers themselves. We can conclude that the application of the spatial model does not affect the central regions (Riga, Vilnius, Harju) and regions without powerful neighbours (Saare) significantly. However, efficiency estimates for regions located near the popular centres for tourists accommodation are changed significantly under the influence of a spatial structure inclusion (Liepaja, Rapla, Telsiai). This result is economically explainable and can be considered as evidence for the utility of spatial stochastic frontier models.

6. Conclusions

In this paper we have proposed a spatial modification of the stochastic frontier model for estimation of efficiency of units with strong spatial dependencies. The model is a combination of stochastic frontier approach, frequently used for econometric estimation of efficiency, and a spatial autoregressive model. This enhancement allows including spatial relationships as a possible resource used by an economic unit for its purposes. Also the spatial relationships can be used to explain the observed levels of inefficiency. The proposed model was applied to data sample of regions in the Baltic States as places for tourists accommodation. We have used information about the regional spatial structure to estimate the effects of competition for tourists between regions and its influence on the relative efficiency levels.

We have estimated parameters of the suggested model for data about Estonian, Latvian, and Lithuanian regions between 2005 and 2008. This model allows us to distinguish the effects of different factors (inputs) on the regions attractiveness for tourists and efficiency levels. We have discovered a significant positive relationship between a number of tourists attracted and infrastructure objects (hotels) and transport ways (travel time to the nearest airport). Also significant positive effects of a sea-side have been confirmed.

The suggested model was estimated using three different approaches to the spatial contiguity – geographical distance-based, travel-time based, and border-based. We have also investigated unobservable country-specific effects via including dummy variables for the countries in the model. We have compared the spatial models against the model without spatial components and have noted the considerable advantages (theoretical and empirical) of the spatial models.

We have discovered that the competition effects in the Baltic States are stronger than the cooperation ones. Regional tourism in the Baltic countries is still separated significantly, and the development of transport networks and international holiday tours is highly desirable. We have found a significant positive relationship between competition between adjacent regions and those regions efficiency levels. This matches our economic expectation.

We have also estimated the efficiency levels of the regions and found a significant level of inefficiency in all three Baltic States.

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