ASSESSMENT OF REGIONAL EFFICIENCY IN CROATIA USING DATA ENVELOPMENT ANALYSIS

Danijela Rabar
Juraj Dobrila University of Pula
Department of Economics and Tourism "Dr. Mijo Mirković"
Preradovićeva 1, 52 100 Pula, Croatia
E-mail: danijela.rabar@unipu.hr

Abstract

In this paper, regional efficiency of Croatian counties is measured in three-year period (2005-2007) using Data Envelopment Analysis (DEA). The set of inputs and outputs consists of seven socio-economic indicators. Analysis is carried out using models with assumption of variable returns-to-scale.

DEA identifies efficient counties as benchmark members and inefficient counties that are analyzed in detail to determine the sources and the amounts of their inefficiency in each source. To enable proper monitoring of development dynamics, window analysis is applied. Based on the results, guidelines for implementing necessary improvements to achieve efficiency are given. Analysis reveals great disparities among counties.

In order to alleviate naturally, historically and politically conditioned unequal county positions over which economic policy makers do not have total control, categorical approach is introduced as an extension to the basic DEA models. This approach, combined with window analysis, changes relations among efficiency scores in favor of continental counties.

Key words: *Data envelopment analysis, Regional efficiency, County, Window analysis, Categorical variables*

1. INTRODUCTION

Regional efficiency and possibilities of its improvement have become one of the leading imperatives of all world economies. This paper is the result of a research related to multicriterial evaluation of the achieved regional development level in Croatia.

The purpose of this paper is to present the results of the analysis of regional efficiency in Croatia using Data Envelopment Analysis (DEA) investigating the possibility of application of different extensions to DEA models in the treatment of the same problem.

DEA is a non-parametric productive efficiency measurement method for operations with multiple inputs and multiple outputs. This approach first establishes an efficient frontier formed by a set of decision making units (DMUs) that exhibit best practices and then assigns the efficiency level to other non-frontier units according to their distances to the efficient frontier. In this way the method combines and transforms multiple inputs and outputs into a single efficiency index.

The study of Liu et al. (2013) surveys the DEA literature by applying a citation-based approach and rates Charnes, Cooper and Rhodes (1978, 1981), Banker, Charnes and Cooper (1984) and Charnes et al. (1985) as four most influential papers in DEA development. The same study identifies five major branches of DEA literature, or in other words, five active DEA subareas: “two-stage contextual factor evaluation framework”, “extending models”, “handling special data”, “examining the internal structure” and “measuring environmental performance”. While the papers in the first four subareas are mostly studies of theoretical orientation, the papers in the last subarea are basically application works that, among others, include the applications of DEA on regional performance evaluation.

An interesting and often cited example in the international literature is evaluation of the relative achievement of regional development in 23 administrative regions of Taiwan in 1990, in which the use of DEA was extended by merging with the Malmquist productivity approach to determine whether the relative change of their regional development moved forwards or backwards between 1983 and 1990 (Chang, Hwang and Cheng, 1995).

DEA is relatively rarely used in the measurement of regional efficiency in Croatia. Among the first to address this issue were Babić and Grčić (1999) who evaluated relative regional development level for Croatian counties and macroregions in 1991 comparatively using two multicriterial analysis methods – PROMETHEE and DEA.

Although the DEA method itself is present in the literature concerning the assessment of regional efficiency, the combination of categorical approach and window analysis is original as well as the use of unique combination of inputs and outputs. The results of the study underline the importance of combining categorical approach and window analysis for future research.

2. DATA AND MODEL SETUP

Croatian counties represent 21 entities whose relative socio-economic efficiency is evaluated in this paper. The choice of indicators for the purposes of this study followed the subsequent line of thought: capturing human and material components and living standards as three outstanding criteria for determining the degree of socio-economic development; exact measurability of indicators; availability and accessibility of data on indicators. In addition, in any DEA application, it is suggested as rule of thumb that the number of entities should be at least three times the number of indicators (Banker et al., 1989).

Accordingly, seven socio-economic indicators[1] are included into analysis. The inputs are represented by registered unemployment rate and number of support allowance users. The outputs are share of the secondary sector in gross value added (GVA), gross fixed capital formation in fixed assets (by headquarter of investor), level of import coverage by export[2], number of graduated students (by residence) and gross domestic product (GDP). Data for these indicators are relating to the period 2005-2007 and were taken from the Croatian Employment Service, the Croatian Bureau of Statistics and the Ministry of Health and Social Welfare of the Republic of Croatia[3].

Basic DEA models commonly used in applications are CCR (Charnes, Cooper and Rhodes, 1978) and BCC (Banker, Charnes and Cooper, 1984). CCR model is built on the assumption of constant and BCC model on the assumption of variable (either increasing or decreasing) returns to scale activities. In addition, the DEA model can be adjusted to the strategy chosen by management and therefore oriented on input reduction (*input-oriented model*) or on output augmentation (*output-oriented model*).

Let us consider the set of *n* DMUs. Each of them (DMU_j, j = 1, 2, ..., n) produces *s* outputs and for their production uses *m* inputs. Let us denote $x_j = \{x_{ij}, i = 1,2,...,m\}$ the vector of inputs and $y_j = \{y_{rj}, r = 1,2,...,s\}$ the vector of outputs for the DMU_j. Then the data set is given by two matrices – the matrix of inputs: $X = (x_{ij}, i = 1,2,...,m, j = 1,2,...,n)$ and the matrix of outputs: $Y = (y_{rj}, r = 1,2,...,s, j = 1,2,...,n)$.

The basic principle of DEA models in evaluation of efficiency of the DMU_o, $o \in \{1, 2, ..., n\}$[4] consists in looking for a virtual DMU with inputs and outputs defined as the linear combination of inputs and

[1] The variables for which smaller amounts are preferable will be considered inputs, while those for which larger amounts are preferable will be considered outputs.
[2] level of import coverage by export = (total exports / total imports) *100
[3] The data were adjusted as follows: numbers of support allowance users and graduated students were taken per 100,000 inhabitants while capital formation and GDP were taken per capita at constant prices of the year 2005.
[4] The following procedure is based on Cooper, Seiford and Tone, 2006, pp. 87-89.

outputs of the other DMUs in the decision set, i.e. $X\lambda$ and $Y\lambda$, where $\lambda = (\lambda_1, \lambda_2, ..., \lambda_n)$, $\lambda > 0$ is the vector of weights (coefficients of linear combination) of the DMUs. The virtual DMU should be better (or at least not worse) than the analysed DMU$_o$. The problem of looking for a virtual DMU can generally be formulated as standard linear programming problem:

Input-oriented model		**Output-oriented model**		
$(BCC - I_o)$	$\min \theta_B$	$(BCC - O_o)$	$\max \eta_B$	
subject to	$\theta_B x_o - X\lambda \geq 0$	subject to	$X\lambda \leq x_o$	(1)
	$Y\lambda \geq y_o$		$\eta_B y_o - Y\lambda \leq 0$	(2)
	$e\lambda = 1$		$e\lambda = 1$	(3)
	$\lambda \geq 0$		$\lambda \geq 0$	(4)

where e is a row vector with all elements equal to 1. Conditions (1) consist of m, conditions (2) of s, and conditions (4) of n constraints. In our case, n = 21, m = 2, s = 5. Vector λ shows the proportions contributed by efficient DMUs to the projection of DMU$_o$ onto efficient frontier. The optimal objective value θ_B^* ($0 < \theta_B^* \leq 1$) in the input-oriented model is the efficiency result, and for inefficient DMU$_o$ also the input reduction rate. In the output-oriented model, the optimal objective value η_B^* ($\eta_B^* \geq 1$) is the reciprocal of the efficiency result, and for inefficient DMU$_o$ also the output enlargement rate. This makes the most important difference between input-oriented and output-oriented BCC models.

It is obvious from constraints (1) and (2) that in the input-oriented model $(X\lambda, Y\lambda)$ outperforms $(\theta_B^* x_o, y_o)$ when $\theta_B^* < 1$. With regard to this property, the input *excesses* $s^- \in \mathbf{R}^m$ and the output *shortfalls* $s^+ \in \mathbf{R}^s$ are defined and identified as „slack" vectors by

$$s^- = \theta_B x_o - X\lambda, \quad s^+ = Y\lambda - y_o,$$

with $s^- \geq 0$, $s^+ \geq 0$ for any feasible solution (θ_B, λ) of $(BCC - I_o)$.

To discover the possible input excesses and output shortfalls, a two-phase procedure is used. In the first phase, θ_B is minimized and, in the second phase, the sum of the input excesses and output shortfalls is maximized keeping $\theta_B = \theta_B^*$ (the optimal objective value obtained in the first phase).

Definition 1 (BCC-Efficiency):

If an optimal solution $\left(\theta_B^*, \lambda^*, s^{-*}, s^{+*}\right)$ *obtained in this two-phase process satisfies* $\theta_B^* = 1$ *and has no slack (* $s^{-*} = 0$ *,* $s^{+*} = 0$ *), then the DMU$_o$ is called* BCC-efficient, *otherwise it is* BCC-inefficient.

Definition 2 (Reference Set):

For a BCC-inefficient DMU$_o$, its reference set E_o *is defined based on an optimal solution* λ^* *by*

$$E_o = \left\{ j \middle| \lambda_j^* > 0 \right\} \ \left(j \in \{1, 2, ..., n\} \right).$$

An optimal solution can be expressed as

$$\theta_B^* x_o = \sum_{j \in E_o} x_j \lambda_j^* + s^{-*},$$

$$y_o = \sum_{j \in E_o} y_j \lambda_j^* - s^{+*}.$$

These relations suggest that the efficiency of $\left(x_o, y_o\right)$ for DMU$_o$ can be improved if the input values are reduced radially by the ratio θ_B^* (thus removing technical inefficiency) and the input excesses recorded in s^{-*} are eliminated, and if the output values are augmented by the output shortfalls in s^{+*} (thus removing mix inefficiency). Described improvement can be expressed by the following formula known as *the BCC-projection:*

$$\hat{x}_o = \theta_B^* x_o - s^{-*},$$

$$\hat{y}_o = y_o + s^{+*}.$$

Using an analogous procedure, the slack $\left(t^-, t^+\right)$ of the output-oriented model is defined by $t^- = x_o - X\lambda$ and $t^+ = Y\lambda - \eta y_o$, while the projection is expressed by:

$$\hat{x}_o = x_o - t^{-*},$$

$$\hat{y}_o = \eta_B^* y_o + t^{+*}.$$

Based on the foregoing, it is evident that efficiency scores, reference sets and projections of inefficient DMUs depend on model orientation, while the efficient frontier does not.

The need for the monitoring of regional development dynamics, which is extremely important for economic policy makers, leads to the use of window analysis as one of the extensions to DEA models.

In that case, data for several periods for each DMU are included into analysis, and each DMU is regarded as if it were a different DMU in each of the reporting periods.

Another issue in evaluating the relative efficiency is dealing with situations when DMUs operate under different conditions over which they do not have total control. In such cases, the evaluation of all DMUs on equal footing would be unfair to those in worse position. The solution is proposed with the use of categorical approach that provides appropriate comparisons by dividing DMUs into L categories. Thus, DMUs in category 1 are in the most disadvantageous condition and will be compared only among themselves. DMUs in category 2 are in a better position than those in category 1, and will be compared with reference to DMUs in categories 1 and 2 and so on. In conclusion, DMUs in category L will be compared with reference to all DMUs. This way, evaluating the efficiency by comparing DMUs in worst position with those in better position is avoided.

3. MODEL APPLICATION AND EMPIRICAL RESULTS

Knowledge of the production frontier characteristics for the process to be analyzed is crucial for model type selection. Since that could not be determined with certainty in the case of regional performance, the analysis was carried out under both (constant and variable returns-to-scale) assumptions. It appeared that differences between the results obtained by CCR and BCC model were significant. They may be attributed to the return effect with respect to the range of activities thus making the BCC model more suitable for describing the analyzed socio-economic activity.

Since economic growth is aimed at decreasing all here selected inputs and increasing all here selected outputs at the same time, both orientations are utilized and the obtained results are compared.

The assessment of Croatian counties' relative efficiency is performed in two steps, based on empirical data on seven socio-economic indicators, and computed by program package DEA-Solver-Pro 7.0F (Saitech, Inc.). Due to the nature of selected indicators, comparisons of the counties were made on a yearly basis.

The first step of this research was carried out using window analysis. Since a three-year period 2005-2007 is chosen, the window (i.e. the period within which the comparisons are performed) ranges from one to three years. For the purposes of this study, one window which includes all three years is used. The relative efficiency results are listed in Table 1. Among 63 observed entities, 15 turned out to be efficient. The highest efficiency results were achieved in 2007 toward both orientations. None of the 21 counties were efficient during the entire period. The worst efficiency results according to the number of efficient counties were achieved in 2006, while the lowest average efficiency was achieved in 2005. Average efficiency scores for all three periods are greater in output orientation than in input orientation. The differences related to orientation are extreme in certain aspects, for instance, in minimum efficiency scores. However, it does not mean that the efficiency is easier to achieve toward output-orientation because that depends on the specific situation in which particular county operates. Large differences between the average and worst efficiency results give evidence of great regional disparities in Croatia.

Table 1: Window analysis results – one window (2005-2006-2007)

County	Relative efficiency results							
	Input-orientation				Output-orientation			
	2005	2006	2007	Average per county	2005	2006	2007	Average per county
City of Zagreb	0.8162	0.8741	1	**0.8968**	0.9888	0.9735	1	**0.9874**
Zagreb	1	0.7345	0.9606	**0.8984**	1	0.9356	0.9932	**0.9763**
Krapina-Zagorje	1	0.8093	1	**0.9364**	1	0.9591	1	**0.9864**
Varaždin	0.5661	0.7222	1	**0.7628**	0.8328	0.9331	1	**0.9220**
Koprivnica-Križevci	0.7201	0.7543	1	**0.8248**	0.9432	0.9743	1	**0.9725**
Međimurje	0.6478	0.6879	1	**0.7786**	0.9077	0.9251	1	**0.9442**
Bjelovar-Bilogora	0.2447	0.2636	0.2880	**0.2655**	0.6430	0.7198	0.7508	**0.7045**
Virovitica-Podravina	0.8109	1	0.7599	**0.8569**	0.9504	1	0.9486	**0.9664**
Požega-Slavonia	1	0.8310	1	**0.9437**	1	0.9513	1	**0.9838**
Brod-Posavina	0.2590	0.2252	0.2809	**0.2550**	0.7693	0.7240	0.8529	**0.7821**
Osijek-Baranja	0.4949	0.4742	0.3921	**0.4537**	0.8754	0.8861	0.8572	**0.8729**
Vukovar-Sirmium	0.2459	0.2132	0.2502	**0.2364**	0.6648	0.6596	0.7698	**0.6981**
Karlovac	0.3026	0.2768	0.3694	**0.3163**	0.9264	0.9158	0.9741	**0.9388**
Sisak-Moslavina	0.5427	1	0.6007	**0.7145**	0.9825	1	0.9795	**0.9873**
Primorje-Gorski Kotar	0.6249	0.9815	0.8424	**0.8163**	0.9182	0.9982	0.9158	**0.9441**
Lika-Senj	1	0.4429	0.4378	**0.6269**	1	0.8560	0.8446	**0.9002**
Zadar	0.3030	0.3707	0.3761	**0.3499**	0.7418	0.8916	0.8637	**0.8324**
Šibenik-Knin	0.2450	0.2734	0.5163	**0.3449**	0.8431	0.8723	0.9559	**0.8904**
Split-Dalmatia	0.3760	0.4457	0.7792	**0.5336**	0.8833	0.9384	0.9787	**0.9334**
Istria	0.9178	1	1	**0.9726**	0.9867	1	1	**0.9956**
Dubrovnik-Neretva	0.5881	0.8755	1	**0.8212**	0.8231	0.9514	1	**0.9249**
Average per year	**0.6050**	**0.6312**	**0.7073**	**0.6479**	**0.8895**	**0.9079**	**0.9374**	**0.9116**
Minimum efficiency result	**0.2447**	**0.2132**	**0.2502**	**0.2364**	**0.6430**	**0.6596**	**0.7508**	**0.6981**
Number (%) of efficient counties	**4 (19%)**	**3 (14%)**	**8 (38%)**		**4 (19%)**	**3 (14%)**	**8 (38%)**	
Number (%) of inefficient counties	**17 (81%)**	**18 (86%)**	**13 (62%)**		**17 (81%)**	**18 (86%)**	**13 (62%)**	

Source: Author's calculations

Sources and amounts of relative inefficiency and proposed improvements are extremely valuable information on which authorities can set goals and make decisions that will lead to them. The importance of reference set should also be emphasized because it provides information on the role models for each inefficient county. Since window analysis, unlike basic DEA models, does not bring these results, a new model will be constructed as follows. Three data sets on seven selected indicators, one for each of the observed years, are included into a basic BCC model for each county. In this way, each of 63 of them is treated as separate entity. Such model construction is justified because it does not affect relative efficiency scores identified by window analysis using one three-year window[5] and yet calculates additional crucial results.

County that was rated efficient usually appears in the reference sets of inefficient counties. The frequency of its occurrence in those sets can be considered as an indication of whether it is a role model to other counties. Table 2 displays these frequencies for every efficient county.

Table 2: The reference set frequency according to window analysis – one window (2005-2006-2007)

Efficient county	Reference set frequency							
	Input-orientation				Output-orientation			
	2005	2006	2007	Σ	2005	2006	2007	Σ
Zagreb-2005	1	2	1	4	1	1	1	3
Krapina-Zagorje-2005	0	0	0	0	0	1	0	1
Požega-Slavonia-2005	0	0	0	0	7	8	7	22
Lika-Senj-2005	0	0	0	0	1	1	1	3
Virovitica-Podravina-2006	2	0	1	3	4	5	4	13
Sisak-Moslavina-2006	1	0	0	1	6	7	5	18
Istria-2006	3	2	6	11	0	0	1	1
City of Zagreb-2007	4	9	5	18	14	14	11	39
Krapina-Zagorje-2007	1	3	1	5	0	1	0	1
Varaždin-2007	8	8	5	21	1	2	1	4
Koprivnica-Križevci-2007	2	2	1	5	5	6	1	12
Međimurje-2007	2	1	1	4	1	1	0	2
Požega-Slavonia-2007	2	3	5	10	4	4	7	15
Istria-2007	10	14	8	32	4	8	4	16
Dubrovnik-Neretva-2007	3	2	2	7	2	2	2	6

Source: Author's calculations

Istria-2007 sets a good example for the input-oriented case (32) and City of Zagreb-2007 leads in the output-oriented case (39). While the City of Zagreb stands out due to the performances in 2007, the County of Istria excels in two years (2006 and 2007) and it makes it relatively most successful county.

The average differences per inefficient county between empirical and projected values in every input and output are displayed in Table 3. Gross fixed capital formation in fixed assets has far the strongest influence on inefficiency during the whole period and toward both orientations. On the other hand, mostly the number of graduated students least affects relative efficiency.

Another issue in evaluating the performance of Croatian counties is their great disparities caused by reasons over which economic policy makers do not have complete control. In that context, the evaluation carried out in the first step of this research seems unfair to continental counties and too indulgent to coastal counties and particularly to the City of Zagreb. Therefore, it appears most

[5] For example, the County of Istria is represented by three entities which, due to the need of mutual distinguishing, are marked as Istria-2005, Istria-2006 and Istria-2007. Thus the efficiency score in the row relating to the County of Istria and in the column relating to the year 2006 is in fact the efficiency score of the entity named Istria-2006.

appropriate to classify Croatian counties into three categories. Hence, the City of Zagreb is placed in category 3 (*good*), all 7 counties of Adriatic Croatia in category 2 (*average*) and the rest of 13 counties in category 1 (*poor*).

Table 3: Sources and average amounts of inefficiency according to window analysis – one window (2005-2006-2007)

Inputs/Outputs		Input and output improvements					
		Input-orientation			Output-orientation		
		2005	2006	2007	2005	2006	2007
Inputs	Registered unemployment rate	-50.03%	-46.78%	-49.15%	-22.66%	-22.94%	-16.66%
	Support allowance users	-53.87%	-48.01%	-56.28%	-12.37%	-12.64%	-14.21%
Outputs	Share of secondary sector in GVA	31.26%	23.93%	26.18%	27.06%	18.15%	16.78%
	Gross fixed capital formation in fixed assets	221.61%	193.25%	224.03%	219.45%	194.74%	236.38%
	Level of import coverage by export	16.17%	18.80%	22.83%	21.37%	31.48%	32.12%
	Graduated students	24.23%	15.70%	8.39%	22.71%	14.76%	12.39%
	GDP	48.30%	46.78%	46.07%	34.78%	32.22%	31.41%

Source: Author's calculations

The second step of this research was therefore carried out using a categorical approach. The role of categorical models in measuring regional efficiency in Croatia is to alleviate the impact of naturally, historically and politically conditioned unequal position of its counties. At the same time, the primary role of window analysis models is to monitor the dynamics of achieving socio-economic efficiency of the counties. Those extensions to basic DEA models solve two independent problems but there is the question of model choice in the case of their simultaneous resolution. A satisfactory solution is provided by the combination of categorical model and window analysis.

Since no existing model meets these requirements, the new model is constructed based on the previous window analysis model by assigning corresponding categories to all of 63 entities. This means that the category of a particular county is assigned to each of three entities that represent the county. So designed model will be hereafter referred to as the combined BCC model. Its results are identical to the results of window analysis using one three-year window with the categorical approach. This opens the possibility of their comparison with the results of afore described window analysis model (with no categorical variables).

Table 4: Combined BCC model results – one window (2005-2006-2007) and three categories

County (category)	Relative efficiency results / Reference set frequency							
	Input-orientation				**Output-orientation**			
	2005	**2006**	**2007**	**Average efficiency Total frequency**	**2005**	**2006**	**2007**	**Average efficiency Total frequency**
City of Zagreb (3)	0.8162	0.8741	1	**0.8968**	0.9888	0.9735	1	**0.9874**
			2	**2**			2	**2**
Zagreb (1)	1	0.9191	1	**0.9730**	1	0.9433	1	**0.9811**
	1		3	**4**	1		2	**3**
Krapina-Zagorje (1)	1	0.9499	1	**0.9833**	1	0.9802	1	**0.9934**
	1		15	**16**	1		1	**2**
Varaždin (1)	0.7139	0.7840	1	**0.8326**	0.8371	0.9370	1	**0.9247**
			27	**27**			18	**18**
Koprivnica-Križevci (1)	0.7201	0.7607	1	**0.8269**	0.9432	0.9839	1	**0.9757**
			3	**3**			14	**14**
Međimurje (1)	0.6478	0.6879	1	**0.7786**	0.9084	0.9266	1	**0.9450**
			6	**6**			5	**5**
Bjelovar-Bilogora (1)	0.3980	0.4132	0.4439	**0.4184**	0.7450	0.8067	0.8037	**0.7851**
Virovitica-Podravina (1)	0.8109	1	0.8019	**0.8709**	0.9504	1	0.9635	**0.9713**
		3		**3**		11		**11**
Požega-Slavonia (1)	1	0.8310	1	**0.9437**	1	0.9614	1	**0.9871**
	2		8	**10**	20		3	**23**
Brod-Posavina (1)	0.3389	0.3510	0.4066	**0.3655**	0.7773	0.7390	0.8794	**0.7986**
Osijek-Baranja (1)	0.4949	0.4742	0.4521	**0.4737**	0.9150	0.9398	0.9531	**0.9360**
Vukovar-Sirmium (1)	0.3199	0.3349	0.3682	**0.3410**	0.6971	0.7170	0.8234	**0.7458**
Karlovac (1)	0.4176	0.6430	1	**0.6869**	0.9434	0.9460	1	**0.9631**
			2	**2**			14	**14**
Sisak-Moslavina (1)	0.5427	1	0.6007	**0.7145**	0.9867	1	0.9863	**0.9910**
		1		**1**		11		**11**
Primorje-Gorski Kotar (2)	0.6249	1	0.8456	**0.8235**	0.9516	1	0.9638	**0.9718**
		1		**1**		3		**3**
Lika-Senj (2)	1	0.4429	0.4378	**0.6269**	1	0.8560	0.8578	**0.9046**
	0			**0**	1			**1**
Zadar (2)	0.3158	0.3742	0.3761	**0.3554**	0.7742	0.9096	0.8934	**0.8591**
Šibenik-Knin (2)	0.2491	0.2934	0.6860	**0.4095**	0.8578	0.9028	0.9729	**0.9111**
Split-Dalmatia (2)	0.3760	0.4476	1	**0.6079**	0.9136	0.9680	1	**0.9605**
			0	**0**			2	**2**
Istria (2)	0.9178	1	1	**0.9726**	0.9869	1	1	**0.9956**
		3	14	**17**		0	10	**10**
Dubrovnik-Neretva (2)	0.5881	0.9760	1	**0.8547**	0.8468	0.9995	1	**0.9488**
			8	**8**			12	**12**
Average efficiency per year	**0.6330**	**0.6932**	**0.7819**	**0.7027**	**0.9059**	**0.9281**	**0.9570**	**0.9303**
Minimum efficiency result	**0.2491**	**0.2934**	**0.3682**	**0.3410**	**0.6971**	**0.7170**	**0.8037**	**0.7458**
Number (%) of efficient counties	**4 (19%)**	**4 (19%)**	**11 (52%)**		**4 (19%)**	**4 (19%)**	**11 (52%)**	
Number (%) of inefficient counties	**17 (81%)**	**17 (81%)**	**10 (48%)**		**17 (81%)**	**17 (81%)**	**10 (48%)**	

Source: Author's calculations

Application of the combined BCC model using both orientations led to the results shown in Table 4. Comparisons of the results listed in Tables 1 and 4 show their significant differences, with the exclusion of City of Zagreb and Istria[6]. With the categorical approach, among 63 observed entities, 19 turned out to be efficient, which were four more than according to the previous model.

Similar to the previous model, the best results of average efficiency according to all criteria were achieved in the year 2007. The worst results according to the efficiency score were achieved in 2006, while the number of counties that were efficient in 2005 and 2006 was the same.

Most of the reference set frequencies generated by this model (Table 4) are significantly different compared to the previous model, mainly at the expense of Istria and City of Zagreb. That happened mostly because those two counties now cannot be members of reference sets of inefficient counties in the most numerous category 1.

Table 5: Sources and average amounts of inefficiency according to the combined BCC model – one window (2005-2006-2007) and three categories

Inputs/Outputs		Input and output improvements					
		Input-orientation			Output-orientation		
		2005	2006	2007	2005	2006	2007
Inputs	Registered unemployment rate	-46.58%	-40.55%	-45.81%	-17.92%	-19.72%	-21.38%
	Support allowance users	-49.43%	-41.60%	-54.02%	-15.47%	-13.45%	-22.44%
Outputs	Share of secondary sector in GVA	40.53%	33.88%	43.88%	26.51%	26.10%	31.73%
	Gross fixed capital formation in fixed assets	103.60%	80.53%	104.38%	49.65%	42.16%	65.73%
	Level of import coverage by export	23.39%	26.86%	10.23%	18.26%	14.27%	12.22%
	Graduated students	17.94%	8.05%	6.93%	19.29%	11.97%	10.94%
	GDP	30.05%	24.43%	22.60%	18.02%	14.94%	14.75%

Source: Author's calculations

Average differences per inefficient county between empirical and projected values in every input and output are displayed in Table 5. Similar to the previous model, gross fixed capital formation in fixed assets has the strongest influence on inefficiency. On the other side, this influence is not nearly as strong as in the previous model. That is because capital formation in continental counties is generally considerably low compared with the rest of Croatia, thus raising the amount of average inefficiency in that output. Since the comparison of category 1 with the other two categories is here bypassed, the inefficiency related to capital formation is significantly reduced.

[6] The reasons of keeping the efficiency unchanged differ for these two counties. The City of Zagreb is in both models compared to the same set of counties and therefore nothing changes. Istria is relatively the best performing county, so the comparison with City of Zagreb does not threaten its efficiency score.

4. CONCLUSION

Assessment of relative efficiency of Croatian counties according to window analysis and to the combined model was based on their two common features. Specifically, the counties were compared to one another at the level of one three-year period and based on the same set of indicators. In the window analysis model, which enabled monitoring of development dynamics, each county was compared to all other counties. Besides the development dynamics, specifically constructed combined model took into account unequal position of counties by comparing each of them only to the counties from the same or lower categories. Therefore, relative efficiency scores according to this model were not lower than according to the previous one. After classification of counties, a significant number of them improved the efficiency. Some even became efficient. Therefore, the total average relative efficiency increased, advancing forward the categorical approach for most counties as preferred.

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