Development index: analysis of the basic instrument of Croatian regional policy

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Abstract

The development level assessment and categorization of Croatian local and regional units is based on the value of the development index which is the main instrument of Croatian regional policy. The development index is a composite indicator calculated as a weighted average of five socio-economic indicators. The goal of this paper is to analyze the uncertainty and sensitivity of the development index that arise from the procedures and indicators used in its construction. This analysis is then used to propose useful guidelines for future impovements. The methodology of the Croatian regional development index has been critically reviewed, revealing problems of multicollinearity and the existence of outliers. An empirical and relatively more objective multivariate approach for weight selection has been proposed. The uncertainty and sensitivity analysis were conducted using Monte Carlo simulations and variance-based techniques. Instead of a unique point estimate for the development level of territorial units an alternative confidence interval approach was considered.

Keywords: development index, composite indicators, multivariate analysis, uncertainty analysis, sensitivity analysis, Croatia

1 INTRODUCTION

The State has a constitutional obligation to promote the economic development of all the regions in Croatia and to promote economic progress and the social welfare of all citizens. Accurate assessment of the level of development of territorial units is crucial for regional planning and development policy, and is a key criterion for the allocation of various structural funds and national subsidies (Cziraky et al., 2005). Poor economic situations in local units entail low fiscal capacities, making them dependent on state subsidies and incapable of pursuing their own development (Puljiz, 2009). This prompted several groups of authors to propose that the criteria for allocating state grants and subsidies are unclear and non-transparent (Ott and Bajo, 2001; Bronić, 2008, 2010).

Therefore, in 2009, a new Law on Regional Development inaugurated a new categorization of local (LGU) and regional (RGU) government units based on the value of a development index. The development index is a composite indicator calculated as the weighted average of five basic normalized socio-economic indicators: (1) income *per capita* (X_1), (2) budget revenue *per capita* (X_2), (3) unemployment rate (X_3), (4) change in population number (X_4), (5) educational attainment rate (X_5), relative to the national average. The value of the development index for a territorial unit *c* is calculated using the formula

$$I_c = 0.25x_{c1} + 0.15x_{c2} + 0.3x_{c3} + 0.15x_{c4} + 0.15x_{c5} \quad c = 1,2,\ldots,m \tag{1}$$

where x_{ic}, i = 1,2..., 5 represent the normalized value of a sub-indicator X_i for a territorial unit *c*. The indicators, their corresponding weights and other issues are determined by a government decree (Decree on Development Index, 2010). According to the values of their development indices, LGUs are categorized into 5 groups, while RGUs are classified into 4 groups. LGUs classified in groups I or II, and RGUs classified into group I are rated as lagging behind in development, and thus have a special status and are granted special support from the state level. The evaluation and classification of LGUs and RGUs on the basis of the development index are conducted every three years.

Poorly constructed or misinterpreted composite indicators may send misleading policy messages. Therefore, the validation of such models is of major importance, and many methods and approaches of model validation have been devised. Since models cannot be validated in the sense of being proven true (Oreskes et al., 1994), Rosen (1991) proposed that the justification for a composite indicator lies in its fitness for the intended purpose and in peer acceptance. However, a group of authors (Saisana and Saltelli, 2008) report that it is more defensible and correct to say that a model can be corroborated if it passes tests that assess the model's capacity to explain or predict the "system" in a convincing and parsimonious way. In order to maximize their utility and minimize their misuse, composite indicators need to be developed using the best available evidence, documented transparently, and validated using appropriate uncertainty and sensitivity analyses. Uncertainty analysis focuses on how uncertainty in the input factors propagates through the structure of the composite indicator and affects the values of the composite indicator (Saisana et al., 2005). Sensitivity analysis examines the effects of variability and interactions of indicators as possible sources of instability. While in most cases the sensitivity and the uncertainty analysis are conducted separately, a synergistic use of an uncertainty and a sensitivity analysis during the development of a composite indicator could improve the structure (Nardo et al., 2005; Saisana et al., 2005; Tarantola et al., 2000; Gall, 2007). For example, Saisana et al. (2005) conducted uncertainty and sensitivity analyses using Monte Carlo simulation and variance-based techniques. Furthermore, Paruolo et al. (2013) suggest Pearson correlation coefficient as a measure of variable importance. Also, they conducted sensitivity analysis using variance-based techniques and applied these methods to various composite indicators. On the other hand, Hoyland et al. (2012) criticize the approach in aggregating variables into a composite index without incorporating uncertainty. They suggest a Bayesian approach when assessing uncertainty and apply this method to three composite indicators. Another group of authors (Nardo et al., 2008) provide directions for the construction of composite indicators and give recommendations for implementation of sensitivity and uncertainty analyses. Apart from the papers analyzing regional disparities in Croatia and the classification of Croatian LGUs and RGUs according to socio-economic development (e.g. Rimac et al., 1992; Grčić and Filipić, 2002; Cziraky et al., 2003, 2005; Perišić, 2014) there is a lack of related work regarding sensitivity of categorization and uncertainty in the construction of the development index.

The main goal of this study is to examine the existing methodology of the construction of the development index and to propose an improved method for its calculation by taking into account the uncertainty and sensitivity of the categorization of LGUs and RGUs. Uncertainty of the development index is assessed considering the construction methodology and sensitivity is evaluated with respect to the indicators involved in its construction. Uncertainty and sensitivity analyses play an important role in the construction of composite indicators and because of their generality these methods can be applied in wide-ranging fields. The study also includes the analysis of data structure using multivariate methods. The methods presented in this paper can be useful to policymakers and experts in assessing the reliability of the composite indicators.

2 THE METHODOLOGY OF MODELLING REGIONAL DEVELOPMENT IN CROATIA

2.1 THE DEVELOPMENT OF THE REGIONAL DEVELOPMENT POLICY

In its beginning, Croatian regional policy was focused on the renewal of areas affected by war. Some progress was made when the Law on the Areas of Special State Concern (ASSC) was implemented. These areas were established in order to encourage their more rapid development and thus they have a special status in the financing regime (Ott and Bajo, 2001). According to the Law on ASSC adopted in 1996, three categories of units were formed. The first two categories were defined on the basis of damage caused by the war in Croatia. The third category, introduced in 2002, comprises local units that are lagging behind in development according to four criteria: economic development, structural difficulties, demographic, and a special criterion (Bronić, 2008). The introduction of socio-economic criteria was a step forward in developing regional policy. Eleven indicators were used for the designation of the third category of ASSC: income *per capita*, share of population earning an income, municipality (direct) income *per capita*, unemployment rate, employment rate, social aid *per capita*, change in population number, educational attainment rate, population density, age index and vitality index (Puljiz et al., 2005). In addition to the four aforementioned socio-economic criteria, two special criteria related to border position and mine area status were used. In total, 185 LGUs enjoyed a special status; of these, 50 were classified in the first category, 61 in the second category, and 74 in the third category of ASSC. However, it appeared that the criteria for designation of ASSC were not related to the real socio-economic indicators. Bajo and Primorac (2013) report that preferential status was also given to some economically more developed (above average) LGUs. Furthermore, a group of authors (Maleković et al., 2011) conclude that the regional development approach, inherited from central planning, was inconsistent and lacking clearly defined goals, actors, and instruments. The regional policy has been often conducted within the scope of fiscal equalization and *vice versa*, whereby the instruments and the objectives of these policies often clashed, and the effects were neutralized at a high cost to the state budget. Consequently, laws related to regional policy needed to be changed. The introduction of a simple and transparent system of fiscal equalization based on appropriate criteria and fiscal instruments remains a challenge for the Government (Bajo and Primorac, 2013).

The establishment of a comprehensive and coherent regional development policy system based on the principles of contemporary regional policy started along with the preparatory activities for the accession of Croatia to the European Union (Sumpor et al., 2012). The basis for the implementation of regional policy was the adoption of the Law on Regional Development in 2009. This Law regulates regional policy by introducing the development index as a basis for the socio-economic development assessment and categorization of territorial units. In addition to that, the development level of LGUs was assessed for the first time. According to the Ministry of Regional Development and EU Funds (MRRFEU), the single system based on the development index contributes to the simplicity and transparency of the whole system, enabling the better direction of incentives and the acquisition of a high-quality basis for the inclusion or exclusion of units from the supported areas (MRRFEU, 2012).

Supported areas were supposed to replace the ASSC, but instead, a parallel existence of different categories of underdeveloped areas occurred. This perennial problem will be solved by the adoption of a new Law on Regional Development. Furthermore, this new Law will introduce a uniform system for development level assessment of territorial units applicable to the whole state. The application of measures introduced by the new law is expected in 2015. Some of the novelties of the new Law are introduction of the category of urban area (and additionally, among such areas, agglomeration centers), the formation of the Council for regional development and binding all future measures to development index, which acts as the basic instrument for development level assessment of LGUs and RGUs (MRRFEU, 2013c). By changing the Law on ASSC, the Law on Regional Development, the Law on Hill and Mountain Areas and the Personal Income Tax Act, the Government endeavors to harmonize tax reliefs and distribution of grants to LGUs with their development level measured by the development index. The main changes in the grant distribution to LGUs involve redirecting the grants from the state budget to LGUs, according to the development index, in the amount of corporate income tax generated in their area, and changes in the basic personal allowance (Bajo and Primorac, 2013). By this, LGUs classified in categories I and II will obtain the right to the entire (100%) corporate income tax revenue collected in their area, in category III to aid in the amount of 75%, in group IV 60%, and in category IV 40%. A limitation of this distribution can be presented by following example: Tovarnik municipality, having the development index value of 74.82%, will obtain the right to Governmental support in the amount of 100%, while the City of Ozalj, with a development index value of 75.08%, will obtain the right to aid in the amount of 75%. These two marginal examples show that more legitimate support is needed. For example, introducing partially linear deductions would contribute to an equitable support system.

Adopting the new Law on Regional Development will stop there being two laws that define supported areas. However, ASSC again have a special status during assessment of the development level. The Decree on Amendments to the Decree on the Development index implies that the development index value of the LGUs in the ASSC will be reduced by 10 points (the adjusted index) if their original index value is higher than 75% (Decree on Amendments to the Decree on Development index, 2013). In this paper, two indices will be obtained for the local level (LGU): the unadjusted development index I^V (without the reduction by 10 points for ASSC) and adjusted development index I^{KV} (with the reduction by 10 points for ASSC).

The methodology for construction of the development index for the period 2010-2012 is different from that used for the period 2006-2008. In 2013, the Decree on Amendments to the Decree on the Development Index introduced two main modifications: when calculating budget revenue *per capita*, revenues from the disposal of non-financial assets are excluded; also, the value of the development index is reduced by 10 points for LGUs from the first or second category of ASSC that have a value of the development index greater than 75%. The first modification prevented the impact of short-term funding sources in budget revenues on the value of development index. The second modification was introduced in order to assure the retention of the status of supported area for undeveloped LGUs that were affected by the war. By this modification, 24 LGUs from the first or second category of ASSC are, according to the adjusted development index, categorized as supported areas, although according to the unadjusted development index they belong to categories of middle or higher development level.

2.2 THE CATEGORIZATION OF LGUs AND RGUs ACCORDING TO DEVELOPMENT INDEX

According to the value of the development index, LGUs are classified into 5 groups (table 1). Table 1 also provides the number of LGUs classified into each group (*N*), average values of indicators X_1,.., X_5 along with standard deviation (in brackets). Large standard deviations indicate heterogeneity within the group.

According to the development index, RGUs are classified into 4 groups (table 2). Table 2 also provides the number of LGUs classified into each group (*N*), average values of indicators X_1,..., X_5 along with standard deviation (in brackets).

LGUs classified into categories I or II, and RGUs classified in category I are rated as lagging behind in development and thus have a special status. In Croatia, there are 556 LGUs, composed of 429 municipalities and 127 towns, with the City of Zagreb, the capital of Croatia, having the status of both county and town. More than one third of LGUs are located on ASSC, while according to the development index, almost one half of LGUs and more than a half of RGUs are categorized as areas lagging behind in development.

TABLE 1
The categorization of LGUs according to development index

Category	Development index value (%)	N	X_1	X_2	X_3 (%)	X_4	X_5 (%)
I	<50	47	13,049.28 (2,146.69)	748.87 (288.98)	37.67 (6.59)	86.20 (11.01)	54.07 (8.7)
II	<50, 75>	217	18,095.3 (3,333.85)	1,020.29 (472.4)	22.89 (6.3)	92.83 (8.91)	62.17 (8.1)
III	<75, 100>	173	23,355.31 (3,668.74)	1,912.6 (1,064.74)	14.89 (4.5)	99.92 (9.27)	72 (6.78)
IV	<100, 125>	93	28,557.11 (4,426.46)	3,556.06 (1,179.26)	10.84 (3.6)	108.1 (12.15)	80.35 (5.1)
V	>125	26	29,938.73 (6,000.14)	7,060.54 (1,359.8)	8 (3.1)	119.48 (28.22)	83.32 (4.9)

Source: Authors' calculation.

TABLE 2
The categorization of RGUs according to development index

Category	Development index value (%)	N	X_1	X_2	X_3 (%)	X_4	X_5 (%)
I	< 75	12	22,798 (2,494)	1,912 (472)	20.47 (4.78)	94.1 (2.67)	69.38 (3.93)
II	<75, 100>	3	25,460 (785)	2,597 (506)	16.43 (3.58)	100.3 (3.57)	78.84 (4.32)
III	<100, 125>	3	27,156 (2,746)	3,166 (337)	13.20 (1.95)	106.53 (2.55)	79.51 (3.71)
IV	>125	3	35,662 (5,655)	5,213 (682)	10.37 (2.46)	101.77 (2.4)	84.23 (3.14)

Source: Authors' calculation.

3 METHODOLOGICAL ASPECTS OF THE CONSTRUCTION OF COMPOSITE INDICATORS

In the indicators literature there is a fundamental division between those who choose to aggregate variables into a composite indicator, the aggregators, and those who do not, the non-aggregators. The aggregators believe that composite indicators can capture reality and are meaningful. Moreover, they believe that composite indicators are extremely useful in garnering media interest and hence the attention of policy makers. On the other hand, the non-aggregators emphasize the arbitrary nature of the weighting process by which the variables are combined (Sharpe, 2004). Certain disagreements also exist as to how to select indicators and techniques for measuring disparities. Relying solely on economic indicators is questionable due to the fact that development either leaves behind, or in some ways even creates, large areas of poverty, stagnation, marginality, and actual exclusion from economic and social progress is too obvious and too urgent to be overlooked (United Nations, 1969). The need for including more indicators for the purpose of measuring socio-economic development resulted in a considerable number of composite indicators.

The main pros of using composite indicators are the ability of summarizing complex, multi-dimensional realities, an easy and direct interpretation, facilitation of communication with general public and reducing the amount of a set of indicators without dropping the underlying information base. The main cons are related to a problem of misleading policy messages if the indicators are poorly constructed or misinterpreted, they can invite simplistic policy conclusions, the selection of indicator and weight could be the subject of political dispute and lead to inappropriate policy (Nardo et al., 2005). If the construction process is not transparent and/or lacks sound statistical or conceptual principles, composite indicators can be misused and index values can be manipulated in order to support preferred policy. The basic steps in the construction of composite indicators are: theoretical framework construction, data selection, imputation of missing data, multivariate analysis, normalization, weighting and aggregation, uncertainty analysis, sensitivity analysis, linking to other variables, presentation and visualization (Nardo et al., 2005).

3.1 INDICATORS SELECTION

The strengths and weaknesses of a composite indicator are derived from the quality of the underlying variables. Variables should be selected on the basis of their relevance, analytical soundness, timeliness, accessibility, etc. The choice of indicators must be guided by the theoretical framework, limiting the developer's subjectivity. The use of multivariate analysis helps to identify the data structure, and can increase both the accuracy and the interpretability of final results. Multivariate methods can also help to investigate the presence of multicollinearity. Multicollinearity causes an unequal variable position because multicollinear variables measure the same phenomenon, which in turn has a multiple contribution to the value of the composite indicator. An additional problem is the difficulty of interpretation, while it is hard to assess the impact of the individual variable. If two variables are highly correlated, the inclusion of both of them in the model may be redundant (Salzman, 2003).

In the process of the construction of new composite indicator, the development index, the main criterion for variable selection was the estimation of the variable's contribution to the objective estimation of socio-economic differences among territorial units. Thereby, income *per capita* and unemployment rate became key indicators of socio-economic disparities, while some indicators were excluded on the basis of their weak credibility, and too high or too low correlation with the key economic indicators (Puljiz et al., 2005). For instance, infrastructural indicators were rated as not reliable; the indicators "share of persons earning an income" and "income *per capita*" were highly correlated (coefficient of correlation was 0.93); the indicators "vital index" and "age index" had a too low correlation coefficient with the indicators "income *per capita*" and "unemployment rate" (Puljiz, 2007). Due to some methodological difficulties, gross domestic product *per capita* (GDP per capita) was not involved in the construction of the development index. However, the GDP *per capita* is still considered as a potential indicator while it is expected that the reliability of the estimation of GDP will grow (Puljiz, 2007). However, it is not possible to use the GDP *per capita* as an indicator on the local level because it is calculated on the regional and state level. The Decree on the Development Index prescribes the indicators used in the construction of the development index: income *per capita*, budget revenue *per capita*, unemployment rate, change in population number, and educational attainment rate. The indicator values have been acquired from MRR-FEU (2013a, 2013b, 2010a, 2010b). Local/regional income *per capita* is calculated by dividing the total income in a tax period (one calendar year), generated by taxpayers, persons domiciled or habitually resident, in the territory of the local/regional unit, by the total population number of a local/regional unit. Budget revenue *per capita* is calculated by dividing the realized reduced local/regional budget revenue by the population number of a local/regional unit. Budget revenue is reduced by: receipts from domestic and foreign aid, subsidies and transfers, receipts derived pursuant to special contracts (co-financing by citizens), additional share in income tax, equalization aid for the decentralized functions and disposal of non-financial assets. Unemployment rate is determined by dividing the total number of unemployed persons by the sum of unemployed and employed persons in the area of the local/regional unit. Change in population number is expressed as the ratio of the number of the population in a local/region unit according to the last two consecutive censuses. Educational attainment rate is calculated as the number of persons with secondary education and higher, aged over 15 years, as a proportion of the total number of population aged 16-65 in the area of the LGU/LRU.

Minimum value (min), maximum value (max), mean value ($\bar{x}$), standard deviation (σ) and asymettry coefficient (skew) are presented in tables 3 and 4 for the LGUs and RGUs respectively. Variable X_2 has the largest dispersion both on local and regional level.

TABLE 3
Indicators LGU

Indicator	Min.	Max.	$\bar{x}$	σ	skew
X_1	7,105	42,175	21,609.14	6,088.6	0.38
X_2	223	10,115	1,981.59	1,695.36	1.96
X_3 (%)	4.5	54.48	18.94	9.24	0.86
X_4	41.3	247.8	98.3	13.8	2.72[a]
X_5 (%)	31.65	90.41	68.58	11.07	-0.36

[a] *The effect of an outlier, when the outlier is excluded, asymmetry coefficient is 0.65.*
Source: Authors' calculation.

TABLE 4
Indicators RGU

Indicator	Min.	Max.	$\bar{x}$	σ	skew
X_1	19,455	42,175	25,638.19	5,262.95	1.66
X_2	1,368	5,997	2,660.48	1,248.45	1.36
X_3 (%)	7.80	25.90	17.41	5.54	0.17
X_4	90.7	109.1	97.86	5.42	0.50
X_5 (%)	62.49	86.93	74.30	7.01	0.15

Source: Authors' calculation.

3.2 NORMALIZATION

Data normalization is often required because the indicators in a data set have different measurement units or large differences in their means or standard deviations. The normalization phase can be crucial for the accuracy of a composite indicator and accordingly for the ranking of units. The simplest normalization technique is ranking. This method is not affected by outliers. Standardization, or converting to z-scores, on the other hand, is one of the most popular normalization methods. It is affected by outliers since indicators with extreme values have a greater effect on the composite indicator value. The third widely used normalization method is the min-max method, which normalizes the indicators so that they have an identical range. Distance to a reference measures the relative position *vis-à-vis* a reference point (the reference could be the average value, minimum value, maximum value or some other value determined by the expert decision).

TABLE 5
Evaluated normalization methods

Normalization methods	The calculation
Standardization (z-score)	$x_{ci}^{*} = \frac{x_{ci} - \bar{x}_i}{\sigma_i}$ (2)
Min-max	$x_{ci}^{*} = \frac{x_{ci} - x_{i,min}}{x_{i,max} - x_{i,min}}$ (3)
Distance to a reference	$x_{ci}^{*} = \frac{x_{ci}}{x_i^0}$ (4)

Remark: x_{ci} is the value of indicator X_i for a local unit c; $\bar{x}_i$ represents the average value of indicator X_i across all units c; σ_i is the standard deviation of indicator X_i; $x_{i,min}$ is the minimum value of indicator X_i across all units c; $x_{i,max}$ is the maximum value of indicator X_i across all units c; x_i^0 is the reference value for indicator X_i.

By the Decree on the Development Index, the min-max method was selected as a suitable normalization method. The min-max normalization of an indicator X_i is conducted by subtracting the minimum value and dividing by the range of the indicator values. Furthermore, this normalized value is divided by the normalized state average value of the indicator X_i (formula 5)

$$x_i^* = \frac{\dfrac{x_i - x_{i,min}}{x_{i,max} - x_{i,min}}}{\dfrac{x_{i,HR} - x_{i,min}}{x_{i,max} - x_{i,min}}} = \frac{x_i - x_{i,min}}{x_{i,HR} - x_{i,min}}. \tag{5}$$

Since the extreme values are usually outliers, this normalization method should be revised (in the sense of excluding outliers or even changing the normalization method). Changing the minimum value of an indicator can affect the composite indicator values of all units. The normalization defined in formula 5 reduces the nominal value of each indicator to a distance to the minimum value relative to the distance of the national average to the minimum value.

3.3 WEIGHTING AND AGGREGATION

Perhaps the most difficult aspect of constructing a multidimensional index is choosing weights for the components (Tofallis, 2013). A number of weighting techniques exist. Some are derived from statistical models, such as factor analysis, principal component analysis (PCA), data envelopment analysis, or from participatory methods that incorporate various stakeholders – experts, citizens and politicians, like budget allocation processes, analytic hierarchy processes and conjoint analysis (Nardo et al., 2008). The weights are often selected in order to reflect the relative importance of the indicator for the phenomenon to be measured. This approach is often criticized as too arbitrary since weighting can have a significant effect on composite index value and ranking of units. On the other hand, multivariate techniques present an empirical and relatively more objective option for weight selection, allowing for no control over the selection of weighting scheme. This is due to the fact that the weights are selected based on the data themselves. The problem of selecting an indicator's weights is often bypassed by equal weighting, i.e. all variables are given equal weights. Composite indices generally seem to be additive, with equally weighted components (Booysen, 2002). This essentially implies that all variables are "worth" the same in the composite, but it could also disguise the absence of a statistical or an empirical basis, e.g. when there is insufficient knowledge of causal relationships or a lack of consensus on the alternative (Nardo et al., 2005). When a few highly correlated indicators exist and equal weighting is applied, double counting may be introduced into the index. Thus, it is desirable to perform correlation analysis prior to weight selection and to adjust weights according to results of correlation analysis.

An *a priori* determination of weights for various components implies the existence of a universally acceptable human welfare/development function, which is not the case (Noorbakhsh, 1998). Thus, the empirical approach, as an alternative approach to weight setting, is worth pursuing. In order to generate a set of non-subjective weights, PCA has been applied for the calculation of development index both for the period 2008-2010 and for 2010-2012. PCA enables the reduction of the variables by a small number of their linear combinations. The objective is to explain the variance of the data through a few linear combinations of the original data minimizing the information loss. Therefore, $k \leq 5$ linear combinations Y_j of variables X_i are chosen, maximizing the variance of the original data.

$$Y_j = \sum_{i=1}^{5} w_{ij} X_i, \quad j = 1, \ldots, k. \tag{6}$$

The first principal component, Y_1, is the linear combination of the variables that has the greatest possible variance. Various guidelines have been developed on the issue of how many linear combinations k should be retained. For instance: the latent root criterion (only components that have an eigenvalue greater than 1 are retained), the *a priori* criterion, scree test and proportion of variance criterion (Hair et al., 1995). In practice, very few composite indices use PCA weights, in part because it is difficult to explain the process to non-statisticians, in part because the weights themselves change as the data changes over time, but mainly because the results using equal weights and PCA weights tend not to differ substantially (Foa and Tanner, 2011).

Because the composite indicators describe multidimensional phenomena by a unidimensional construct, it is necessary to find an appropriate aggregation method. Additive aggregation is the simplest aggregation method and is independent of outliers. Linear aggregation, the most widespread method, is the summation of weighted individual indicators. An undesirable feature of linear aggregation is that it implies full compensability, such that poor performance in some indicators can be compensated for by sufficiently high values in other indicators. Geometric aggregation is better suited if the modeller wants some degree of non-compensability.

3.4 UNCERTAINTY AND SENSITIVITY ANALYSIS

The absence of an "objective" way to determine weights and aggregation methods does not necessarily lead to rejection of the validity of composite indicators, as long as the entire process is transparent. A combination of uncertainty and sensitivity analysis can help gauge the robustness of the composite indicator and improve transparency (Nardo et al., 2008). The methodological choices, such as the treatment of missing data, indicator selection, choosing the normalization method as well as the aggregation method, and the weighting scheme have a major influence on the composite indicator. The goal of the uncertainty analysis is to evaluate how the subjective choices taken by the modeller are reflected in the confidence in the model. Since the development level of a territorial unit cannot be directly measured, it is not possible exactly to determine how well the composite index describes this phenomenon. However, a composite indicator needs to be validated. Thus, each construction of a composite index needs to involve uncertainty analysis and sensitivity analysis. Generally, uncertainties during the development of a composite indicator are associated with a number of factors: data error, choice of the mechanism for indicator inclusion and exclusion, the transformation of indicators, missing data, choice of normalization method, aggregation method and especially of the weighting scheme (Nardo et al., 2005). The uncertainty of a composite index can be assessed by exploring the main sources of uncertainty, with the aim of capturing all possible synergy effects among uncertain input factors (Nardo et al., 2008), directly or by Monte Carlo simulation.

High sensitivity to small changes in input information makes the composite index unstable and unreliable. Thus, when a composite index is being created, it is necessary to determine the effect of the variation in the individual indicator on the overall index value. Therefore, methods that are not based on the assumptions of the model, such as variance-based techniques, are used (Satelli et al., 2008).

For the composite index Y and indicators $X_1,\ldots, X_k$, the first-order sensitivity index is assessed as the contribution of an individual indicator X_1 to the total output variance $V(Y)$,

$$S_i = \frac{V_i}{V(Y)} \tag{7}$$

where

$$V_i = V_{X_i}\left[E_{X_{-i}}(Y \mid X_i)\right] \tag{8}$$

is the variance of Y due to the uncertainty in X_i. In order to compute a variance-based sensitivity measure, the first factor X_i needs to be fixed to a specific value x_i^0 in its range. Then the mean of the output is computed by averaging over all factors but factor X_i, $E_{X_{-i}}\left(Y|X_i = x_i^0\right)$ and the variance of the resulting function of x_i^0 is averaged over all possible values of the indicator X_i. Higher values of the sensitivity index S_i indicate a higher dependance between the index Y and the individual indicator X_i.

Analogously, it is possible to compute conditional variance to more than one factor (interactions) and then to compute high-order sensitivity indices. When an additive model is concerned (a model without interactions) the contribution of an individual indicator to the variance of a composite is entirely obtained by the first-order sensitivity index and therefore formula (9) is valid.

$$\sum_{i=1}^{k} S_i = 1. \tag{9}$$

S_i is a good model-free sensitivity measure, and it always gives the expected reduction of the variance of the output that one would obtain if one could fix an individual indicator (Saltelli et al., 2004). In general,

$$\sum_{i=1}^{k} S_i \leq 1. \tag{10}$$

For a non-additive model, instead of computing higher-order sensitivity indices, the total effect sensitivity index S_{Ti} is obtained; this is determined by their sum.

$$S_{T_i} = S_i + \sum_{j=1}^{k} S_{ij} + \sum_{j<k} S_{ijk} + \ldots + S_{1\ldots k} = \frac{V(Y) - V_{X_{-i}}\left[E_{X_i}(Y|X_{-i})\right]}{V(Y)}, \tag{11}$$

where $V_{X_{-i}}\left[E_{X_i}(Y|X_{-i})\right]$ represents the variance of the composite index Y due to the uncertainty of all indicators but indicator X_i. As in the first-order sensitivity indices, high values of the total effect S_{Ti} indicate a higher dependence of the index Y on the variability of an individual indicator X_i. However, unlike the first-order sensitivity indices, this approach considers all possible interactions with other indicators. Therefore, by comparing the pairs (S_i, S_{Ti}) it is possible to compute the intensity of indicator interaction.

4 RESULTS

4.1 MULTICOLLINEARITY AND OUTLIER PRESENCE TESTING

Correlation matrices of indicators on the local and regional level are presented in tables 6 and 7. The correlation of indicators is high and statistically significant (at significance level 1%). On the regional level, correlation coefficients of indicators income *per capita* and budget revenue *per capita*, and also budget revenue *per capita* and educational attainment rate are problematic in the sense of too high correlation.

Table 6

Correlation matrix LGU

	X_1	X_2	X_3	X_4	X_5
X_1	1				
X_2	0.92	1			
X_3	-0.68	-0.67	1		
X_4	0.44	0.55	-0.59	1	
X_5	0.79	0.81	-0.57	0.66	1

Source: Authors' calculation.

Table 7

Correlation matrix RGU

	X_1	X_2	X_3	X_4	X_5
X_1	1				
X_2	0.51	1			
X_3	-0.67	-0.48	1		
X_4	0.25	0.51	-0.39	1	
X_5	0.73	0.55	-0.55	0.51	1

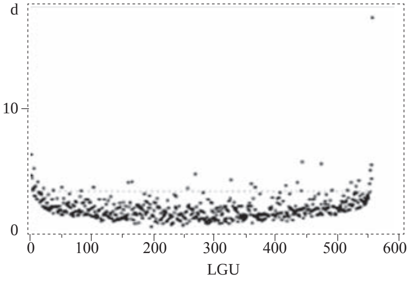
Source: Authors' calculation.

Multicollinearity was assessed using variance inflation factor and condition index. It can be concluded that multicollinearity is present since the value of variance inflation factor is higher than 7 and value of condition index is 13.8 (Bahovec and Erjavec 2009; Gujarati, 2004). The problem of multicollinearity can be solved by excluding one of the indicators or by replacing it with another indicator. For example, for the development index calculated for the period 2006-2008, the problem of multicollinearity was solved by excluding the indicator budget revenue *per capita*, and also by replacing this indicator with alternative indicators of regional budget strength (Perišić, 2014.). A high correlation of budget revenue *per capita* and income *per capita* is expected. Furthermore, local revenues depend mostly on tax revenues, especially on income tax and surtax on income tax (Ott, 2009). Therefore, the inclusion of both indicators may be redundant, especially when the key economic indicator GDP *per capita* is available on a regional level. This issue can be circumvented by introducing realized local/regional budget revenue in the total income of LGU/RGU: an alternative indicator of strength and independence of local budgets. In that case, the realized local/regional budget revenue should be reduced by receipts from domestic and foreign aid, subsidies and transfers, receipts derived pursuant to special contracts (co-financing by citizens), additional share in income tax, equalization aid for the decentralized functions and disposal of non-financial assets.

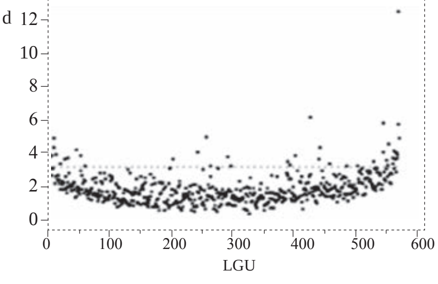
Outliers were detected using Mahalanobis distance, where observations with large Mahalanobis distances were indicated as outliers (Ben Gal, 2005). Squared Mahalanobis distances (*d*) corresponding to LGUs for the period (a) 2006-2008, and (b) 2010-2012 are presented in figure 1.

FIGURE 1

Detection of outliers in LGUs using the squared Mahalanobis distance (d) for the period (a) 2006-2008 and (b) 2010-2012



(a) Period 2006-2008



(b) Period 2010-2012

Source: Authors' calculation.

In both periods one outlier can be detected in the upper right side of the figure. For the period 2006-2008 the outlier is the municipality Dugopolje which has the largest development index and extremely high budget revenue *per capita*. In that period, the second largest development index corresponds to Kostrena municipality. This municipality, however, has a three times smaller budget revenue *per capita*. Furthermore, Dugopolje municipality has more than twenty times the budget revenue *per capita* of the average of all LGUs. Dugopolje municipality is an example of the failure of aggregation methods, since the deficit in one dimension can be compensated by a surplus in another and thus create a false image on the unit's development level. The extremely high budget revenue of Dugopolje municipality is the result of short-term funding sources, such as sale of land. A similar situation occurred with other LGUs. For the period 2010-2012 the municipality of Vir stands out as an outlier with an extremely high change in the population number (247.8). These examples show that outliers create a false image of the development level of a territorial unit, and also affect the value of the development index of all units. This effect, as well as the effect of different data range, is removed with transformation and normalization of the data.

4.2 PRINCIPAL COMPONENT ANALYSIS RESULTS

Principal component analysis is conducted for the development index, and calculated for both periods, 2006-2008 and 2010-2012. *A priori* only one linear combination was selected ($k = 1$), representing an alternative to the development index. It is statistically justified to retain only one component since only one principal component has the eigenvalue greater than 1, which satisfies the latent root criterion. Indicator weights have been calculated on the basis of PCA, and afterwards normalized. The resulting weights are represented in table 8. It is important to note that outliers have been excluded prior to performing the PCA.

TABLE 8

Normalized indicator weights according to PCA, LGU and RGU level

Normalized weights w^{PCA}	Income w_1^{PCA}	Budget revenue w_2^{PCA}	Unemployment rate w_3^{PCA}	Change in population number w_4^{PCA}	Educational attainment rate w_5^{PCA}	Variance explained (%)
Index LGU 2010-2013	0.21	0.2	0.2	0.17	0.22	62
Index LGU 2006-2008	0.23	0.18	0.21	0.15	0.23	55
Index RGU 2010-2013	0.21	0.22	0.19	0.17	0.21	74
Index RGU 2006-2008	0.24	0.24	0.2	0.1	0.22	66

Source: Authors' calculation.

One of the weaknesses of the weights derived from PCA is the minimization of the contribution of individual indicators which do not move along with other individual indicators. In case of development index, the indicator change in population number has the smallest weight determined by PCA because this indicator exhibits the weakest correlation with other indicators. However, weights derived from PCA assigned to demographic indicators are higher than those determined by the government decree, at both a local and a regional level.

According to the index computed with the use of PCA-derived weights (I^{PCA}), in total 57 LGUs are classified into category I, and 211 LGUs are classified into category II. When using the adjusted development index (reducing the index value for 10 points for the undeveloped LGUs on the ASSC), category II contains 239 LGUs. Also, only three LGUs classified into categories I or II by the development index are now, according to PCA-derived index, classified into groups with a higher development level. On the regional level, there is no difference between the classification of RGUs according to government decree and the PCA derived index. The values of PCA derived indices are presented in table 10.

4.3 ALTERNATIVE NORMALIZATION METHOD

Development index, I_c, of a local unit c is calculated as the weighted average of five basic normalized socio-economic indicators

$$I_c = \sum_{i=1}^{5} w_i \frac{x_{c,i} - x_{i,min}}{x_{i,HR} - x_{i,min}}. \tag{12}$$

Section 3.2 gives a critical review of the normalization method used in the construction of the development index. The direct influence of the maximum value of an individual indicator on the LGU/RGU development index can be removed by combining the min-max normalization and averaging relative to the development index of Croatia (formula 13). The calculation of the development index as a weighted average of the same indicators, but on the state level, would result with an indicator less sensitive to extreme values.

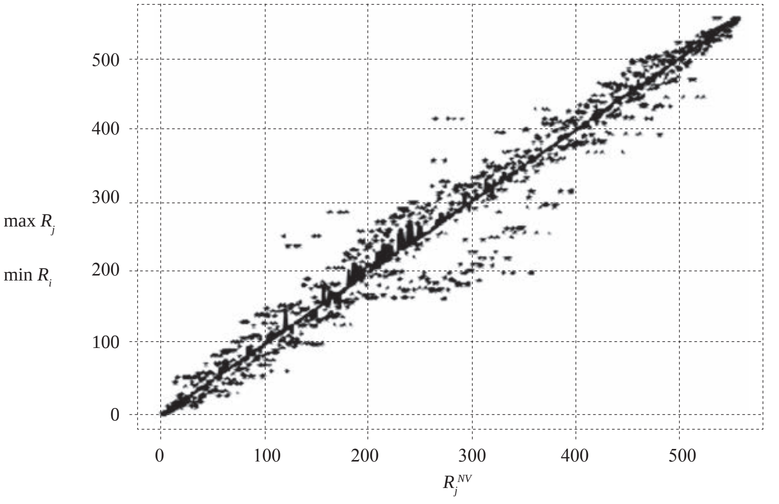
$$I_c^{N'} = \frac{\sum_{i=1}^{5} w_i \frac{x_{ci} - x_{i,min}}{x_{i,max} - x_{i,min}}}{\sum_{i=1}^{5} w_i \frac{x_{i,HR} - x_{i,min}}{x_{i,max} - x_{i,min}}}. \tag{13}$$

4.4 UNCERTAINTY ANALYSIS OF THE DEVELOPMENT INDEX

4.4.1 Uncertainty analysis of the LGU development index

Taking into account analogous indices of countries in the region, one can recognize weights and normalization method selection as the main sources of uncertainty. In total, 12 models have been obtained: 3 normalization methods are presented in table 5 and the normalization method determined by the government decree (formula 5); 3 weighting methods (weighting method determined by the government decree w^V; weights derived from PCA for the period 2010-2012 w^{PCA} (table 8); and equal weights $w^E = (0.2, 0.2, 0.2, 0.2, 0.2)$). Indices computed with different normalization methods are not mutually comparable. Thus, the uncertainty was obtained due to the corresponding LGU ranks. For each model $i = 1,...,12$ and for each LGU c ($c = 1,..., 556$), the development index I_c^i and corresponding rank R_c^i were calculated. Figure 2 shows the smallest, greatest and the median rank value for a LGU c relative to the rank R_c^{NV} determined by the unadjusted development index I_c^v.

FIGURE 2
Uncertainty analysis due to LGU rank, LGU level



Source: Authors' calculation.

Analysis of the data presented in figure 2 shows good agreement in low and high regions of R^{NV} and certain jumps of the median rank for the middle region. This behavior may indicate a possible overestimation, or underestimation of certain LGUs, especially LGUs with medium development level. On the same set of units, it can be observed that a wider range of indicator values follow this behavior. This indicates the inability of a model to concisely estimate the development level of these units. Furthermore, this leads to significant disparities in the categorization based on development index compared to the categorization based on other models.

A key issue in the construction of a composite indicator is determining the relative importance of indicators and by that choosing appropriate indicator weights. This is especially important because the sensitivity of the composite indicator, due to change in weights, opens up the possibility of manipulation of the categorization of units lagging behind in development. Thus, uncertainty due to change in weights is analyzed.

For every LGU c, the minimum I_c^{min} and maximum I_c^{max} possible values of the index are calculated. Weights were chosen from the interval [0.1, 0.6] and scaled to a unity sum.

$$I_c^{min} = \min_{\substack{w_i \in [0.1, 0.6] \\ \sum_{i=1}^{5} w_i = 1}} \left\{ \sum_{i=1}^{5} w_i x_{ci} \right\} \text{ and } I_c^{max} = \max_{\substack{w_i \in [0.1, 0.6] \\ \sum_{i=1}^{5} w_i = 1}} \left\{ \sum_{i=1}^{5} w_i x_{ci} \right\} \tag{14}$$

Results obtained by formula (14) were compared to the results obtained by using the development index. The comparison showed that 56% of units classified into categories I or II by the development index are classified into categories III, IV or V when I_c^{max} was used, i.e. 56% of the units from the supported areas are not rated as lagging behind in development. Similar results occur when the classification according to minimum possible index value, I_c^{min} is analyzed. More than 43% of units classified into categories III, IV and V by the development index are now classified into categories that are lagging behind in development.

Uncertainty analysis on the LGU level was performed using the Monte Carlo simulation. Three types of simulations were performed due to the distribution of weights:

(a) The first simulation S_1 was conducted by generating 2500 weights from the uniform distribution, $w_i \sim U(0.25, 0.6)$. Afterwards, weights were scaled to a unity sum. The latter ensured for weights to range between 0.1 and 0.35, preventing domination of an individual indicator over others.

(b) The second simulation S_2 was conducted by generating 2500 weights from uniform distribution, $w_i \sim U(\frac{3}{4}w_i^V, \frac{5}{4}w_i^V), i = 1,2,..,5,$ where w_i^v represents weights determined by the government decree.

(c) Third simulation S_3 was conducted by generating 2500 weights from the uniform distribution, $w_i \sim U\left(\frac{3}{4}w_i^{PCA}, \frac{5}{4}w_i^{PCA}\right)$, $i = 1,2,..,5$ where w_i^{PCA} represent weights determined from PCA.

After being generating, all weights were scaled to unity sum. For each simulation, and for every LGU c, 500 values of development index $I_{c,k}$, $k = 1,2,...,500$ were calculated The first simulation is almost nonrestrictive, while the second and third simulation generate weights around values determined by the government decree w^v, and PCA, w^{PCA}.

The percentage of simulations resulting in a classification corresponding to the development index I^V is calculated for each simulation and each unit. The average percentage for each category is provided in table 9, as well as the average range of simulated indices, $\bar{I}_{max-min} = \frac{1}{556}\sum_{k=1}^{556}\left(I_c^{max} - I_c^{min}\right)$, where $I_c^{max} = \max_{k=1,..,500} I_{c,k}$ and $I_c^{min} = \min_{k=1,..,500} I_{c,k}$ are the maximum and minimum value in each simulation. Additionally, table 9 provides the frequency of incorrectly classified units (n_w) which have the probability of wrong classification $p_w(c)$ higher than 0.45:

$$n_w = \sum_{c=1}^{556} 1_{p_w(c)>0.45} \quad (15)$$

For simulations S_1 and S_2, the probability of incorrect categorization was estimated as the relative frequency of incorrect categorization of LGUs due to the categorization based on I_c^V. Also, for simulations S_1 and S_3, the probability was estimated due to a categorization based on I_c^{PCA}.

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TABLE 9
Simulation result, LGU level

Simulation	Category retention (%)					n_w	$\bar{I}_{max-min}$
	I	II	III	IV	V		
$S_1\ w_i \sim U(0.25, 0.6)$	87	92	80	82	98	71[a] 31[b]	0.14
$S_2\ w_i \sim U\left(\frac{3}{4}w_i^V, \frac{5}{4}w_i^V\right)$	96	94	94	96	96	9	0.08
$S_3\ w_i \sim U\left(\frac{3}{4}w_i^{PCA}, \frac{5}{4}w_i^{PCA}\right)$	96	94	94	95	98	6	0.08

[a] *Number of incorrect categorizations according to* I^V.
[b] *Number of incorrect categorizations according to* I^{PCA}.
Source: Authors' calculation.

The simulation S_1, which is the least restrictive in the choosing of weights, resulted in 31 LGUs being incorrectly categorized due to the categorization based on the I^{PCA}. This is a significantly lower number than the number of incorrect categorizations resulting from the categorization based on the development index I^V (71 LGUs incorrectly categorized). Thus, it can be concluded that the categorization according to the development index I^V is less confident than the PCA categorization. In addition to that, a greater confidence of the PCA-categorization can be obtained by considering smaller perturbations of weights around the values of w^V or w^{PCA}.

Monte Carlo simulations open up the possibility of employing confidence intervals for the estimation of the development level of territorial units. Moreover, when using simulations it is possible to estimate the probability of incorrect categorization for every unit. This is particularly beneficial in the case of marginal units. For instance, Lećevica municipality, according to development index value (75.36%), is not categorized in the group of supported units. However, 84% of simulations S_1 resulted in the categorization of this municipality in the group of supported units. A similar situation occurs with more than 20 LGUs (see appendix). Due to the large number of LGUs, interval estimations are presented only at a regional level (table 10).

4.4.2 Uncertainty analysis of RGU development index

The Decree says that the methodology for the construction of the development index on the local level is the same as that for the regional level (Decree on the Development Index, 2010). However, one can pose the question whether one methodology can be reliably applied to two different cases? In particular, is it justified to select the same weights at a local and a regional level?

For every RGU *c*, two types of development indices were computed: the development index I_c^V using weights determined by the government decree and the index

I_c^{PCA}, computed using weights derived from PCA. Based on indices values, corresponding ranks were determined. The results are presented in table 10, where the ranks are presented in brackets.

Table 10

Comparison of the index value and corresponding rank (in brackets)

County of c	$\bar{I}_c^{S_1}$ (%)	I_c^{V} (%)	I_c^{PCA} (%)	90% CI for $I_c^{S_1}$	90% CI for $I_c^{S_2}$	90% CI for $I_c^{S_3}$
Virovitica-Podravina	7.18 (1)	5.56 (1)	7 (1)	<0.06, 0.08>	<0.05, 0.06>	<0.06, 0.08>
Slavonski Brod-Posavina	24.03 (4)	18.43 (2)	22.42 (4)	<0.19, 0.29>	<0.16, 0.21>	<0.20, 0.25>
Vukovar-Sirmium	22.65 (3)	18.73 (3)	21.74 (2)	<0.19, 0.26>	<0.17, 0.21>	<0.20, 0.24>
Bjelovar-Bilogora	21.96 (2)	23.29 (4)	21.84 (3)	<0.21, 0.23>	<0.23, 0.24>	<0.21, 0.22>
Požega-Slavonia	30.25 (5)	33.81 (5)	29.01 (5)	<0.26, 0.34>	<0.31, 0.36>	<0.27, 0.31>
Sisak-Moslavina	39.75 (6)	38.70 (6)	41.54 (6)	<0.35, 0.44>	<0.36, 0.42>	<0.39, 0.44>
Osijek-Baranja	49.11 (7)	46.07 (7)	49.21 (7)	<0.47, 0.52>	<0.44, 0.48>	<0.48, 0.51>
Karlovac	53.28 (9)	56.34 (8)	54.47 (9)	<0.49, 0.57>	<0.54, 0.59>	<0.52, 0.57>
Koprivnica-Križevci	52.63 (8)	59.19 (9)	51.64 (8)	<0.46, 0.59>	<0.55, 0.64>	<0.48, 0.56>
Lika-Senj	59.61 (10)	64.82 (10)	61.04 (10)	<0.54, 0.65>	<0.61, 0.68>	<0.58, 0.64>
Međimurje	64.79 (12)	69.65 (11)	62.03 (12)	<0.58, 0.72>	<0.64, 0.75>	<0.58, 0.66>
Krapina-Zagorje	62.78 (12)	73.24 (12)	61.45 (11)	<0.56, 0.69>	<0.68, 0.78>	<0.58, 0.66>
Šibenik-Knin	83.04 (14)	80.93 (13)	82.14 (14)	<0.80, 0.87>	<0.79, 0.83>	<0.80, 0.84>
Varaždin	78.81 (13)	86.34 (14)	77.39 (13)	<0.73, 0.84>	<0.82, 0.90>	<0.74, 0.81>
Split-Dalmatia	102.55 (15)	93.75 (15)	101.2 (15)	<0.97, 1.09>	<0.90, 0.98>	<0.98, 1.05>
Zadar	112.62 (16)	106.39 (16)	109.13 (16)	<1.04, 1.23>	<1.01, 1.12>	<1.04, 1.14>
Dubrovnik-Neretva	123.62 (18)	120.84 (17)	122.31 (18)	<1.2, 1.28>	<1.18, 1.23>	<1.20, 1.25>
Zagreb	121.21 (17)	124.23 (18)	118.03 (17)	<1.15, 1.28>	<1.21, 1.28>	<1.14, 1.22>
Primorje-Gorski kotar	139.69 (19)	139.21 (19)	141.71 (19)	<1.35, 1.44>	<1.37, 1.41>	<1.39, 1.44>
Istria	154.36 (20)	156.80 (20)	154.20 (20)	<1.5, 1.59>	<1.54, 1.6>	<1.51, 1.57>
City of Zagreb	185.45 (21)	186.44 (21)	188.5 (21)	<1.76, 1.93>	<1.81, 1.92>	<1.83, 1.93>

CI – interval estimation.

Source: Authors' calculation.

Due to the selection of weights, uncertainty analysis was conducted using Monte Carlo simulations. Analogously to the analysis conducted on the local level, 5,000 samples of weights from three types of uniform distributions were generated. For each simulation S_j and every RGU c, 1,000 values of development index $I_{c,k}^{S_j}$, $k = 1,2,..., 1000$, $j = 1,2,3$ were calculated. For 21 RGUs, interval estimations of development index, based on percentile index values, are computed with 90% confidence level.

The comparison of lower bounds of the interval estimations obtained by simulations S_1 and S_3, shows that the development index I^V underestimates the development level for following counties: Virovitica-Podravina, Slavonski Brod-Posavina, Vukovar-Sirmium, Bjelovar-Bilogora, Osijek-Baranja and Split-Dalmatia. These counties have a development index value lower than the lower bounds of interval estimations provided by simulations S_1 and S_3. Similarly, the comparison of the development index I^V and the upper bounds of the interval estimations indicates a possible overestimation of the development level for the following counties: Bjelovar-Bilogora, Koprivnica-Križevci and Varaždin since the development index is higher than the upper interval bounds. The selection of weights doesn't significantly affect the categorization of RGUs determined by the government decree, but it has an impact on the units ranking. According to the development index, the county of Split-Dalmatia is categorized in the second group, while according to the average simulated index and PCA derived index is categorized in the group having a higher development level.

4.5 SENSITIVITY ANALYSIS OF THE DEVELOPMENT INDEX

4.5.1 Sensitivity analysis of the development index, LGU level

First order sensitivity indices S_i and total effect sensitivity indices S_{T_i} are calculated for indicators X_i, i=1, 2,..., 5. The results on the LGU level are presented in table 11.

Table 11

Sensitivity indices (LGU level)

I	1	2	3	4	5
S_i	0.084	0.145	0.087	0.021	0.022
S_{Ti}	0.394	0.485	0.390	0.155	0.216

Source: Authors' calculation.

It can be concluded that a change in the value of a single indicator affects the values of the development index. This is due to the fact that a single indicator interacts with other indicators and thus the cumulative effect is observable on the value of development index. Significantly higher values of total effect sensitivity index indicate stronger interactions between economic indicators: budget revenue *per capita*, income *per capita* and unemployment rate.

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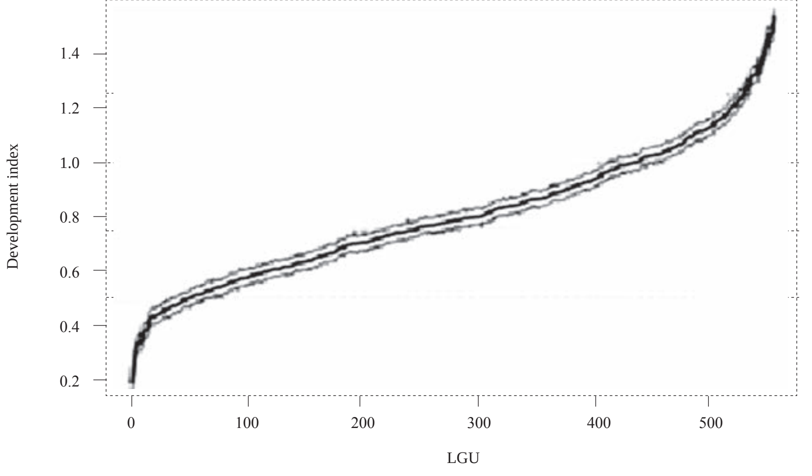
The effect of small changes in the values of economic indicators on the sensitivity of the development index was examined directly by using the Monte Carlo simulations. For every regional unit *c*, 100 values of the indicator X_i, $i = 1,..., 5$ were generated from the normal distribution with a mean equal to the observed indicator value x_{ci} and variance σ_i^2 equal to the quarter of the sample variance. This way the simulation is limited only to small perturbations of the parameters, which can appear as the result of imprecise measurement or the fact that indicator values tend to change over time.

FIGURE 3
Interval estimates



Source: Authors' calculation.

TABEL 12
Category changed (%)

Category according to I^V	Falling into lower category (%)	Advancing into higher category (%)
I	–	19
II	9	12
III	15	12
IV	15	7
V	8	–

Source: Authors' calculation.

The values of the development indices on the LGU level, together with corresponding interval estimations, are presented on figure 3. The interval estimations are assessed *via* simulations at the 95% confidence level. The LGUs that shift to categories with lower or upper development levels are determined by intersections of level boundaries according to I^V and interval estimations. Table 12 provides the percentages of shifts between groups. LGUs switching between catego-

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ries should be analyzed in more detail due to the possibility of incorrect classification.

4.5.2 Sensitivity analysis of the Development index, RGU level

First order sensitivity indices S_i and total effect sensitivity indices S_{T_i} are calculated for indicators X_i, i=1, 2,...,5. The results at the RGU level are presented in table 13.

Table 13

Sensitivity indices (RGU level)

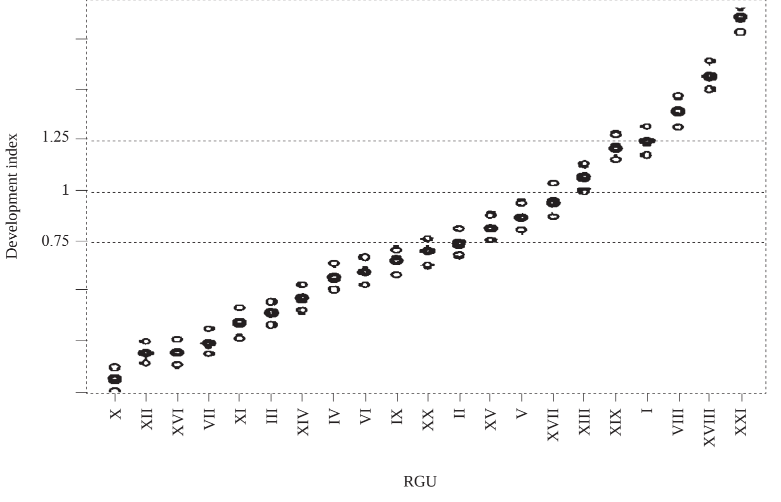
I	1	2	3	4	5
S_i	0.084	0.039	0.119	0.021	0.022
S_{T_i}	0.439	0.322	0.481	0.239	0.221

Source: Authors' calculation.

Similar to the results obtained with the sensitivity analysis of LGUs, the interaction of economic indicators emerges as the main source of variability of the development index on the RGU level. The values of the development indices on the RGU level together with corresponding interval estimations are presented on figure 4.

Figure 4

Interval estimations (RGU level)



Source: Authors' calculation.

Interval estimations of the development index for the counties Krapina-Zagorje, Split-Dalmatia, Dubrovnik-Neretva and Zagreb are partially placed in the categories of higher development level according to the category determined by the index I^V. This indicates a possible underestimation of the specified counties. Thus, these counties should be analyzed in more detail. Using interval estimates allows for a briefer analysis of these marginal units considering the estimation of an incorrect classification of territorial units.

5 CONCLUSION

Prior to the implementation of the development index, the categorization process of territorial units was often criticized as unbalanced and fragmented. A turnaround started with the employment of composite indices as a basis for the development level assessment of LGUs and RGUs. The development index is calculated as the weighted average of normalized indicator values relative to the state average. For many local units that are lagging behind in development, the categorization based on the development index is crucial for further development as it provides it different benefits and incentive intensity.

The main goals of this paper were to assess the uncertainty of development index considering the construction methodology and to evaluate sensitivity considering the indicators involved in its construction. By taking this to account, useful guidelines for the improvement of the index can be proposed. Furthermore, the methodology of the construction of the development index is presented. In order to examine the data structure, multivariate analysis was conducted, indicating the presence of outliers. In particular, the results of multivariate analysis carried out at the regional level indicate the presence of collinearity between indicators income *per capita* and budget revenue *per capita*. This problem can be bypassed by excluding or replacing one of the collinear indicators or by correcting indicator weights.

The researchers' subjective decisions, such as choosing normalization and aggregation methods and selecting indicators and corresponding weights, play an important role in the construction of a composite index. Thus, it is necessary to detect all sources of uncertainty and to analyze their consequences. One of the main features of the construction of composite indicators is the lack of consensus concerning relative weights selection. In this study, a development index derived directly from the data by principal component analysis was proposed as a reference index. The uncertainty of the development index, especially due to the weight selection, was analyzed using Monte Carlo simulations. This analysis indicated the inability of the development index to rank LGUs uniformly, particularly for LGUs categorized in groups II and III. Because weight selection is the main source of uncertainty, categorization on the basis of the development index was revealed to be less confident compared to the PCA-categorization.

The analysis of the model determined by the Government decree indicated strong interactions of economic indicators which dominantly affect the variability of the development index, both on the local and the regional level. Because even small perturbations of input variables can significantly affect the categorization outcome, a special emphasis was placed on the inclusion of these methods in the construction of composite indicators. The inclusion of uncertainties in the model is needed since the measurement errors are frequent, and for some indicators, data are often not provided on time. For this purpose, interval estimations are proposed instead of point estimation. Therefore, it is possible to incorporate uncertainties in the model. This also enables some units to be closely analyzed (for example, territorial units having the development index values 5 points away from the marginal values of the categories).

Due to the lack of scientific papers on this subject, the intention of the authors was to emphasize the need for analyzing the sensitivity and the uncertainty of the development index and of composite indicators in general. Since composite indicators are increasingly used, this study provides useful guidelines for the application, as well as for development, of composite indicators in a wide variety of academic and professional fields.

In three years a new calculation of the development index is expected. It will be interesting to observe the development of the construction methodology, especially the indicator selection process and quality, as well as the assessment of the relative importance due to the socio-economic conditions in the state. With the aim of the general acceptance of the development index, it is necessary to improve the transparency of the construction process. The methodology of the new calculation should follow the expected changes in the dynamics of indicators and their interaction in order to ensure a modern approach to the assessment of the development level of territorial units.

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Basic guidelines for improving the methodology of the development index

1) The correlation of indicators income *per capita* and budget revenue *per capita* should be corrected in one of the following ways:
    a) correction of weights,
    b) excluding an individual indicator,
    c) replacement with an alternative indicator.

    On the regional level, the inclusion of the indicator GDP *per capita*, as a key economic indicator, should be considered.

2) The outliers should be excluded when using the min-max normalization. As an alternative normalization method we propose normalization relative to the state's index value (given with formula 13).

3) Alternative weighting methods should be considered. Furthermore, uncertainty analysis and sensitivity analysis should be conducted in order to improve the transparency and the quality of the development index.

4. Interval estimations of the development index should be provided prior to the categorization of LGUs and RGUs. LGUs/RGUs with the interval estimates overlapping partially with one of the supported groups should be more closely analyzed in order to avoid incorrect categorization.

5) An inclusion/exclusion of marginal units in/from supported areas should be considered. This can be achieved by using Monte Carlo simulations and estimating the probability of (incorrect) categorization (see section 4.4).

    5.1) In particular, regarding simulation results, LGUs listed in table A1 should be considered for inclusion into group II, i.e. into supported areas. Table A1 also provides values of the development index and the percentage of the categorization in groups II and III from MC simulations S_1 (see section 4.4.1).

    5.2) Furthermore, LGUs listed in table A2 should be considered for inclusion into group III, i.e. exclusion from supported areas. Table A2 also provides the development index values and the percentage of the categorization in groups II and III from MC simulations S_1 (see section 4.4.1).

Table A1

Proposal for the inclusion of LGUs into supported areas

LGU	Development index	Categorization into group (%)	
		II	III
Ozalj	0.7508	0.876	0.124
Donji Vidovec	0.7517	0.902	0.098
Jesenje	0.7522	0.860	0.140
Sveti Martin na Muri	0.7525	0.760	0.240
Lećevica	0.7537	0.980	0.020
Petrijanec	0.7543	0.788	0.212
Donji Miholjac	0.7612	0.546	0.454
Krašić	0.7624	0.942	0.058
Klenovnik	0.7671	0.742	0.258
Vratišinec	0.7681	0.676	0.324
Hrašćina	0.7683	0.862	0.138
Pregrada	0.7688	0.872	0.128
Đelekovec	0.7689	0.926	0.074
Lepoglava	0.7695	0.584	0.416
Kraljevec na Sutli	0.7700	0.802	0.198
Mače	0.7728	0.766	0.234
Jalžabet	0.7775	0.550	0.450
Đurmanec	0.7829	0.570	0.430
Breznički Hum	0.7856	0.756	0.244
Bedenica	0.7901	0.562	0.438
Veliki Bukovec	0.8231	0.526	0.474

Table A2

Proposal for the exclusion of LGUs from the supported areas

LGU	Development index	Categorization into group (%)	
		II	III
Vrsi	0.728	0.176	0.824
Imotski	0.735	0.206	0.794
Nova Gradiška	0.741	0.456	0.544
Beli Manastir[a]	0.743	0.392	0.608

[a] *AASC, not categorized into supported areas on the basis of unadjusted development index.*

6) Although this study did not involve the analysis of alternative aggregation methods, this would also be worth pursuing. In particular, one could consider the geometric aggregation as it delimitates the compensability between variables.

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