MEASURING THE MACROECONOMIC PERFORMANCE OF THE CROATIAN ECONOMY: AN EMPIRICAL EFFICIENCY ANALYSIS APPROACH

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Abstract

The unbalanced economic growth of Croatia over the years points to the need for an analysis of certain aspects of its economic performance. Among other things, it would be interesting to focus on the relationship between key macroeconomic indicators and foreign direct investment (FDI) as a growth-enhancing component, which is the subject of this paper. The analysis is conducted empirically, using the nonparametric method of data envelopment analysis (DEA). Since this is a single-country study, a time-series of Croatia’s performance data is reported and the performing system of each sub-period (i.e., year) represents a different decision-making unit (DMU). Based on FDI, exports, unemployment rate and gross domestic product (GDP) and covering the period from 2003 to 2016, the analysis results in an efficiency index for each year, also identifying and quantifying inefficiency sources together with improvement directions. The obtained relative efficiency results confirmed two hypotheses: first, that there are significant differences in Croatia’s macroeconomic efficiency across the years, and second, that FDI is the most prominent inefficiency source among the selected indicators. A potential limitation of this research is a general guideline of DEA
that the number of variables should be less than one-third of the number of DMUs (in this case, years). Since data on some of the selected indicators are not available for a longer period, the set of variables could be broadened by using data at the quarterly level. This could also make the conclusions to be drawn in this study more accurate, which is left for future research. The results should serve the economic policymakers in the efforts to improve decisions affecting the macroeconomic performance of the country.

Keywords: macroeconomic performance, foreign direct investment, (in)efficiency, Croatia, data envelopment analysis

JEL Classification: E00, E01,

1. INTRODUCTION

Numerous empirical studies have demonstrated the complexity of economic growth as a macroeconomic phenomenon. Consequently, so far it has not been fully explained which determinants contribute to the growth, to what extent and in what way. Different theories point to different determinants as key ones for economic growth – from natural resources and labor, through capital and technology, to human potentials. Growth theories assign an important role also to research and development, innovations, political and governmental factors, equipment investment, international trade and export capacity, foreign direct investment etc. Therefore, governments should pursue economic policies that foster open markets of goods and service, protection of private property rights, promotion of liberal capital market, reasonable government spending, incentives for entrepreneurial activity, the efficiency of tax systems, incentives for investment in human capital through active labor market policies, as well as macroeconomic stability. Do these policies affect the macroeconomic performance of a country sufficiently and what direction needs to be taken for their further improvement? It is obvious that measuring and comparing the (in)efficiency of macroeconomic performance, which involves the selection of relevant indicators and appropriate methodology, will be of crucial importance for answering the posed question.

GDP is the single most important measure of the health of the macroeconomy and the most widely reported statistic in every developed economy (Mankiw, 2014). In dynamic analyses, it is generally recommended to use real GDP to exclude the impact of inflation on its changes and thus to provide a more reliable
assessment of relative macroeconomic performance. However, theoretical and empirical research and discussions of a large number of economists have shown that to create a deeper and more comprehensive view of macroeconomic performance trends, it is not enough to observe only the gross domestic product, but it is necessary to put it in relation to a number of other indicators.\(^1\) Deciding which indicators – economic, social and/or demographic – need to be considered in the analysis together with GDP, depends on the subject of research to be conducted. The subject of this particular study is to scrutinize certain aspects of Croatia’s macroeconomic performance, with the focus on the relationship between key macroeconomic indicators and FDI. The aim is to present the results of the analysis of the selected indicators’ influence on the relative efficiency of Croatia. The analysis is carried out using the nonparametric method of data envelopment analysis as an alternative to the approaches used so far in related domestic studies. Concerning the goal of this paper, two hypotheses emerge and will be examined. The first hypothesis presumes that there are significant differences in Croatia’s macroeconomic performance across the years. The second hypothesis points to FDI as the most prominent inefficiency source among the selected indicators.

The paper is organized as follows. After the introduction, the second section provides a brief overview of up-to-date research on relative macroeconomic efficiency of Croatia using DEA. A description of the selected indicators and the methodology used to create a methodological framework for the analysis is provided in the third section, while the fourth section presents the model application in an empirical analysis and relative efficiency evaluation. The research results and their possible implications for economic policymakers are summarized in the last section of the paper.

2. CROATIA IN EMPIRICAL LITERATURE ON THE MACROECONOMIC EFFICIENCY BASED ON DEA

As it relates to an assessment of how well a country is doing in reaching improvement in the real standard of living of the population, the macroeconomic\(^1\) In support of this reasoning, there are some cases in which the exclusive use of GDP can result in misleading estimates. Thus, for example, the high GDP levels over a given period do not have to be the result of the country’s objective economic power, but primarily of the significant public sector investment in infrastructure.
performance of countries has been the subject of numerous studies. However, regardless of the aspect under consideration, the empirical approach is of utmost importance. A survey of literature related to the macroeconomic efficiency of Croatia and based on the use of different DEA-inspired approaches is summarized in Table 1.

Table 1. Summarized overview of the empirical literature on the macroeconomic efficiency of Croatia using DEA

<table>
<thead>
<tr>
<th>Author(s) and year</th>
<th>Sample</th>
<th>Period</th>
<th>Variables</th>
</tr>
</thead>
</table>
• Capital  
• Real GDP |
| Škuflić et al. (2013) | 28 European countries | 2000 2004 2008 | • Productivity  
• Exports (% in GDP)  
• Gross wages (% in GDP)  
• Personal consumption (% in GDP)  
• GDP per capita |
| Pavone and Pianura (2014) | 39 European countries | 2006-2010 | • Employment  
• Capital stock  
• Energy use  
• GDP  
• CO₂ emission |
| Mavroeidis and Tarnawska (2015) | 25 EU member states | / | • Number of ISO Technical Committees in which a National Standardization body participates (per billion of GDP)  
• Number of total accredited bodies (per billion of GDP)  
• Total number of Calibration and Measurement Capabilities (per billion of GDP)  
• GDP per unit of net capital stock Sales of new-to-market and new-to-firm innovations (% of turnover)  
• Exports of goods and services (% of GDP) |
| Nežinský (2015) | 25 EU member states | 2012 | • Capital stock  
• Labour force  
• Active population  
• GDP |
| Pavone and Pianura (2015) | 60 upper-middle and high income economies | 2008-2011 | • GDP growth rate  
• GDP per capita  
• Fiscal surplus/deficit (% of GDP)  
• Current account balance (% of GDP)  
• Human development index  
• Unemployment rate  
• Inflation/deflation rate  
• The rate of total carbon dioxide emissions from the consumption of energy on energy use |
Villa and Lozano (2016)

<table>
<thead>
<tr>
<th>28 EU member states</th>
<th>2006-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GDP growth rate</td>
<td></td>
</tr>
<tr>
<td>• Total employment rate</td>
<td></td>
</tr>
<tr>
<td>• Tax revenue (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• Gross debt (% of GDP)</td>
<td></td>
</tr>
</tbody>
</table>

Önder and Boz (2017)

<table>
<thead>
<tr>
<th>36 Union for the Mediterranean countries</th>
<th>2006-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GDP growth rate</td>
<td></td>
</tr>
<tr>
<td>• Total investment (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• Gross national savings (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• Inflation rate</td>
<td></td>
</tr>
<tr>
<td>• The growth rate of volume of imports of goods and services</td>
<td></td>
</tr>
<tr>
<td>• The growth rate of volume of exports of goods and services</td>
<td></td>
</tr>
<tr>
<td>• Unemployment rate</td>
<td></td>
</tr>
<tr>
<td>• General government revenue (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• General government expenditures (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• General government gross debt (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• Current account balance (% of GDP)</td>
<td></td>
</tr>
</tbody>
</table>

Šegota et al. (2017)

<table>
<thead>
<tr>
<th>26 EU member states</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GDP per capita</td>
<td></td>
</tr>
<tr>
<td>• Research and development investments (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• External government debt (% of GDP)</td>
<td></td>
</tr>
<tr>
<td>• Unemployment rate</td>
<td></td>
</tr>
<tr>
<td>• Net salary of employees</td>
<td></td>
</tr>
<tr>
<td>• High technology products (% of total exports)</td>
<td></td>
</tr>
<tr>
<td>• Export (% of GDP)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ survey.

All the above-mentioned papers use DEA approaches to measure and analyze macroeconomic efficiency of the countries, including Croatia, based on their mutual comparison. Except for Škuflić et al. (2013), none of the studies in Table 1 employs window analysis – the dynamic extension of the basic DEA models that allows a country’s performance to be assessed not only in relation to other countries within the same sub-period but also with regard to other countries’ outcomes, including own, from another sub-period. For that reason, if one aims to shift the focus on a single country and to further understand its macroeconomic trends, it would be valuable to observe its time-series macroeconomic performance data in a way that each sub-period is considered a different entity. This approach has already been utilized by numerous authors, many of them on the case of Croatia but none of them using DEA method, which at this moment makes this study unique. The comparative advantage of this approach over the more traditional ones is that the analysis results in an ef-

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2 Dritsaki and Stiakakis (2014) investigate the relationship between FDI, exports and economic growth in Croatia using annual time-series data for the period 1994-2012. Due to these facts, this paper seems remarkably similar to ours. However, although analysing partially overlapping periods and employing similar indicators, these two studies differ in a number of aspects, including their aims and methods used, which has consequently led to a different kind of results and findings.
ficiency index for each sub-period, simultaneously identifying and quantifying inefficiency sources together with improvement directions.

3. MACROECONOMIC EFFICIENCY ASSESSMENT OF CROATIA – INDICATORS, DATA AND METHODOLOGY

A different selection of input and output variables results in different efficiency scores that are further influenced by model selection. Therefore, the selection of indicators and the design of the model suitable for application in the analysis of a particular process, in particular, the assumptions of its orientation and returns-to-scale, are among the most significant and most sensitive steps in building an appropriate DEA model for assessing the comparative or relative efficiency of the country. Attention should also be paid to what data are collected and available.

3.1. Indicators

The uneven macroeconomic performance of Croatia is present over the years. As an omnipresent reminder of the necessity of maintaining macroeconomic stability, it imposes an obligation to investigate the macroeconomic trends in terms of relative efficiency. This phenomenon should be addressed, among others, by proper selection of indicators.

After considering a wide range of relevant indicators and ranking them according to their relevance, four of them were selected for this study. Besides FDI, these are exports, unemployment rate and GDP. The reasons behind their selection are briefly the following. The role of FDI as a compound collection of capital stocks, know-how, and technology is a growth-enhancing component in Central and Eastern Europe countries (Popescu, 2014). The importance of exports for economic growth was seen to be constantly reconfirmed and various studies, including Dritsaki and Stiakakis (2014), point exports as the catalyst for the economic growth of Croatia. The role of employment in economic development has long been recognized and increasing employment (i.e., reducing

3 Since Croatia is the only country in this analysis, the drawbacks due to which registered unemployment rate is not utilized in international comparisons are here irrelevant, which makes the use of this rate justified for this study.
unemployment that has manifold adverse effects on both individuals and the economy as a whole) constantly remains one of the key priorities in achieving sustainable growth and development (Borozan et al., 2008). The importance of GDP as the most widely used single indicator in macroeconomic efficiency evaluation is already explained in the Introduction.

It should be noted that the degree of the government’s influence on each of the selected indicators varies, which should be considered when drawing up guidelines based on results obtained by the empirical analysis. In addition, to make the analysis more reliable and the results’ interpretation easier, some preliminary adjustments of selected indicators are needed. Since the purpose of this study is to make dynamic comparisons, the effect of the price increases is eliminated by taking FDI, exports, and GDP at constant prices of 2010. Thus adjusted four indicators will be integrated into a unique performance measure.

To build a model suitable for analyzing the dynamic relationship between GDP as a standard measure of national economic performance and other selected indicators, only GDP is considered output, while the other three indicators are considered as inputs.

3.2. Data collection

The nature of the selected indicators enables comparison on an annual basis. The data on them, as well as the auxiliary variables\(^4\) necessary for their calculation, were collected from the official web pages of the Croatian Bureau of Statistics, the Croatian Employment Service and the Croatian National Bank, and then adjusted in accordance with the above requirements. The unavailability of data on some of the indicators for the period before 2003 and after 2016 determined the time frame of the research which, for the purpose of time series analysis, includes the data for the period 2003-2016. Table 2 presents the summary statistics for the adjusted data of each variable employed in the analysis.

\(^4\) This is the consumer price index as a variable to which the government cannot directly influence.
Table 2. Data summary statistics, 2003-2016

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDI in mil EUR</td>
<td>1,841.28</td>
<td>1,698.13</td>
<td>1,082.71</td>
<td>183.83</td>
<td>3,787.54</td>
<td>58.80</td>
</tr>
<tr>
<td>Exports in mil EUR</td>
<td>9,012.54</td>
<td>8,965.43</td>
<td>1,226.27</td>
<td>6,724.49</td>
<td>11,484.05</td>
<td>13.61</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>17.19</td>
<td>17.60</td>
<td>2.08</td>
<td>13.20</td>
<td>20.20</td>
<td>12.08</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP in mil EUR</td>
<td>44,012.69</td>
<td>43,673.34</td>
<td>2,842.53</td>
<td>39,085.71</td>
<td>49,886.26</td>
<td>6.46</td>
</tr>
</tbody>
</table>

Note: SD = standard deviation; CV = coefficient of variation;
Source: Authors’ calculations based on data from the Croatian Bureau of Statistics, the Croatian Employment Service and the Croatian National Bank.

Since in this study FDI and exports are specified as inputs but, in practice, preferred to have larger amounts, in the model calculation their reciprocals are taken. This at the same time preserves the relationship between inputs and output and enables the assessment of the performance regarding the government’s capability to maximize all selected variables. Consequently, recalculation of the obtained results and an additional caution in their interpretation should be exercised.

3.3. Methodological framework

DEA is a non-parametric performance measurement technique commonly employed to estimate the relative efficiency of a group of entities/decision-making units (DMUs) that are homogenous in the sense of using the same set of inputs and produce the same set of outputs. The empirical data on the selected inputs and outputs of the observed entities are incorporated into a linear program that represents the DEA model and provides a single relative performance efficiency index. Based on this data, an efficient frontier is formed by the best performing units that are therefore classified as efficient (i.e., benchmarks). At the same time, this empirically generated ‘best practice’ frontier envelops the input and output data of all the other DMUs that are consequently considered inefficient. The efficient ones are assigned an efficiency measure of 1 (or 100%), while the inefficient ones are scored between 0 and 1 depending on their distance from the frontier. This inefficiency is the result of using excessive inputs at a given output level and/or producing poor output at a given input level and can be removed by reaching a model-calculated efficient projection point on the efficient frontier. Since empirically constructed, this frontier appears as an objectively attainable goal for each inefficient DMU and, at the same time, serves as the basis for recognizing and quantifying its inefficiency sources and
their amounts, improvement directions and reference DMUs for most direct comparison.

Due to its robust properties, DEA has been applied across the spectrum of both profit and non-profit domains, and at both micro and macro-economic levels. The concept of the method is based on the seminal work of M. J. Farrell (1957). Since its initial introduction by Charnes, Cooper, and Rhodes in 1978 up to the year 2016 approximately 10,300 DEA-related articles of theoretical and practical interest have been published (Emrouznejad and Yang, 2018), a great deal of which in ISI Web of Science database (Liu et al., 2016). A considerable number of DEA models has been developed, primarily differing in the returns-to-scale assumption (constant or variable) and orientation (to input minimization or to output maximization) and consequently in the type of efficiency being calculated. Besides, there are numerous advanced models, built upon the basic ones, that are mutually distinguished by various extensions. Therefore, this approach has been internationally and academically recognized and proven as a decision support tool.

The determining factor in choosing this method over traditional benchmarking techniques was its ability of dynamic efficiency measurement, with inputs and outputs scaled in different and often incompatible units of measurement, and with no need for predetermining variable weights nor for explicit specification of the functional form connecting inputs and outputs. Moreover, the weights are assigned by the model itself, in a manner that maximizes the efficiency rating for each assessed entity, thus eliminating the subjectivity in the evaluation of each weight’s significance.

However, it would be unfair to omit to mention that, despite the advantages, the DEA also has several shortcomings regarding empirical applications. One of the major is a commonly suggested rule of thumb, according to which the number of DMUs should be at least three times the number of indicators (for a more detailed discussion see Sarkis, 2007). The reason for this request is an attempt to assure that the basic productivity models are more discriminatory thus achieving greater reliability of the efficiency results. Also, unlike general application of multi-criteria approaches to ex-ante problems where data are not available at the moment, especially if referring to a discussion of future technologies that do not yet exist, DEA provides an ex-post analysis of the past from which to learn (Adler et al., 2002).
The first step an analyst should perform after selecting indicators is to determine the type of returns to scale in accordance with which the production frontier is estimated. In this respect, two basic models most widely used in DEA applications are CCR (Charnes, Cooper and Rhodes, 1978) and BCC (Banker, Charnes and Cooper, 1984), named after the initials of their authors. The first model assumes that the production function shows constant returns to scale, while the second model, with the assumption of variable returns to scale, is one of its numerous theoretical extensions. A preliminary investigation of the process to be analyzed and the testing of its properties can result in the indication of returns-to-scale type. Despite that, the production frontier characteristics, as in the case of this research, are sometimes hard to identify with certainty. In such cases, it is not justifiable to rely on a single model. One of the possible solutions is to run models under both constant and variable returns-to-scale assumptions, compare their results and, based on the significance of their differences and using expert knowledge of the problem, find the most appropriate type of assumption for the analysis. The preliminary phase of the here presented study showed the similarity among the results derived from the mentioned models (Table 3). It can, therefore, be assumed that the return effect with respect to the range of activities does not play a significant role in this case, which makes the CCR model more relevant to describe the examined process and is the reason for choosing that model for further analysis. This is additionally supported by the fact that 11 out of 14 years are characterized by constant returns to scale.

Table 3. Summary statistics for the input-oriented CCR and BCC models

<table>
<thead>
<tr>
<th>Results of the pre-analysis</th>
<th>CCR model</th>
<th>BCC model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of efficient years</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Number of inefficient years</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Average efficiency score</td>
<td>0.8032</td>
<td>0.8610</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.1322</td>
<td>0.1011</td>
</tr>
<tr>
<td>Minimum efficiency score</td>
<td>0.5416</td>
<td>0.6912</td>
</tr>
<tr>
<td>Number (%) of years with below average efficiency</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(57%)</td>
<td>(50%)</td>
</tr>
</tbody>
</table>

Source: Authors’ work based on DEA-Solver-Pro calculations.

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5 In differently oriented models with the same returns-to-scale assumption, the number of efficient entities is unchanged. At the same time, the efficiency scores can differ significantly, but only in the case of the BCC model. Also, due to different production frontiers’ characteristics, BCC efficiency scores are never lower than CCR estimates.
The next problem the analyst has to cope with is the choice of model orientation. Namely, depending on whether management is predominantly focused on input reduction or output augmentation, DEA models are oriented toward inputs or outputs. Different model orientations result in different projection directions onto efficient frontier and consequently in different projection points for each inefficient DMU. The distances from these points to the correspondent inefficient DMU evidently differ, which is why the efficient frontiers in differently oriented models unequally attainable. As GDP is the only variable taken as output among the four chosen indicators, the input orientation was selected as more adequate since it offers an assessment of the extent to which inputs should be improved, without reducing the actual output amounts, to make the DMU relatively efficient. The following brief description of the model is based on Cooper et al. (2006, pp. 87-89). Accordingly, it is the relative efficiency assessment of $n$ DMUs ($DMU_{j=1,2,...,n}$), each of which uses $m$ inputs to generate $s$ outputs. The input-oriented CCR model evaluates the efficiency of $DO_o$ by solving the following linear program:

$$\begin{align*}
\text{min}_{\theta, \lambda} & \quad \theta \\
\text{subject to} & \quad \theta x_o - X \lambda \geq 0 \quad (1) \\
& \quad Y \lambda \geq y_o \quad (2) \\
& \quad \lambda \geq 0 \quad (3)
\end{align*}$$

where $X = (x_j) \in \mathbb{R}^{m \times n}$ denotes the matrix of inputs and $Y = (y_j) \in \mathbb{R}^{s \times n}$ denotes the matrix of outputs, $\lambda \in \mathbb{R}^n$. Therefore, the conditions (1), (2) and (3) consist of $m$, $s$ and $n$ constraints, respectively. In the case that is analysed here, $n$ is 14, $m$ is 3 and $s$ is 1. Vector $\lambda$ indicates the proportions in which efficient entities contribute to the projection of inefficient $DO_o$ on efficient frontier. The optimal objective value $\theta$ represents the efficiency score for $DO_o$ and, in the case of its inefficiency, also the input reduction rate ($0 \leq \theta^* \leq 1$).

This first phase minimizes $\theta$, and the first two constraints of the corresponding linear program show that $(X\lambda, Y\lambda)$ outperforms $(\theta^* x_o, y_o)$ when $\theta^* < 1$. In this context, the input surpluses and the output shortfalls (i.e., slack $DO_o$ values) are calculated by the formulas:

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

where $s^- \in \mathbb{R}^m$, $s^- \geq 0$ and $s^+ \in \mathbb{R}^s$, $s^+ \geq 0$ for any feasible solution $(\theta, \lambda)$.
In the second phase, possible remaining input surpluses and output shortfalls will be detected by maximizing their sum while keeping $\theta = \theta^*$.

**Definition 1 (CCR-efficiency):**

If an optimal solution $(\theta^*, \lambda^*, s^{-*}, s^{++})$ of the CCR model (obtained in this two-phase solution procedure) satisfies $\theta^* = 1$ and has no slack ($s^{-*} = 0, s^{++} = 0$), then the $DO_o$ is called CCR-efficient, otherwise it is CCR-inefficient.

The provided information can be used as a basis for goal setting for the DMU being evaluated as inefficient. A first step in identifying its targets is to compare it with the efficient DMUs that constitute its reference set.

**Definition 2 (Reference Set):**

For a CCR-inefficient $DO_o$, its reference set is defined based on an optimal solution $\lambda^*$ by

$$E_o = \{j \mid \lambda_j^* > 0\} \ (j \in \{1,2,\ldots,n\}).$$

Any of the eventually multiple optimal solutions is expressed as:

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

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

These relationships suggest that the efficiency of $(x_o, y_o)$ for $DO_o$ can be improved if the input values are reduced radially by the ratio $\theta^*$ and the input surpluses recorded in $s^{-*}$ are then removed, and if the output values are augmented by the output shortfalls recorded in $s^{++}$. The described improvement can be represented by the following formula (i.e., CCR-projection):

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

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

This type of studies usually includes more than one entity and/or involve more than one sub-period. It is therefore common to calculate average efficiencies – either by the entity in a particular sub-period or by the sub-period for a particular entity. But, apart from the usual calculation of mean value, in which all observed units are equally represented, there are weighted means where weighting can be made according to different criteria. Among them is the progressive time-weighted means – PTWM (Kumar and Vincent, 2011) as the method for computing a sort of weighted average of a non-empty set of numbers that assigns more weight to recent data points and makes it more responsive to the...
new information. For the period 1 to \( T \), a set of relative efficiency values, say \( e_t \), \( t = 1, \ldots, T \) is considered. The progressive time-weighted mean is defined as

\[
PTWM = \sum_{t=1}^{T} w_t e_t
\]

where \( w_t = 2t/(T^2 + T) \), \( t = 1, \ldots, T \) are associated non-negative normalized weights.

In the case that is analyzed here, the period spans from 1 (2003) to 14 (2016).

4. APPLICATION OF THE MODEL IN AN EMPIRICAL ASSESSMENT OF THE MACROECONOMIC EFFICIENCY OF CROATIA

The relative macroeconomic efficiency of Croatia, presented below, was obtained by authors’ calculations using DEA-Solver-Pro software, based on the input-oriented model with constant returns-to-scale assumption. The efficiency scores, rankings, total proposed input, and output improvements and referential years (i.e., reference sets) are shown in Table 4 for each of the observed years. This spectrum of results enables a meaningful analysis of Croatia’s efficiency based on the comparisons of its macroeconomic performance over the entire period under consideration.

Table 4. Relative macroeconomic efficiency results of Croatia, 2003-2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Efficiency score</th>
<th>Rank</th>
<th>Total input and output improvements (%)</th>
<th>Referential year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>FDI Inputs</td>
<td>Exp. Un. rate</td>
</tr>
<tr>
<td>2003</td>
<td>0.5416</td>
<td>14</td>
<td>138.32</td>
<td>84.64</td>
</tr>
<tr>
<td>2004</td>
<td>0.6396</td>
<td>13</td>
<td>162.88</td>
<td>56.35</td>
</tr>
<tr>
<td>2005</td>
<td>0.7116</td>
<td>12</td>
<td>52.72</td>
<td>40.53</td>
</tr>
<tr>
<td>2006</td>
<td>0.8619</td>
<td>5</td>
<td>16.02</td>
<td>16.02</td>
</tr>
<tr>
<td>2007</td>
<td>0.9569</td>
<td>3</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>2008</td>
<td>1</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2009</td>
<td>0.8083</td>
<td>6</td>
<td>82.45</td>
<td>38.75</td>
</tr>
<tr>
<td>2010</td>
<td>0.7975</td>
<td>8</td>
<td>99.44</td>
<td>25.39</td>
</tr>
<tr>
<td>2011</td>
<td>0.7831</td>
<td>9</td>
<td>96.58</td>
<td>27.70</td>
</tr>
<tr>
<td>2012</td>
<td>0.7356</td>
<td>10</td>
<td>65.29</td>
<td>35.94</td>
</tr>
<tr>
<td>2013</td>
<td>0.7203</td>
<td>11</td>
<td>154.65</td>
<td>38.83</td>
</tr>
<tr>
<td>2014</td>
<td>0.8010</td>
<td>7</td>
<td>24.84</td>
<td>24.84</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Croatia was relatively efficient in the years 2008 and 2016. The lowest efficiency score (0.5416) was recorded in the initial year of the analysis. By observing the efficiency trend shown in Figure 1, three sub-periods can be recognized. The first sub-period was 2003-2008, with steady and continuous efficiency increase. After a sudden decrease in 2009, most likely due to the beginning of the Great Recession in Croatia, relative efficiency continued to decline slowly by the end of the second sub-period in 2013. Similar to the first one, the third sub-period (2014-2016) was characterized by sustained efficiency growth. Compared to a year earlier, the highest efficiency improvement was achieved in 2006 (+0.1503), while the most significant efficiency decrease was recorded in 2009 (–0.1917). The overall average efficiency of approximately 0.8 indicates that Croatia was on average 20% inefficient.
None of the results were classified as an outlier since all were within two standard deviations of the mean value. At the same time, 5 out of 14 scores did not fall within one standard deviation of the mean value, indicating that between-scores variability was not insignificant. This fact, together with the considerable difference between the highest and lowest achieved scores (0.4584), proves our first hypothesis that there are significant differences in Croatia’s macroeconomic efficiency across the years.

Observing the selected input and output variable movements (Figure 2), it can be noted that exports and GDP have trends very similar to the efficiency trend, while FDI is characterized by significantly larger fluctuations. The rates of unemployment, expectedly, move in the opposite direction. These claims are mutually supportive, also revealing the causes of such efficiency trend. As a further confirmation of these conclusions, Table 5 shows coefficients of correlation between efficiency scores and performance indicators.

**Figure 2.** Input and output variable trends, 2003-2016

![Input and output variable trends, 2003-2016](chart)

**Source:** Authors’ work based on data from the Croatian Bureau of Statistics, the Croatian Employment Service and the Croatian National Bank.
means the required increase of 25%. Specifically, the reduction of the reciprocal value of as explained earlier, for these two inputs reciprocal values are taken, so the required reduction of, for example, 20% actually.

Since the model always tends to require input reductions, particular attention should be given to FDI and exports. Namely, as explained earlier, for these two inputs reciprocal values are taken, so the required reduction of, for example, 20% actually means the required increase of 25%. Specifically, the reduction of the reciprocal value of $\frac{1}{X}$ to $0,8 \cdot \frac{1}{X}$ is equivalent to increasing the value of $X$ to $1,25 \cdot X$.

It is understandable that behind significant average required changes in input and output quantities stand major required improvements of Croatia’s efficiency in particular years, as a result of an imbalance in its macroeconomic performance of the analyzed period. As can be seen from Table 4, all three inputs contribute to inefficiency, to a greater or lesser extent, in every single year, demonstrating the relevance of their selection for this research. GDP, as the only

### Table 5. Correlation matrix between efficiency scores and performance indicators

<table>
<thead>
<tr>
<th></th>
<th>Efficiency</th>
<th>FDI</th>
<th>Exp.</th>
<th>Un. rate</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>0.43</td>
<td>0.85</td>
<td>-0.77</td>
<td>0.84</td>
</tr>
<tr>
<td>FDI</td>
<td>0.43</td>
<td>1</td>
<td>0.01</td>
<td>-0.64</td>
<td>0.65</td>
</tr>
<tr>
<td>Exp.</td>
<td>0.85</td>
<td>0.01</td>
<td>1</td>
<td>-0.38</td>
<td>0.45</td>
</tr>
<tr>
<td>Un. rate</td>
<td>-0.77</td>
<td>-0.64</td>
<td>-0.38</td>
<td>1</td>
<td>-0.86</td>
</tr>
<tr>
<td>GDP</td>
<td>0.84</td>
<td>0.65</td>
<td>0.45</td>
<td>-0.86</td>
<td>1</td>
</tr>
</tbody>
</table>

**Source:** Authors’ calculations based on data from the Croatian Bureau of Statistics, the Croatian Employment Service, the Croatian National Bank, and the DEA-Solver-Pro calculations.

Input surpluses and output shortfalls, i.e. differences between initial and projected values, are calculated in each variable, considering the above-mentioned adjustment of the actual data. These differences were then averaged over the whole sample and presented in Table 4 as percentages of the corresponding initial values, thus representing the necessary improvements that can be achieved by using the previously explained two-phase procedure. In 2009, for example, the most pronounced is the shortfall of 82.45% of FDI, 19.17% of which can be ascribed to radial inefficiency and removed in the first phase, while the remaining 63.28% is a result of mixed inefficiency that is being removed in the second phase. In the same year, the shortfall of exports is 38.75%, which corresponds to 19.17% of radial and 19.58% of mix inefficiency. In the case of the unemployment rate, all technical inefficiency is radial, and slacks do not occur.

It is understandable that behind significant average required changes in input and output quantities stand major required improvements of Croatia’s efficiency in particular years, as a result of an imbalance in its macroeconomic performance of the analyzed period. As can be seen from Table 4, all three inputs contribute to inefficiency, to a greater or lesser extent, in every single year, demonstrating the relevance of their selection for this research. GDP, as the only

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6 Since the model always tends to require input reductions, particular attention should be given to FDI and exports. Namely, as explained earlier, for these two inputs reciprocal values are taken, so the required reduction of, for example, 20% actually means the required increase of 25%. Specifically, the reduction of the reciprocal value of $\frac{1}{X}$ to $0,8 \cdot \frac{1}{X}$ is equivalent to increasing the value of $X$ to $1,25 \cdot X$.

7 $19.17 = (1 – 0.8083)*100$, where 0.8083 is the efficiency achieved in the year 2009.
output variable, is not a source of inefficiency, which should be attributed to the selection of model orientation. With an average requested increase of 29.02%, exports are not the most prominent inefficiency source in either one of the observed years. On the other side, the unemployment rate, although relatively the least influential source of inefficiency with an average required decrease of 23.17%, affects efficiency the most in 3 out of 12 inefficient years (2006, 2007 and 2014). Overall, the FDI has by far the greatest average impact on efficiency and its average increase demanded in order to attain efficiency is 125.92%. Such a result is largely caused by a sudden drop in FDI levels in 2015⁸. These findings support our second hypothesis that FDI is the most prominent inefficiency source among the selected indicators. Given the relative contribution of each indicator to inefficiency presented in Figure 3, FDI and unemployment rate apparently have the highest (71%) and lowest (13%) shares, respectively.

**Figure 3.** Input and output contribution to inefficiency

<table>
<thead>
<tr>
<th>Proportions of variables in potential improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment rate: 13%</td>
</tr>
<tr>
<td>Exports: 16%</td>
</tr>
<tr>
<td>Foreign direct investment: 71%</td>
</tr>
</tbody>
</table>

**Source:** Authors’ work based on DEA-Solver-Pro calculations.

The efficiency scores of inefficient DMUs allow their direct ranking according to efficiency scores, while efficient DMUs cannot be ranked immediately because of the maximum efficiency score achieved. Since the reference set of an inefficient DMU is composed of efficient ones, one among many approaches proposed by researchers for ranking an efficient DMU is to sum the frequencies of its appearance in individual reference sets. As a consequence, the higher the

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⁸ The biggest share amongst activities in FDI inflows in this year was caused by the acquisition of Tovrnic Duhana Rovinj by the British American Tobacco. However, this positive contribution was more than reversed by the effect of the write off of a part of the principal of CHF loans due to their conversion to euro.
frequency, the more robust the DMU is. In our case, Croatia’s performance in the year that has been declared efficient occurs as a reference to performances in inefficient years. As can be seen from Table 4, both efficient years are referential to the great majority of inefficient years. The only exceptions are the years 2009, 2013 and 2015. The year 2008 serves thus as a reference in 10, and the year 2016 in 11 cases, resulting in fairly equal success.

5. CONCLUDING REMARKS

The relative macroeconomic efficiency of Croatia is empirically assessed based on the comparison of key macroeconomic indicators, using the input-oriented data envelopment analysis model with the assumption of constant returns to scale. The analysis covered 14-years period (2003-2016), thus enabling monitoring of Croatia’s efficiency dynamics.

The empirical results suggest several important findings. Firstly, the efficiency scores averaged across all 14 years of data collection witness serious fluctuations in Croatia’s macroeconomic efficiency, thus indicating the empirical foundation of accepting our first hypothesis. As a result, the year 2003 is ranked as the worst, while the years 2008 and 2016 are ranked as the best. Secondly, based on the magnitude of inefficiency in each year, the average inefficiency for the whole period under consideration is calculated, suggesting that there is a definite possibility of increasing efficiency levels. The average overall inefficiency could thus be reduced by nearly 20%. Thirdly, as a general conclusion, the main inefficiency source is FDI, which empirically confirms our second hypothesis. At the same time, the unemployment rate is most commonly the least significant source of inefficiency.

The conclusions of this study, based on the empirical cross-year comparison, should be of interest to analysts and should assist policymakers in recognizing the strengths and weaknesses of Croatian macroeconomic environment and its impact on further growth and development, and thus in shaping a targeted macroeconomic policy. They offer an insight into relative efficiency levels and trends and result in guidelines for creating new or re-examining existing macroeconomic conditions in the Republic of Croatia.

To make this insight more comprehensive, the study should be conducted using data at the quarterly level and should include more indicators that would
reflect some other important aspects of macroeconomic performance. Thus, for example, foreign debt and/or gross salaries could be incorporated as variables with which the robustness of the results obtained here could be additionally checked. The analysis based on the indicators employed herein may also be performed using output-orientation. It would be interesting to compare the results and conclusions thus obtained with those based on input-orientation, including different types of efficiency (technical, pure technical and scale). Similar research can also be carried out on a sample that would involve more countries, in which case a time-series cross-country analysis should be conducted. All these possibilities are left open for future research.

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