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A COUNTERFACTUAL APPROACH TO MEASURING IMPACT OF POLICY INTERVENTION ON EFFICIENCY – SYNTHETIC CONTROL METHOD AND DEA

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Abstract: *This paper investigates the combination of the Synthetic Control Method (SCM) and Data Envelopment Analysis (DEA), to evaluate the effect of policy intervention on the efficiency of decision-making unit. Specifically, the study was conducted to assess the efficiency of Serbian banks over a period of 12 years, focusing on the influence of acquisition of Credy bank, and answering a counterfactual question whether efficiency of a bank would be the same if the acquisition had not happened. The study demonstrates that SCM in combination with DEA can be an effective method for analyzing the repercussions of policy measures on decision-making unit efficiency. In other words, we suggest combining these two methods in the future, in order to conclude whether an intervention really has an impact on efficiency.*

Keywords: *data envelopment analysis, synthetic control method, banks, efficiency, intervention effect.*

1. INTRODUCTION

The year 2023 proved to be significant for European banks, as highlighted in Deutsche Bank's report [8], which noted a 13% increase in total income compared to 2022. Additionally, the report indicated a reduction in costs, leading to an average cost-income ratio of 53% and a median of 49%. This resulted in a substantial rise in banks' profitability, with net income increasing by 52% year-over-year. The report concludes with the expectation that the sector's profitability will remain robust, though further improvements may be challenging.

This trend of enhanced profitability and increased held assets was also observed in Serbian banks [12]. A significant portion of the Kinstellar report focuses on key mergers and acquisitions (M&A) that occurred in Serbia over the past four years. Currently, Serbia hosts 20 banks, many of which have undergone mergers or acquisitions [16].

This paper examines the impact of M&A on banks' performance by analyzing the case of Credy Bank, acquired by Nova KBM [11]. It assesses banks' efficiency using Data Envelopment Analysis (DEA) and employs the Synthetic Control Method (SCM) to evaluate the impact of the acquisition on Credy Bank's performance.

The remainder of the paper is structured as follows. The second chapter provides a detailed explanation of DEA and SCM and how their combination can yield significant results. The third chapter presents the study's findings, using both Controlled and Uncontrolled SCM, and reveals that while SCM suggests a positive impact of the acquisition, the results are inconclusive due to statistically significant differences in the placebo studies. The final chapter offers a conclusion, outlines directions for further research, and discusses the potential of combining DEA and SCM.

2. METHODOLOGY

Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a non-parametric method used for measuring relative efficiency of decision-making units (DMUs) that use the same types of inputs to generate the same types of outputs. The main idea of DEA is not to have predetermined targets of inputs and outputs according to which the degree of efficiency is calculated, but to empirically identify the frontier of efficiency, on which the efficient DMUs lie on and in that way envelop the inefficient ones [17]. The primary CCR DEA model with n number of DMUs, where jth DMU produces s outputs, by using m inputs, is given by:

$$\max h_k = \sum_{r=1}^{s} u_r y_{rk} \tag{1}$$

$s.t.$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{2}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1, \dots, n \tag{3}$$

$$u_r \geq 0, r = 1, \dots, s \tag{4}$$

$$v_i \geq 0, i = 1, \dots, m \tag{5}$$

where h_k is the score of relative efficiency of the kth DMU, maximized in comparison to other DMUs, $u_r (r = 1, \dots, s)$ weights assigned to the rth outputs, and v_i $(i = 1, \dots, s)$ weights assigned to the ith inputs, both calculated as to achieve maximal possible efficiency score.

DEA has been used in various fields, but most of the application-based research addressed banking, healthcare, agriculture, transportation, and education [13]. Recent years have seen a growth in the application of DEA for energy and efficiency [15]. As for the banking sector, there was 791 DEA articles from 1986-2019, with 67% of paper being published from 2011 [7], with the number of articles addressing the efficiency of the potential bank mergers [4], [5] and [6], as well as their performance after the merger was completed [14] and [18], where they used various methods to the determine the success rate of the merger, but there wasn't any articles that used Synthetic Control Method as method for measuring the impact of M&As.

Synthetic Control Method

Synthetic Control Method (SCM) is a relatively new method for determining the impact of interventions on treated units. The idea of the SCM is to analyze what would've been if the intervention didn't happen by simulating a synthetic unit of the treated unit, by using the data of the similar untreated units, and then comparing it to actual state – a counterfactual approach [3]. SCM is most widely used to assess impact of policy interventions, such as effect of Tobacco Control Program in California [1], effect of concealed carry laws on murder rates [10] and was used in something similar to bank M&As – effect of reunification of West Germany with Germany [2].

The problem being inspected with SCM can be represented as:

$$Y = \begin{bmatrix} Y_{t,post}^{(1)} & Y_{c,post}^{(0)} \\ Y_{t,pre}^{(0)} & Y_{c,pre}^{(0)} \end{bmatrix} \tag{6}$$

Where Y represents the numerical output one is interested in inspecting, t is a DMU one is inspecting (treated DMU), c represents every other DMUs (control DMU), and pre and $post$

representing the time of inspection, prior and after the intervention respectively. Finally, a signal (1) and (0) shows if a treatment was assigned to the DMU or not. All the values in the Y are known from the data itself. However, one is interested in $Y_{t,post}^{(0)}$, which represents the counterfactual value. In other words, synthetic control method answers the question *what would happen with the DMU if the treatment didn't occur*?

A very neat way to estimate the counterfactual outcome for a single treated DMU was proposed by [9] using a linear combination of the observed outcomes for the control units. In other words:

$$\hat{Y}_{t,post}^{(0)} = \sum_{i \in c} \beta_i Y_{i,post}^{(0)} \tag{7}$$

where β_i denotes a weight of the control group DMU i. However, one needs to estimate the regression coefficients β_0 and β_i. We opted for the constraint regression optimization approach proposed in [1].

$$\beta = \arg\min_{\beta} \sqrt{\sum_p \left(Y_{t,p} - \sum_{i \in c} \beta_p Y_{i,p}\right)^2} \tag{8}$$

$s.t.$

$$\sum_p \beta_p = 1 \tag{9}$$

$$\beta_p \geq 0, p = 1, \dots, k \tag{10}$$

Basically, a SCM represents a regression model that uses instances from the previous years (prior to treatment) and trains a model that explains the value of the outcome for the DMU of interest as a weighted average of control DMUs. The difference between the traditional regression method and SCM is that outcomes are now treated as instances, while instances are now treated as rows (or what were columns are now rows and vice versa). This procedure is mathematically viable even having the i.i.d. assumption in mind. This is due to the setup of SCM where only a single value is estimated and regression model must be same regardless of how the data matrix is set up [1], [2]. In addition, there are two constraints stating that regression weights must sum to one (formula (9)) and that regression weights are positive (formula (10)).

As a final result, one obtained a counterfactual outcome of the treated unit as a weighted average of untreated ones. In addition, the interpretation potential of the new value is high as it can be presented through other DMUs in a similar manner as DEA.

3. RESULTS

The data encompasses the operations of 25 Serbian banks from 2005 to 2016. The inputs for each Decision-Making Unit (DMU) included salary expenses, fixed assets, capital, and deposits, while the outputs comprised given loans, other placements, and non-interest income.

A critical step in the SCM is selecting similar units to ensure the validity of the results [2]. This was achieved using DEA, which measures relative efficiency. DEA produced a time series of relative efficiencies for each bank, facilitating the algorithm's ability to identify similar units based on efficiency patterns akin to those of the treated unit, Credy Bank. Figure 1 illustrates the time series of Credy Bank's efficiencies, the average efficiencies of other banks, and the corresponding coverage area. Volksbank was excluded from the analysis at this stage, as only a single counterfactual estimate can be obtained at a time.

Figure 1 demonstrates that Credy Bank's efficiency consistently fell below the envelopment line, except in 2015 and 2016, when its efficiency reached 1. The treatment year for Credy Bank was 2014, following its acquisition in September 2013. While it might appear that the increase in efficiency resulted from the acquisition, SCM provides a more nuanced conclusion by simulating whether this improvement would have occurred without the acquisition.

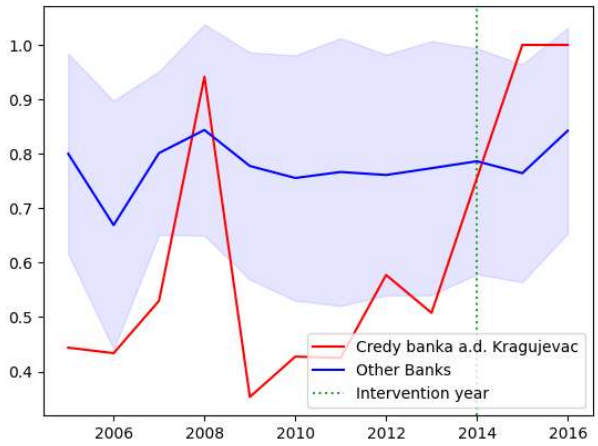

Figure 1: Time series of relative efficiencies

Uncontrolled Synthetic Control

The Uncontrolled Synthetic Control (USC) does the optimization of the weighted attributes on its own, and the coefficients used in linear regression to simulate the Synthetic Credy bank are shown in Figure 2.

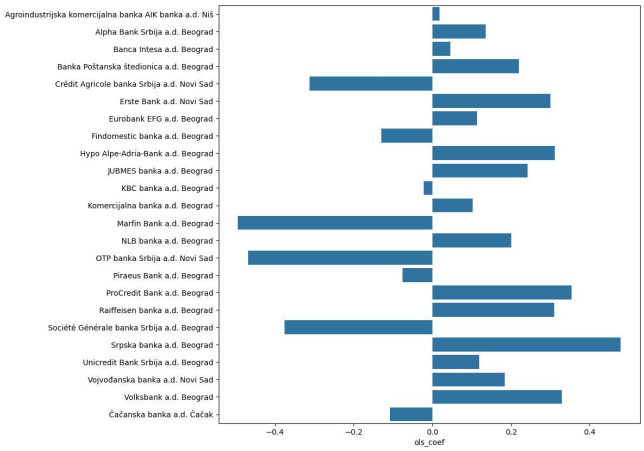

Figure 2: Coefficients of banks for Synthetic Credy bank in USC

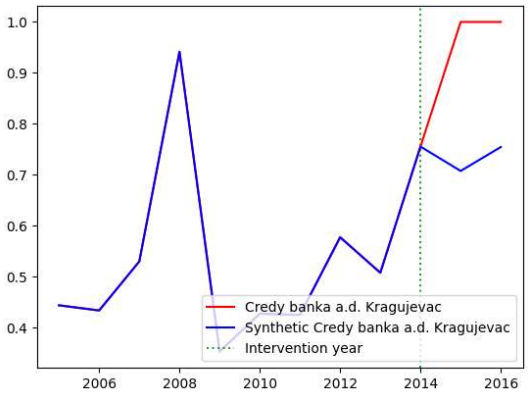

Figure 3: The results of the Uncontrolled Synthetic Control

From Figure 3, it can be concluded that the Synthetic Credy Bank would have experienced a decline in efficiency when simulated using the other DMUs, indicating that the intervention had a positive impact on the actual Credy Bank. Figure 3 illustrates the contribution of each bank to the creation of the Synthetic Credy Bank by displaying the coefficients used in the linear regression.

Controlled Synthetic Control

The Controlled Synthetic Control was modified to include only those banks that demonstrated similar efficiency over the years. These selected banks are shown in Figure 4. Consequently, only four banks were used to create the Synthetic Credy Bank, instead of including all the banks.

As depicted in Figure 5, the Synthetic Credy Bank now appears slightly different. However, the same conclusion can be drawn from the graph: the policy intervention had a positive impact on the efficiency of Credy Bank.

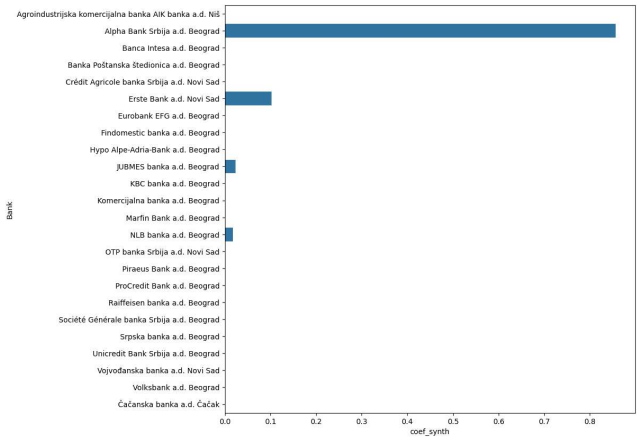

Figure 4: Coefficients of banks for Synthetic Credy bank in CSC

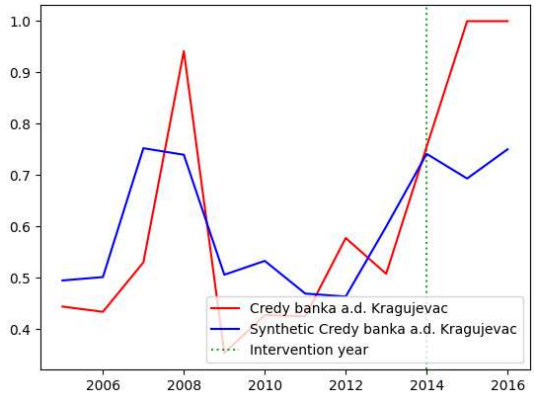

Figure 5: The results of the Controlled Synthetic Control

Placebo studies

The final step is to assess the significance of the SCM with the given data to determine if the linear regression accurately simulates the state that would have existed without the intervention. This can be achieved by creating synthetic versions of other banks and comparing the real outcomes with the simulated ones for these banks.

The results indicate that the SCM yields inconclusive results in this case. The placebo studies reveal a statistically significant difference between the real outcomes and the synthetic ones, with a p-value of 0.08.

4. CONCLUSION

This paper analyzes the combination of DEA and the SCM to demonstrate how these two methods can be utilized to determine the impact of policy interventions on a company's efficiency. SCM has predominantly been used to investigate the effects of laws and has not previously been combined with DEA for this purpose.

The study concludes that although the results indicate that the acquisition of Credy Bank impacted its efficiency, the linear regression used in SCM, when tested on placebo studies, reveals a statistically significant difference between the prediction model and the real scenario. Consequently, the results cannot be considered conclusive. Future work aims to improve the model and apply it to other scenarios, in combination with DEA, to analyze the effects of policy interventions on business performance.

The main contribution of this paper is the integration of these two methods, enriching the literature and generating ideas for analyzing and counterfactually checking real scenarios of policy interventions on businesses. This approach aims to derive accurate conclusions about the factors that truly impact business performance.

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