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# EXPLORING EFFICIENCY DYNAMICS IN CROATIAN RETAIL TRADE: A WINDOW DATA ENVELOPMENT ANALYSIS APPROACH

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## ABSTRACT

*Retail trade in Croatia plays an important role in the economy, as the share of trade in GDP at market prices amounted to 20.0% and the share of trade in employment (legal entities) amounted to 15.2% in 2022. Its importance is highlighted by its vulnerability to external shocks, such as the COVID-19 pandemic and subsequent economic disruptions, including high inflation. In this study, Window Data Envelopment Analysis (WDEA) is used to assess the efficiency of 23 large and very large retail companies in Croatia between 2013 and 2022, focusing on the impact of economic fluctuations on the companies' operational performance. The results show that Croatian retailers operate close to the efficiency frontier, with scale efficiency consistently performing better than pure technical efficiency, highlighting management and technological challenges as primary inefficiency factors. A detailed analysis of the top five retailers in terms of operating revenue shows their resilience, with some of them achieving full efficiency during the observed period. In particular, Tommy d.o.o. showed consistent efficiency in the Adriatic region due to its strategic focus on small stores in tourist areas, while Schwarz Group members Lidl Hrvatska d.o.o. and Kaufland Hrvatska k.d. showed robust revenue growth and improved efficiency after 2020. The results emphasize the adaptability and resilience of the sector, especially in response to the disruption caused by the pandemic. They also highlight the urgent need for strategies to improve operational efficiency, address labor shortages and leverage digital transformation to meet increasing competition and economic challenges. This study fills a gap in the Croatian retail literature by applying the WDEA to assess the impact of global disruption on the efficiency of large retailers.*

***Keywords:*** *retail, efficiency, Window Data Envelopment Analysis, Croatia*

## 1. INTRODUCTION

The retail sector is an important pillar of the Croatian economy, contributing around 20.0% to GDP at market prices and employing 15.2% of the workforce in 2022 (Anić, 2023). With food retail turnover of EUR 7.73 billion in 2023 (Croatian Competition Agency, 2023), the stability of the sector has a significant impact on the resilience of the national economy. However, recent crises have shown the vulnerability of the sector to external shocks. Therefore, there is a need for efficiency analyses that capture dynamic changes in performance.

The COVID-19 pandemic triggered unprecedented disruption, forcing a rapid digital transformation amid store closures and supply chain disruptions. Subsequent inflationary pressures exacerbated these challenges, as energy and transport costs rose by 22% in 2022 alone (Eurostat, 2023), squeezing retailers' margins and changing consumer behavior. These successive shocks highlight a major limitation of previous research: while Data Envelopment Analysis (DEA) has become the standard tool for measuring retail efficiency (Barros & Alves, 2003), most applications have remained static and are unable to track performance development in times of crisis (Halkos & Petrou, 2019).

This study addresses two fundamental gaps in the literature. First, despite extensive DEA applications in developed markets (Chen et al., 2004; Xavier et al., 2015; Álvarez-Rodríguez, et al., 2020), transition countries such as Croatia remain under-researched, particularly in terms of how their concentrated market structures (CR10 = 86.7%) respond to disruptions. Second, efficiency dynamics during the pandemic inflation cycle are not captured by the vast majority of cross-sectional analyses.

This study uses Window DEA (WDEA) to analyze 23 large and very large Croatian retailers (NACE 4711 – Retail sale in non-specialised stores with food, beverages or tobacco) in the period 2013–2022. The data for the analysis was obtained from the Orbis Europe BvD database. This approach offers three main advantages: improved discriminatory power through overlapping time windows (Asmild et al., 2004), tracking of efficiency trends across stable and crisis periods, and identification of persistent and transitory inefficiencies. The analysis makes both a methodological and a practical contribution by providing the first longitudinal efficiency benchmark for the Southeast European retail sector while offering evidence-based strategies for crisis adaptation.

The paper is structured as follows: the Introduction outlines the importance of the retail trade in the Croatian economy and the research objectives. The Literature Review looks at previous studies on retail efficiency. The Methodology describes the WDEA framework, followed by Empirical Data, which explains the variables used and the data set for the period 2013–2022. The Results and Discussion section presents and interprets the findings on efficiency dynamics, focusing on both the overall sample and the top five retailers, highlighting key inefficiencies and strategies to address them. The Conclusion summarizes the results, the implications for policy and practice, and the opportunities for future research.

## 2. LITERATURE REVIEW

The evaluation of efficiency in the retail sector has been shaped by two dominant perspectives: the analysis of the performance of individual stores within retail chains and the comparative evaluation of the efficiency of competing retailers. Norman and Stocker (1991) pioneered the application of Data Envelopment Analysis (DEA) in the retail context and demonstrated its effectiveness in measuring relative efficiency. This foundation was extended by Donthu and Yoo (1998), who established key input-output configurations for productivity evaluation in restaurant chains and emphasized the adaptability of the method to different retail formats.

A critical review of store-level efficiency studies reveals several consistent findings. Barros and Alves (2003) have shown that the profitability of retail chains is largely dependent on the performance of individual stores, with efficient store management having a direct impact on overall resource allocation. Subsequent studies have identified various operational and environmental factors that influence store efficiency. Álvarez-Rodríguez et al. (2020) found that efficiency scores vary significantly depending on whether managers prioritize operational performance (e.g., revenue, labor productivity) or environmental sustainability (e.g., carbon footprint, energy consumption). Nong (2022) found that dynamic market conditions significantly increase efficiency, while store size has a surprisingly small impact, suggesting that management adaptability may outweigh economies of scale. Similarly, Xavier et al. (2015) found significant efficiency differences between locations of a retail chain, emphasizing the need for tailored improvement strategies. Šegota (2008) corroborated these findings by demonstrating how the external business environment influences relative efficiency measures and questioning the validity of standardized performance metrics for different regions.

Comparative studies of retail efficiency in different companies have also provided important insights. Chen et al. (2004) demonstrated the disruptive potential of digital transformation, with e-commerce retailers outperforming their traditional counterparts on certain financial metrics. In a more recent work by Okur and Ercan (2023), sector-specific efficiency frameworks were developed to show how industry characteristics influence optimal performance measurement. Regional studies have provided valuable context: Lukić and Hadrović Zekić (2019) show how macroeconomic conditions in transition countries such as Serbia constrain efficiency gains, while Arbula Blecich (2024c) identifies management practices and other exogenous factors as primary drivers of efficiency in the concentrated Croatian retail market.

Despite these contributions, there are still considerable limitations in the literature. According to Halkos and Petrou (2019), the dominance of cross-sectional analyses is a critical methodological limitation that leads to an insufficient understanding of the dynamic efficiency development of the sector. This gap is particularly problematic as the retail sector is subject to economic shocks and technological disruptions. In addition, the geographical distribution of research remains heavily focused on developed markets, with disproportionately little attention devoted to emerging markets. While Arbula Blecich (2024c) provided valuable insights into the efficiency of the Croatian retail sector, her cross-sectional approach failed to capture the temporal dynamics that have become particularly relevant in the context of the pandemic.

This study addresses these limitations by introducing a longitudinal perspective into the analysis of retail efficiency by capturing both cyclical and structural changes in efficiency. By examining efficiency trends over a complete business cycle that includes both stable periods and large economic shocks, this analysis provides new insights into the resilience mechanisms of retail firms in concentrated market environments. As far as the authors are aware, there are no studies analyzing the efficiency of Croatian retail companies over time. This study aims to fill this gap by analyzing the dynamic efficiency of Croatian retail companies, thus contributing to the existing body of knowledge.

## 3. METHODOLOGY

Data Envelopment Analysis (DEA) is a non-parametric mathematical method developed by Charnes, Cooper and Rhodes in 1978. Originally developed to measure the efficiency of non-profit organizations in particular, its application was later extended to for-profit organizations such as banks and companies. The rapid increase in the use of DEA is likely due to its interdisciplinary applicability and its ability to provide results in cases where other approaches fail, especially when the relationships between multiple inputs and outputs are complex or unknown (Šporčić et al., 2008). DEA is now used in various sectors, including healthcare (Buljan and Šimović, 2022; Dukić et al., 2018), banking (Gržeta et al., 2023; Davidovic et al., 2019; Kordić and Višković, 2018; Visković et al., 2022), education and R&D (Andersson and Sund, 2022; Arbula Blecich, 2020, 2021; Arbula Blecich, 2024a), logistics and transport (Asić, 2011), tourism (Arbula Blecich, 2024b; Arbula Blecich et al., 2025; Fotova Čiković et al., 2022; Lozano-Ramírez et al.,2023;). DEA is primarily used to compare the efficiency of multiple homogeneous decision-making units (DMUs) (Beasley, 2023). The two main DEA models are the CCR model (Charnes et al., 1978), which assumes constant returns to scale, and the BCC model (Banker et al., 1984), which assumes variable returns to scale. The CCR model evaluates technical efficiency, also known as overall efficiency and assumes constant returns to scale (CRS), while the BCC model measures pure technical efficiency and assumes variable returns to scale VRS (Škrinjarić, 2016). The CCR and BCC models are presented below.

CCR model:

$$\max \theta = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_r x_{i0}}$$

$$\textit{Subject to } \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_r x_{i0}} \leq 1, \quad j = 1, \dots, n; \; with$$

$$u_r, v_i > 0, \quad i = 1 \dots, m; \quad r = 1, \dots s$$

BCC model:

$$\max \theta = \frac{\sum_{r=1}^{s} u_r y_{r0} - u_0}{\sum_{i=1}^{m} v_r x_{i0}}$$

$$\textit{Subject to } \frac{\sum_{r=1}^{s} u_r y_{r0} - u_0}{\sum_{i=1}^{m} v_r x_{i0}} \leq 1, \quad j = 1, \dots, n; \; u_r, v_i \geq 0$$

$$\textit{with } u_0 \textit{ unrestricted in sign}$$

$\theta$ stands for the relative efficiency, input and output for DMU j are denoted by y_rj, x_ij>0, ($x1j$,..., $xmj$) represents the input vector of DMU$j$ with the input weighting vector ($v1$,...,$vm$), and ($y1j$,..., $yqj$) represents the output vector of DMU$j$ with the output weighting vector ($u1$,..., $uq$).

The Window DEA method (WDEA), an extension of traditional DEA, is used to evaluate the efficiency of DMUs over time. (Cooper et al., 2006). This method makes it possible to analyze efficiency changes in a dynamic context and provides information on how the performance of a DMU develops over several periods of time. It is particularly useful when the aim is to track efficiency trends and fluctuations rather than just a static efficiency value over a period of time. In contrast to the basic CCR and BCC DEA models, which provide a single efficiency rating, the WDEA tracks efficiency over multiple time periods. This makes trends visible, e.g., whether the performance of a DMU improves, deteriorates, or remains stable. With the WDEA, the evaluation is carried out using "windows". Each window covers a selected number of time periods, and as time progresses, the window shifts to include the next period, while the earliest is discarded. In this way, both short-term and long-term efficiency patterns can be captured. Each DMU is treated as a separate unit in each period, allowing comparisons within a given time window and between different time windows. Since the same DMU is evaluated in multiple time windows, the WDEA helps to determine not only the average efficiency, but also the variability or volatility of performance. In addition, the method identifies periods of stability or instability in efficiency and highlights the impact of economic shocks, such as the COVID-19 pandemic, on business activity (Emrouznejad and Yang, 2018).

A group of DMUs N (n = 1...N) uses r inputs to produce s outputs in a time period T (t = 1...T). The notation DMUn t refers to the quantities of inputs or outputs for DMU n in the time period t. The input vector ($X_n^t$) and the output vector ($Y_n^t$) are defined as follows (Jia and Yuan, 2017):

$$X_n^t = \begin{bmatrix} x_n^{1t} \\ \vdots \\ x_n^{rt} \end{bmatrix} \qquad Y_n^t = \begin{bmatrix} y_n^{1t} \\ \vdots \\ y_n^{st} \end{bmatrix}$$

Assuming that the window starts at time k ($1 \le k \le T$) and that the length of the window is p ($1 \le w \le T-k$), the input ($X_{kw}$) and output ($Y_{kw}$) matrices of each window (kw) can be written as follows (Jia and Yuan, 2017):

$$X_{kw} = \begin{bmatrix} x_1^k & x_2^k & \dots & x_N^k \\ x_1^{k+1} & x_2^{k+1} & \dots & x_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ x_1^{k+w} & x_2^{k+w} & \dots & x_N^{k+w} \end{bmatrix} \qquad Y_{kw} = \begin{bmatrix} y_1^k & y_2^k & \dots & y_N^k \\ y_1^{k+1} & y_2^{k+1} & \dots & y_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ y_1^{k+w} & y_2^{k+w} & \dots & y_N^{k+w} \end{bmatrix}$$

The results of the WDEA are obtained by inserting the inputs and outputs of $DMU_n^t$ into the basic CCR and BCC model.

## 4. EMPIRICAL DATA

This paper analyzes the efficiency of large and very large companies operating in the Republic of Croatia under Nace Rev 2 – 4711 – Retail sale in non-specialized stores with food, beverages or tobacco predominating in the Republic of Croatia. The Croatian retail trade sector, classified under NACE Rev 2 code 4711, consists of approximately 2,300 companies, most of which are small and medium-sized. Within this sector, Orbis Europe identifies 31 large and very large retail companies that fulfil the standard EU criteria for company size. From this initial group, we excluded companies with incomplete information for the observed period, as they were not suitable for the analysis. After applying these filters, 23 retailers remained in the final sample. Three inputs and two outputs were used in this analysis, as shown in the table below. The data for the variables were taken from the Orbis Europe Bureau van Dijk database.

Table 1. Input and output variables

| Inputs | Outputs |
|---|---|
| Employee costs, th EUR | Operating profit (loss) [EBIT], th EUR |
| Total assets, th EUR | Operating revenue (turnover), th EUR |
| Material costs, th EUR | |

Source: Authors

The selected inputs and outputs were chosen based on previous studies with similar samples and topics. The variables used as inputs are employee costs (Donthu and Yoo, 1998), total assets (Pervan, 2020), and material costs (Pervan, 2020; Lukić and Hadrović Zekić, 2019). The outputs selected in this paper are EBIT (Pervan, 2020; Lukić and Hadrović Zekić, 2019; Šegota, 2008; Donthu and Yoo, 1998) and operating revenue (Pervan, 2020; Lukić and Hadrović Zekić, 2019; Donthu and Yoo, 1998).

Since the DEA model assumes that all inputs and outputs are positive, negative or zero values can pose a challenge. For this reason, the data in this paper had to be adjusted as some companies had negative EBIT in certain years. This was done using translational invariance, which was introduced by Pastor and Ruiz (2007). Translational invariance provides a solution in which all values in a data set are shifted by a constant amount to ensure that they are all positive without changing the relative efficiency of the DMUs. In practice, translational invariance means that a constant is added to each value in the data set so that even the smallest (or most negative) value becomes positive. This shift occurs evenly across all observations so that the original relationships and rankings between the DMUs are preserved. In this paper, all variables were shifted by 14.722.

The period for the analysis is from 2013 to 2022, and a WDEA analysis was performed in which the period was divided into eight windows, each with a length of three years. The windows are as follows: Window 1 – 2013, 2014, 2015; Window 2 – 2014, 2015, 2016; Window 3 – 2015, 2016, 2017; Window 4 – 2016, 2017, 2018; Window 5 – 2017, 2018, 2019; Window 6 – 2018, 2019, 2020; Window 7 – 2019, 2020, 2021; Window 8 – 2020, 2021, 2022 (Emrouznejad &

Yang, 2018). The data for three years are analyzed simultaneously using a weighted average, and each subsequent year of the observation period is replaced by the chronologically closer year, after which the weighted average is recalculated. This process is repeated until the entire observation period has been analyzed.

One of the conditions that must be met when applying the DEA analysis is that the ratio between the number of DMUs and the sum of inputs and outputs must be 3–4. By using dynamic models such as WDEA analysis, this condition can be circumvented, as in this type of analysis each DMU is treated as a different DMU in different periods, which significantly increases the number of data points in which the DMU is observed. A time period of 10 years and a window length of 3 years were chosen in this paper. We have calculated that the number of different DMUs is 552 (number of DMUs * window length * number of windows = 23 * 3 * 8). This means that the analysis exceeds the limitations for the number of DMUs in relation to the sum of inputs and outputs.

The basic elements of efficiency are technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) (Al-Refaie *et al*., 2016). TE indicates how efficiently resources are utilized. PTE is considered a measure of management performance as it is influenced by factors such as management practices, technology, and other exogenous factors. The PTE is determined under the assumption of variable returns to scale. This approach excludes scale efficiency. (Kumar and Gulati, 2008). SE indicates whether the DMU is operating at the optimal scale of production and the optimal amount of resources and can be calculated by dividing TE by PTE (Iqbal and Awan, 2015).

A prerequisite for the application of DEA analysis is the condition of isotonicity, i.e., all input and output variables must be positively correlated with each other. In this paper, all variables are positively and highly correlated in all observed years, which means that output increases with an increase in input. This means that the condition of isotonicity is fulfilled and therefore all conditions for the application of DEA are met.

The results of the analysis of the entire sample of retail stores are presented below, followed by the results for the top five retail stores based on operating revenue.

## 5. RESULTS AND DISCUSSION

A window DEA analysis was carried out for the period from 2013 to 2022. The table below shows the average results for each DMU. The results are presented by efficiency elements, TE, PTE, and SE. The results range from 0 to 1, with a value of 1 indicating complete relative efficiency and a value below 1 indicating relatively inefficient DMUs.

Table 2. C-averages for TE, PTE, and SE per DMU from 2013 to 2022 (full sample)

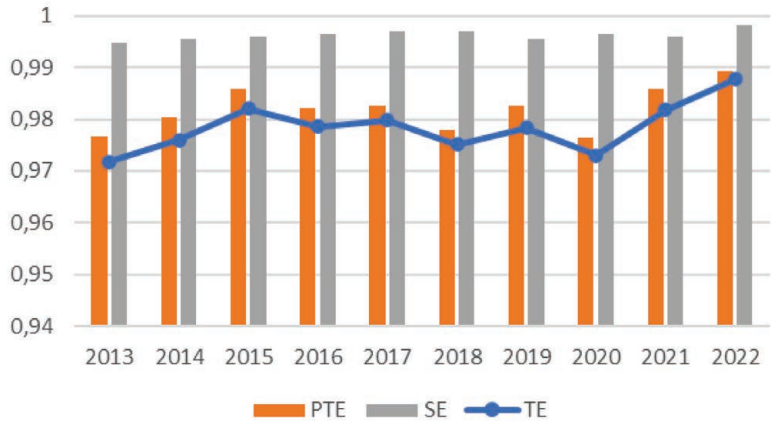
| DMU No | DMU | TE | PTE | SE |
|---|---|---|---|---|
| 1. | LIDL HRVATSKA D.O.O. K.D. | 0.99142519 | 0.9943547 | 0.9970538 |
| 2. | SPAR HRVATSKA D.O.O. | 0.976689142 | 0.982942 | 0.9936386 |
| 3. | PLODINE D. D. | 0.991470376 | 0.9951465 | 0.9963059 |
| 4. | KAUFLAND HRVATSKA K.D. | 0.919172397 | 0.9242946 | 0.9944583 |
| 5. | TOMMY D.O.O. | 0.994002569 | 0.9942048 | 0.9997966 |
| 6. | NARODNI TRGOVACKI LANAC D.O.O. | 0.994111446 | 0.9968414 | 0.9972614 |
| 7. | TRGOVINA KRK D. D. | 0.973787859 | 0.976366 | 0.9973595 |
| 8. | BOSO D.O.O. | 0.94509426 | 0.9606835 | 0.9837728 |
| 9. | RIBOLA D.O.O. | 0.991471676 | 0.9937253 | 0.9977321 |
| 10. | GAVRANOVIC D.O.O. | 0.978858213 | 0.9808085 | 0.9980115 |
| 11. | TRGOCENTAR D.O.O. | 0.973428086 | 0.9779472 | 0.995379 |
| 12. | TP VARAZDIN D.O.O. | 0.958217959 | 0.9618949 | 0.9961774 |
| 13. | BAKMAZ D.O.O. | 0.979346397 | 0.9812942 | 0.9980151 |
| 14. | PREHRANA TRGOVINA D.D. | 0.994431173 | 0.9958692 | 0.998556 |
| 15. | DECENTIA D.O.O. | 0.996097329 | 0.9973747 | 0.9987193 |
| 16. | TERI-TRGOVINA D.O.O. | 0.995016882 | 0.9996598 | 0.9953555 |
| 17. | JADRANKA TRGOVINA D. O. O. | 0.962647746 | 0.9684801 | 0.9939778 |
| 18. | SLAVONIJA-BOSKOVIC D.O.O. | 0.996854721 | 0.9972827 | 0.9995708 |
| 19. | PPK-BJELOVAR D.D. | 0.967834651 | 0.971356 | 0.9963748 |
| 20. | BRODOKOMERC NOVA D. O. O. | 0.948101403 | 0.9517615 | 0.9961544 |
| 21. | LORENCO D.O.O. | 0.982078998 | 0.9833403 | 0.9987174 |
| 22. | TERI TRGOVINA D.O.O. | 0.993605064 | 0.9980792 | 0.9955173 |
| 23. | MALI PALIT D. O. O. | 0.994068222 | 0.9954884 | 0.9985733 |
| **AVERAGE** | | 0.978165729 | 0.9817042 | 0.9963686 |

Source: Authors

Table 2 shows that the selected stores operate on average very close to the efficiency frontier, although on average no store is completely relatively efficient, i.e., none has a value of 1. Looking at the average results, the stores operate close to the efficiency frontier in all segments, with scale efficiency coming closest to 1.

To illustrate the efficiency dynamics in the retail sector more clearly, the following figure shows the dynamics of TE over the years for all stores.

Figure 1. Dynamics of TE, PTE, and SE from 2013 to 2022 (full sample)




Source: Authors

Figure 1 shows the TE as an average of all DMUs in the period from 2013 to 2022. The results show a very high level of TE for the observed DMUs. However, it is evident that this value was lowest in 2013 and improved in the following years until 2020, when the impact of the COVID-19 pandemic led to a slight decrease. From 2020, the value continued to rise until 2022, when the highest value was recorded for TE compared to the other years observed. To determine the causes of the inefficiency, PTE and SE are presented as components of TE over the years. It is evident that, in all observed years, the main causes of inefficiency were management, technology, and other exogenous factors, as shown by the results of PTE, which are significantly lower than those of SE, which is consistent with the results of Arbula Blecich (2024c). This became even clearer in 2020 with the outbreak of the COVID-19 crisis. Thereafter, in 2021 and 2022, the gap between PTE and SE began to narrow.

The following section contains an additional analysis of the five largest retail stores in terms of operating revenue (top 5). As DEA measures relative rather than absolute efficiency, the efficiency frontier changes as inputs, outputs, or DMUs are added or removed. To further analyze the efficiency of the top five retailers, the analysis was conducted with a subsample that forms a new efficiency frontier.

Before proceeding with the results, it is important to mention that all conditions for performing the DEA have been met. From the formula for the number of different data points (number of DMUs * window length * number of windows = 5 * 3 * 8 = 120), it can be concluded that there are more than enough data points compared to the sum of inputs and outputs. In addition, the condition of isotonicity is fulfilled for this subsample.

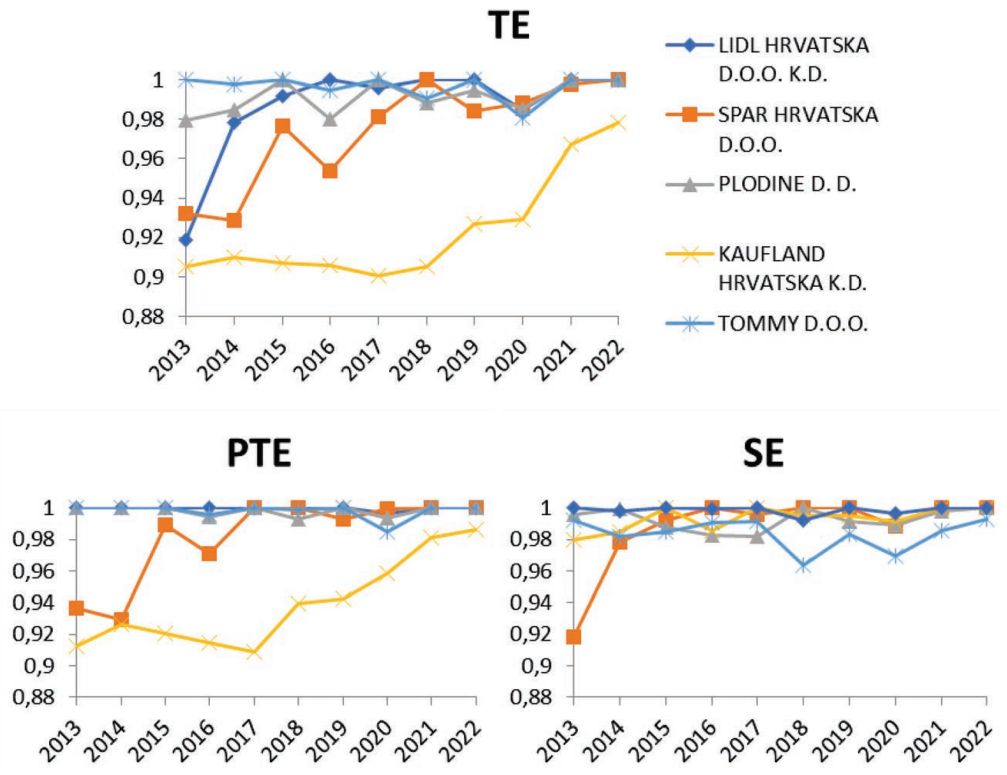
Table 3. C-averages for TE, PTE, and SE per DMU from 2013 to 2022 (top 5)

| DMU No | DMU | TE | PTE | SE |
|---|---|---|---|---|
| 1. | LIDL HRVATSKA D.O.O. K.D. | 0.991420766 | 0.999555593 | 0.9918616 |
| 2. | SPAR HRVATSKA D.O.O. | 0.976696085 | 0.985397828 | 0.9911693 |
| 3. | PLODINE D. D. | 0.991473787 | 0.997662994 | 0.9937963 |
| 4. | KAUFLAND HRVATSKA K.D. | 0.91917429 | 0.936107032 | 0.9819115 |
| 5. | TOMMY D.O.O. | 0.99564065 | 0.997363598 | 0.9982725 |
| **AVERAGE** | | 0.974881116 | 0.983217409 | 0.9914022 |

Source: Authors

The results in the table above show a very high relative efficiency in all three categories for all DMUs. The following figures provide a more detailed overview of the efficiency dynamics of the selected DMUs.

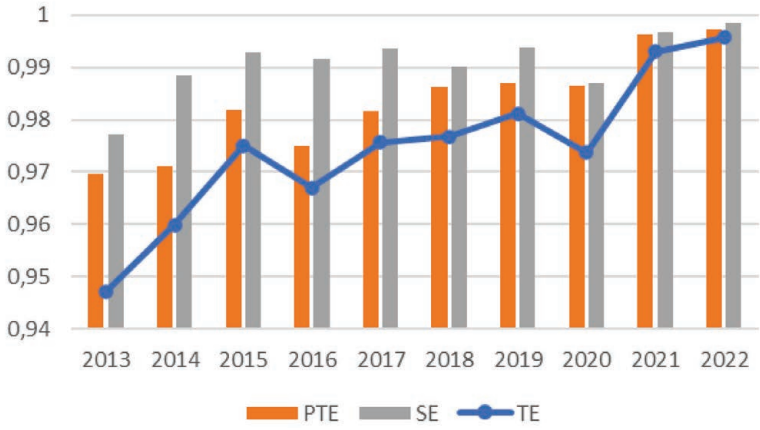
Figure 2. Dynamics of TE, PTE, and SE from 2013 to 2022 (top 5)




Source: Authors

Figure 2 shows the TE, PTE, and SE of the top five retail stores in the Republic of Croatia. Tommy d.o.o., which comes closest to the full TE, has achieved it in 6 of the 10 years observed. In 2020, this efficiency was slightly lower due to the pandemic, but reached full efficiency again in 2021. All five stores are close to full TE. Kaufland Hrvatska k.d. has the lowest result, but the situation has improved since 2020 and has been steadily increasing. To determine the causes of inefficiency, PTE and SE are presented for the five retailers. All stores are close to the PTE and SE frontier, which means that they are all performing well. Lidl Hrvatska d.o.o. achieved 100% PTE in 8 years and was close to the efficiency frontier in the remaining 2 years. Plodine d.d. and Tommy d.o.o. are also close to these results. The lowest PTE was recorded by Kaufland Hrvatska k.d. in 2017, but in the following years, the company improved and got close to the PTE frontier. The lowest SE was recorded by Lidl Hrvatska d.o.o. in 2013 and by Kaufland Hrvatska k.d., which fluctuated during the observation period.

Figure 3. Dynamics of TE, PTE, and SE from 2013 to 2022 (top 5)




Source: Authors

Figure 3 shows the TE as an average of the top five DMUs from 2013 to 2022. The lowest TE value was recorded in 2013, and it generally improved until 2020, when there was a slight decrease due to the pandemic. The pandemic caused severe disruptions to supply chains and retail processes (Li, Wang and Chang, 2021). Empirical studies show that while COVID-19 brought significant operational challenges, the organizational adoption of the technology has led to measurable benefits (Koweyes et al., 2021; Yang et al., 2022). Efficiency has been steadily increasing since 2020. Costa Melo et al. (2023) point out that the most important factor that enabled companies to recover quickly after the pandemic was their ability to be more dynamic during the pandemic. Specifically, they argue that supply chain management during the pandemic likely impacted business performance through multichannel retailing, inventory investment, inventory efficiency, and forecasting accuracy. The figure also shows the PTE and SE to identify the causes of inefficiency. Interestingly, the results shown differ greatly from the results of the overall sample (Figure 1). In the full sample, the main causes of inefficiency in all years observed were management, technology, and other exogenous factors.

Since 2020, the PTE and SE results for the top five have converged, with the gap between them almost disappearing.

Efficiency in retail is an important driver of profitability, customer satisfaction, and long-term success. By leveraging technology, optimizing supply chains, and empowering employees, retailers can achieve measurable improvements in business outcomes. The relationship between efficiency and business results in retail can be explained theoretically using various frameworks. At an operational level, the principles of lean management (Womack & Jones, 1996) show how eliminating waste in retail processes directly increases profitability through cost reductions and improved asset turnover. This positive relationship between efficiency and productivity in retail has been demonstrated by Barros and Alves (2003) and Mostafa (2010). The service-profit chain (Heskett et al., 1994) provides a theoretical bridge between efficiency and market share by showing how operational improvements enable greater customer value through price competitiveness and service reliability. From a strategic perspective, the resource-based view (Barney, 1991) explains how efficiency-enhancing technologies and processes can become sources of sustainable competitive advantage if they fulfil the criteria of value, rarity, and inimitability. This is particularly relevant in the retail industry, where proprietary inventory algorithms or store automation systems can create significant productivity advantages. The relationship between efficiency and employee productivity is theoretically anchored in job characteristics theory (Hackman & Oldham, 1976), which suggests that properly implemented efficiency tools can increase the meaningfulness and responsibility of work, albeit with important caveats about excessive standardization. Recent theoretical developments in the field of digital transformation (Sagar, 2024; Vial, 2019) show that modern efficiency gains in retail increasingly result from data network effects and the platform economics rather than traditional operational improvements, representing a paradigm shift in the understanding of the relationship between efficiency and performance in this sector.

## 6. CONCLUSION

This study presents a longitudinal assessment of efficiency dynamics in the Croatian retail sector from 2013 to 2022 using the window DEA. Our research fills significant gaps in the existing literature by providing a dynamic efficiency analysis that captures performance development through multiple economic shocks. The results provide valuable insights into the resilience and adaptability of retailers operating in Croatia's highly concentrated market environment.

The analysis shows that, while Croatian retailers generally operate close to the efficiency frontier, persistent gaps in pure technical efficiency point to opportunities for improvement in management practices and technology adoption. The consistently better performance of scale efficiency compared to pure technical efficiency suggests that operational scale alone cannot guarantee optimal performance in this market environment. These findings build on previous cross-sectional studies while providing a new temporal dimension to our understanding of retail efficiency.

The study of the top performers in the market provides particularly insightful findings. The success of Tommy d.o.o. with its regional focus on tourist areas and the exceptional pure technical efficiency of Lidl show how tailored strategies can overcome the challenges of market concentration. The good performance of the Schwarz Group subsidiaries also emphasizes the importance of format-specific adjustments, even if the usual efficiency models often do not adequately capture these retail-specific variables.

The sector's response to the COVID-19 pandemic is excellent proof of its resilience. While the initial shock in 2020 led to the expected efficiency losses, the subsequent recovery reached peak performance levels by 2022. This pattern, which is only visible through longitudinal analysis, emphasizes the value of dynamic methods in assessing retail efficiency in times of disruption.

For retail managers, these findings highlight the critical importance of investing in workforce optimization and digital transformation to close persistent efficiency gaps. The results suggest that differentiated strategies based on market position and retail format may prove more effective than generalized efficiency improvements. Maintaining operational flexibility proves to be another important prerequisite for coping with future market shocks.

From a policy perspective, the study underlines the need for targeted support programs to help smaller retailers improve their management skills. Investments in digital infrastructure and careful market monitoring seem essential to maintain healthy competition in concentrated market segments. These measures could help level the playing field while preserving the economies of scale that larger retailers enjoy.

This study provides valuable insights for both researchers and retail stakeholders. The results show that large retailers in Croatia operate with high efficiency, suggesting that future performance improvements are likely to require technological innovation rather than simple operational adjustments. For managers, the results show the importance of optimizing management practices and operational execution, as these prove to be more important constraints than company size. The demonstrated resilience to economic disruption provides useful insights for business continuity planning. Policy makers may find these efficiency patterns informative when designing sector-specific support measures.

Several limitations should be kept in mind when interpreting these results. The focus on large companies limits the applicability to smaller retailers. While the analytical approach is suitable for identifying efficiency patterns, it cannot fully separate the effects of specific external shocks from broader market trends. In addition, the analysis does not take into account macroeconomic factors that may influence efficiency trends, such as GDP growth, inflation, or labor market conditions. This limits our ability to determine whether the observed efficiency changes are due to internal improvements or broader economic changes. Furthermore, the focus on a single country prevents cross-country comparisons that could shed light on whether the results reflect unique market characteristics or broader trends in the retail sector. The inclusion of such comparative analysis with macroeconomic indicators would improve the interpretation of efficiency patterns. These limitations point to promising

directions for future research, including comparative studies across different market segments and the integration of financial performance measures.

As the retail sector continues to struggle with inflationary pressures, technological disruptions, and changing consumer expectations, the ability to systematically measure and improve efficiency becomes increasingly important. This study provides both a methodological framework for such an assessment and substantive insights that can inform decision-making across the industry. Ultimately, the results suggest that continuous efficiency optimization is no longer just an advantage in today's challenging retail environment, but that it has become an absolute necessity for sustainable performance.

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# ISTRAŽIVANJE KRETANJA EFIKASNOSTI U HRVATSKOJ MALOPRODAJI: *WINDOW* DEA METODA

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## SAŽETAK

*Trgovina na malo u Republici Hrvatskoj ima značajnu ulogu u gospodarstvu, čineći oko 10,6 % BDP-a i 14 % ukupne zaposlenosti. Njegova važnost dodatno je naglašena osjetljivošću na vanjske šokove, poput pandemije COVID-19 i visoke inflacije. U ovom istraživanju korištena je* Window Data Envelopment Analysis *(WDEA) za procjenu efikasnosti 23 velika i vrlo velika trgovačka poduzeća u Hrvatskoj u razdoblju od 2013. do 2022., s naglaskom na utjecaj gospodarskih fluktuacija na njihovu operativnu izvedbu. Rezultati pokazuju da hrvatski trgovci posluju blizu granice efikasnosti, pri čemu je efikasnost razmjera (SE) konstantno bolja od čiste tehničke efikasnosti (PTE), što ukazuje na upravljačke i tehnološke izazove kao glavne faktore neefikasnosti. Detaljna analiza pet najvećih trgovačkih poduzeća prema prihodima pokazuje njihovu otpornost, pri čemu su neka od njih postigla potpunu efikasnost tijekom promatranog razdoblja. Posebno se ističe Tommy d. o. o., koji je pokazao dosljednu efikasnost u jadranskoj regiji zahvaljujući strateškom fokusu na male trgovine u turističkim područjima. Istovremeno, članovi Schwarz grupe, Lidl Hrvatska d. o. o. i Kaufland Hrvatska k. d., zabilježili su snažan rast prihoda i poboljšanje efikasnosti nakon 2020. godine. Rezultati ukazuju na prilagodljivost i otpornost sektora, posebno kao odgovor na poremećaje uzrokovane pandemijom. Također naglašavaju hitnu potrebu za strategijama koje će unaprijediti operativnu efikasnost, riješiti problem nedostatka radne snage te iskoristiti digitalnu transformaciju za suočavanje s rastućom konkurencijom i gospodarskim izazovima. Ovo istraživanje popunjava prazninu u literaturi o hrvatskoj maloprodaji primjenom WDEA metode za procjenu utjecaja globalnih poremećaja na efikasnost velikih trgovaca.*

***Ključne riječi:*** *trgovina na malo, efikasnost,* Window Data Envelopment Analysis, *Republika Hrvatska*