ECONOMIC RESEARCH - EKONOMSKA ISTRAŽIVANJA
2025, VOL. 38 NO. 2, (89 - 108)
https://doi.org/10.32728/er-ei.38.2.4

FET Faculty of Economics and Tourism "Dr. Mijo Mirković"

ARTICLE HISTORY
Received 12 December 2024
Accepted 15 July 2025

STRUCTURAL ANALYSIS OF NON-LIFE INSURANCE EFFICIENCY IN CROATIA: A DEA APPROACH

Ticijan Peruško Ph.D., Associate Professor, Juraj Dobrila University of Pula, Faculty of Economics and Tourism "Dr. Mijo Mirković" Pula, P. Preradovića 1/1,52100 Pula, Croatia, e-mail tperusko@unipu.hr, ORCID: 0000-0001-9194-2316

KEYWORDS:
DEA, acquisition costs, administrative costs, earned premium, non-life insurance, insurance market

JEL CLASSIFICATION
G22, M41, C61

ABSTRACT

The main goal of the research is to analyze the efficiency of non-life insurance in Croatia using the DEA method. The paper focuses on analyzing efficiency by types of non-life insurance to determine efficiencies by insurance types, identify areas for improvement, and optimize the Croatian insurance market. Past research has analyzed the overall efficiency of non-life insurance and the efficiency of individual insurance companies in the Republic of Croatia. This paper focuses on evaluating efficiency by specific types of insurance within the non-life insurance category.

The methodological framework is based on the application of the input-oriented CCR and BCC models, which enable the assessment of relative efficiency. A dynamic analysis was conducted using acquisition costs, administrative costs, and settled claims as input variables, and earned premium as the output variable. The analysis reveals significant variations in efficiency by types of non-life insurance. The BCC model, considering variable returns, consistently provides higher efficiency values compared to the CCR model, highlighting the importance of scale effects in non-life insurance.

The comprehensive analysis provides insight into the dynamics of efficiency in the Croatian non-life insurance market. The analysis results show that efficiency levels vary significantly among different types of insurance, with economies of scale significantly impacting efficiency. These research results offer new scientific evidence for optimizing market efficiency and strengthening competitiveness in the Croatian insurance industry. The results contribute to the theoretical understanding of the dynamics of the non-life insurance market and offer new implications for the development of the insurance market.

1. INTRODUCTION

The non-life insurance market in the Republic of Croatia plays a key role in ensuring financial stability and asset protection, providing a wide range of insurance covering various risks. As part of the broader financial sector, the non-life insurance market significantly contributes to the economic development and stability of the country. Maintaining an efficient and competitive insurance industry is important for the economic resilience and security of the entire economy. In this paper, the efficiency of the non-life insurance market in the Republic of Croatia is analyzed using the DEA method. The DEA method was first introduced in the late 1970s in the work of Charnes, Cooper, and Rhodes (1978), and has since been widely used to measure the efficiency of various systems that use multiple input and output variables. DEA is a non-parametric method that allows for the analysis of the efficiency of decision-making units (DMUs) through the comparison of weighted output and input ratios. In the context of the non-life insurance market, the DEA method is used to analyze the

efficiency of the entire market in terms of resource utilization and service provision, enabling the identification of areas where there are opportunities for improvement.

The non-life insurance market in Croatia has undergone significant changes in recent decades, primarily due to integration into the European Union and alignment with new regulatory frameworks. The introduction of stricter regulatory standards has increased the requirements for capital and stability of insurers, aiming to ensure greater protection for policyholders and the long-term sustainability of the sector. Regulation, while ensuring stability, can also limit market flexibility and create additional costs for insurance companies, directly reflecting on the efficiency of the entire market. In addition to regulatory challenges, the non-life insurance market faces the need for technological transformation. Technological advancements, including digitalization, process automation, and the use of big data analytics, are important factors for increasing the efficiency of the insurance market. Barros et al. (2005) emphasize the importance of investing in technology to improve efficiency, which is also crucial for the Croatian market striving to increase competitiveness against foreign competitors. Digitalization enables insurers to better process data, make faster decisions, and provide personalized services to policyholders.

International comparative research provides insights into the efficiency of insurance markets at the macro level. Eling and Luhnen (2010) conducted an analysis of the efficiency of insurance markets in different countries using DEA to compare performance at the international level. Their study indicated significant differences in efficiency between developed and developing countries, with insurers in developed countries often showing higher efficiency due to advanced technology, stricter regulatory frameworks, and greater competition. These analysis results are significant for Croatia, which aims to increase its competitiveness by adopting best practices from developed economies. Biener and Eling (2012) analyzed the impact of organizational structure and international diversification on the efficiency of insurance market participants, concluding that presence in different international markets can contribute to improved efficiency through risk distribution and access to new clients. These analysis results can be applied to the Croatian market to encourage greater integration and diversification in regional markets.

The application of the DEA method in analyzing the efficiency of the non-life insurance market in Croatia provides a comprehensive insight into the efficiency of this sector in terms of resource utilization, cost management, and service provision. The DEA analysis in this paper is based on data collected from the Croatian Financial Services Supervisory Agency for the period from 2005 to 2022, considering acquisition costs, administrative costs, settled claims, and earned premium. Using this data, the analysis evaluates the efficiency of the market as a whole, identifying key challenges and opportunities for improvement. Efficient use and allocation of inputs and outputs are necessary to maximize profits and minimize costs (Učkar and Petrović, 2022). Therefore, more research is focused on measuring the efficiency of the insurance industry at the micro level through the comparison of insurance companies and

at the macro level through the comparison of insurance systems at the country level (Škrinjarić, 2017). Despite numerous analyses, to our knowledge, an analysis of efficiency by types of non-life insurance for Croatia has not been conducted, and therefore the focus of this research is on the structural analysis of non-life insurance efficiency.

The main goal of the research is to analyze and compare the efficiency by types of non-life insurance in the Republic of Croatia. Non-life insurance is classified into 18 groups on which efficiency analysis was conducted using the DEA model. Using the DEA method, insights are provided into how the market can increase its efficiency and competitiveness, creating a basis for informed policy and strategic decisions that will contribute to the sustainability and further development of the insurance market in Croatia. The research analyzes efficiency by types of insurance to form conclusions about efficiency levels through comparison over time and in relation to other types of insurance. The aim of the paper is to use scientific methods to obtain information for defining and describing efficiency in non-life insurance in Croatia. The results of this research can serve as guidelines for policymakers, regulators, and insurers in efforts to improve the efficiency and resilience of the market, which is crucial for the long-term stability and growth of the Croatian economy.

2. LITERATURE REVIEW

Data Envelopment Analysis (DEA) is one of the most significant tools in modern operational research methodology for measuring the efficiency of organizations that use multiple input and output variables. Since its introduction in the late 1970s, DEA has experienced significant growth in application, becoming a key instrument for analysts and researchers in various industries, including banking (Berger and Humphrey, 1997), healthcare (Hollingsworth, 2003), education (Thanassoulis, 2001), and especially insurance (Cummins and Weiss, 2013). In the non-life insurance sector, DEA enables detailed and comprehensive analysis of the efficiency of insurance companies and insurance markets, providing valuable insights into their operational performance, resource allocation, and competitive position in the market.

DEA was first introduced in the work of Charnes, Cooper, and Rhodes (1978), where it was described as a non-parametric method that uses linear programming to assess the relative efficiency of decision-making units (DMUs). This method allows for the measurement of efficiency through the ratio of weighted outputs and inputs, without the need for an assumption about the functional form of the production function, making it extremely flexible and adaptable to different contexts (Cooper, Seiford, and Tone, 2007). The basic CCR model, named after the initials of the authors (Charnes, Cooper, and Rhodes), assumes that the production function shows constant returns to scale (CRS), meaning that changes in inputs are reflected proportionally in changes in outputs. However, this assumption is not always realistic in practice,

especially in industries where there are economies or diseconomies of scale (Banker, Charnes, and Cooper, 1984). In response to this, the BCC model was developed, introducing variable returns to scale (VRS), allowing for more flexible efficiency analysis and better adaptation to real conditions.

The DEA method allows for the identification of efficient and inefficient DMUs, providing guidelines for performance improvement through the analysis of input and output variables (Thanassoulis, Portela, and Allen, 2004). The application of the DEA method in the insurance sector began in the late 20th century, driven by the need for a better understanding of the efficiency of insurance companies in an increasingly competitive and regulated business environment. Cummins and Weiss (1993) were among the first to apply DEA to analyze efficiency in the property and casualty insurance sector in the USA. Their study revealed significant differences in efficiency among companies, indicating the need for improvement in operational practices and resource allocation. Gardner and Grace (1993) applied DEA to life insurance, but their analysis results are also relevant to non-life insurance. They found that there are significant inefficiencies in the industry that may be due to excessive costs, inadequate use of resources, or lack of competition.

International comparative studies provide a broader context for understanding efficiency in the insurance industry, allowing for the analysis of the impact of different market and regulatory frameworks. Eling and Luhnen (2010) conducted an extensive analysis of efficiency in insurance markets in different countries, using DEA to compare performance at the international level. Their analysis results indicated significant differences in efficiency between developed and developing countries, with companies in developed countries often being more efficient, which can be attributed to greater competition, better regulation, and advanced technology. Biener and Eling (2012) analyzed the organization and efficiency in the international insurance industry using cross-frontier analysis. Their study highlighted the importance of international diversification and presence in different markets as factors that can improve efficiency through risk distribution and access to a larger number of clients. An analysis of efficiency in the European Union was also conducted by Žaja, Anđelović, and Kedžo (2018). The results showed that 14 out of the 26 analyzed EU countries are above the average efficiency, including Croatia.

Research on efficiency in the Croatian insurance industry was conducted by Medved and Kavčić (2012). The authors analyzed the efficiency of insurance in Croatia and Slovenia by applying the DEA method. The research proved that, on average, insurance companies in Croatia operate more efficiently than insurance companies in Slovenia and that mergers and acquisitions of insurance companies positively affect the growth of efficiency. The next research on efficiency in Croatia was done by Jurčević and Žaja (2013). The authors measured efficiency using the DEA method and accounting indicators and compared the efficiency results of banks and insurance companies in period before and after the outbreak of the financial and economic crisis in Croatia. Their research was followed by Učkar and Petrović (2022), who analyzed

efficiency levels concerning the size of insurance companies in Croatia. The results showed that large insurers achieve above-average financial indicators and below-average ratios of claims, costs, and debt. Kramarić, Pervan, and Ćurak (2022) analyzed the determinants of efficiency of non-life insurance companies in Croatia. The study examined insurance companies using DEA analysis and truncated regression, and the research results prove that age and ownership affect the efficiency of non-life insurance companies. The same authors conducted research on the efficiency of the life and non-life insurance industry before and after Croatia's accession to the European Union and indicated an increase in overall technical efficiency in the life and non-life insurance sectors in the period after Croatia's accession to the European Union.

In the non-life insurance sector, DEA has also been used to analyze various aspects of efficiency. Cummins and Xie (2008) analyzed the impact of mergers and acquisitions on productivity and efficiency in the US property and casualty insurance industry. Their analysis results showed that mergers can lead to efficiency improvements through economies of scale and scope, but they also warned of the risks associated with integration and cultural differences. Furthermore, Kao and Hwang (2008) applied a two-stage DEA analysis to the non-life insurance market in Taiwan. Their method allowed for the decomposition of efficiency into technical and allocative components, providing a more detailed insight into areas where performance can be improved.

Understanding the factors that affect efficiency in the insurance industry is crucial for making strategic decisions and formulating policies that promote the competitiveness and stability of the insurance industry. Among the most significant factors are company size (Klumpes, 2004), diversification (Eling and Luhnen, 2010), technological investments (Ray, 2004), ownership structure (Adams and Buckle, 2003), and regulatory framework and market conditions (Fenn et al., 2008).

Although DEA is a powerful tool, its application is not without challenges. Methodological issues include the selection of appropriate input and output variables (Cooper, Seiford, and Tone, 2007), ensuring data homogeneity (Paradi and Zhu, 2013), integration with other methods (Cummins and Zi, 1998), statistical inference (Simar and Wilson, 2000), and sensitivity to outputs and noise in the data (Dyson et al., 2001). DEA also has certain limitations, such as the lack of statistical tests, the assumption of homogeneity, sensitivity to variable selection, and the lack of a time dimension (Cook, Tone, and Zhu, 2014). Despite this, its flexibility and ability to handle multiple inputs and outputs make it a valuable tool for managers, investors, and regulators. Effective application of findings from DEA analysis can achieve significant advantages in the insurance industry, including increased profitability (Eling and Schaper, 2017), improved customer service (Rees and Kessner, 1999), and strengthened market position (Liebenberg and Sommer, 2008). Furthermore, integration with technologies such as big data and analytics can further enhance companies' ability to respond to market changes and adapt their strategies.

3. METHODOLOGY

DEA is a non-parametric technique that uses linear programming to measure the efficiency of DMUs in the context of multiple inputs and outputs. The DEA method is based on defining the efficiency frontier, where DMUs on this frontier are efficient, while those below it is considered inefficient. Efficient units are those that achieve the highest possible level of output given the inputs used. The DEA model evaluates efficiency relatively, meaning each unit is compared to the best performances within the set. The application of DEA analysis in this research was chosen because it can be used on a small sample, measure relative efficiency with multiple inputs and outputs, and as a non-parametric method, it does not require a predefined specific functional form (Pervan et al., 74).

In choosing the orientation of the model to input or output, the literature highlights input orientation due to the assumption that insurance companies have more control over inputs than outputs. This assumption is advocated in the works of Elling and Luhnen (2010), Medved and Kavčić (2012), and Cummins and Xie (2016), while Cummins and Weiss (2013) show that most efficiency analyses in the insurance industry are input-oriented. The selection of inputs and outputs was made in accordance with the literature that explores the area of efficiency in the insurance industry. Recommendations on the number of input and output units according to some authors, Golany and Roll (1989), should be at least twice the number of DMUs analyzed, while other authors suggest a stricter criterion where the number of input and output units should be at least three times smaller than the number of DMUs (Bowlin 1989). In the study of the non-life insurance market, the inputs used in the analysis include acquisition costs, administrative costs, and settled claims. The output, earned premium, results from the sale of insurance policies, which is a key indicator of the success of insurance companies.

The CCR model developed by Charnes, Cooper, and Rhodes was first applied in the analysis. The CCR model is based on the assumption of constant returns to scale (CRS). This means that it is assumed that all units have the same efficiency regardless of size and that proportional increases in inputs result in proportional increases in outputs. The CCR model uses linear programming to assess the efficiency of each unit, where inputs are minimized while maintaining the level of outputs.

Mathematically, the CCR model can be described by the following objective function:

$$Minimize\ \theta = \frac{\sum_{r=1}^{s} v_r y_{ro}}{\sum_{i=1}^{m} u_i x_{io}} \tag{1}$$

subject to:

$$\sum_{i=1}^{m} u_i x_{ik} = 1, \quad k = 1,2,\dots,n \tag{2}$$

where:

- y_{ro} represents the value of the r-th output for the analyzed unit o,,
- x_{io} represents the value of the i-th input for the analyzed unit o,
- v_r and u_i are weight factors for outputs and inputs,
- n represents the number of DMUs, i.e., insurance companies,
- m and s represent the number of inputs and outputs.

The goal of the input-oriented CCR model is to minimize the input resources needed to generate a given level of output, achieving the best ratio between resources and results. The model defines efficient units that are on the efficiency frontier with an efficiency coefficient equal to 1, while all units below this frontier are considered inefficient. The CCR model allows the identification of types of insurance that use the least resources to achieve a certain level of earned premium, which is crucial for understanding business optimization and cost reduction.

After the analysis using the CCR model, the input-oriented BCC model developed by Banker, Charnes, and Cooper was applied. The BCC model extends the CCR model by introducing the concept of variable returns to scale (VRS). This model allows the analysis of the efficiency of DMUs that differ in size and resources, considering that different DMUs can have different returns to scale. The BCC model assumes that an increase in inputs does not necessarily lead to a proportional increase in outputs, allowing the analysis of smaller and larger DMUs with different capacities. This model is particularly useful in analyzing the insurance market, where different types of non-life insurance can have different resources and market strategies, but can still achieve similar or better results.

Mathematically, the BCC model is formulated as:

$$Minimize\ \theta = \frac{\sum_{r=1}^{8} v_r y_{ro}}{\sum_{i=1}^{m} u_i x_{io}} \tag{3}$$

subject to:

$$\sum_{i=1}^{m} u_i x_{ik} - \sum_{r=1}^{8} u_r y_{rk} = 0, \quad k = 1,2,\dots,n \tag{4}$$

The data used in the research were collected from the Croatian Financial Services Supervisory Agency for the period from 2005 to 2022. The collected data include key financial indicators related to operating costs, settled claims, and earned premiums. The data were processed and entered into appropriate software tools for DEA analysis, where each input and output were normalized to ensure comparability of different units. After data collection, all inputs and outputs for each type of non-life insurance were defined as variables in the analysis. Inputs included acquisition costs, administrative costs, and settled claims, while the output was earned premium. The

collected data enabled a detailed analysis of each type of insurance and a comparison of their results. The first step of the analysis was to enter the data into the appropriate software tool for DEA analysis. Each type of insurance was defined as a decision-making unit (DMU), and for each DMU, inputs and outputs were analyzed. Using linear programs, the CCR and BCC models optimized the ratio between inputs and outputs for each group of insurance, calculating efficiency indicators.

The CCR model identified those types of non-life insurance that use their resources most efficiently, i.e., that minimize costs while maintaining the level of earned premium. Types of non-life insurance that were efficient according to the CCR model were identified as those on the efficiency frontier, while other types of insurance were considered inefficient. This model allows the identification of areas where efficiency can be improved and business optimized. After the analysis according to the CCR model, the BCC model was applied to enable the assessment of efficiency in the context of different sizes by types of insurance. The BCC model identified types of non-life insurance that are efficient despite possibly using different amounts of resources compared to other types. This is particularly important in the context of the insurance market, where insurance types may differ significantly in size and resources, but may achieve similar or better results.

4. RESEARCH RESULTS

Table 1. shows the correlation analysis between the examined variables. Correlation coefficients in non-life insurance have high values, indicating a strong relationship between inputs and outputs. The strongest correlation coefficients in non-life insurance are between earned premium, administrative costs, and settled claims. All coefficients are positive, indicating that it is possible to continue the DEA analysis. Descriptive statistics for selected inputs and outputs are shown in Table 2., which shows significant differences in the range of minimum and maximum values in inputs and outputs.

Table 1. Correlation analysis for non-life insurance

	Acquisition Costs	Administrative Costs	Settled Claims	Earned Premium
Acquisition Costs	1			
Administrative Costs	0.740873429	1		
Settled Claims	0.796596859	0.891104635	1	
Earned Premium	0.833125577	0.958042011	0.959287244	1

Source: HANFA data (processed by author)

Table 2. Descriptive statistics for non-life insurance

Heading	Inputs			Output
Data	(I) Acquisition Costs	(I) Administrative Costs	(I) Settled Claims	(O)Earned Premium
Mean	68556730.52	73035927.38	193039331.70	317979753,40
Standard Deviation	119201456.40	128262272.30	329698738.90	584102581.70
Minimum	39000	154257.92	3870	5918000
Maximum	774347970.80	790846081.20	1710891623	2899297041
Sum	22212380689	23663640472	62544743485	103025440096.56
Count	324	324	324	324

Source: HANFA data (processed by author)

The results of the calculation of relative efficiency using the input-oriented CCR and BCC DEA models (CCR-I and BCC-I) are shown in Table 3. for the CCR-I model and Table 4. for the BCC-I model, and the average efficiency for both models is shown in Table 5. Using an 18-year period, 18 DMUs were calculated as a total of 324 DMUs, allowing the examination of each DMU combination throughout the period.

Table 3. Efficiency results in the CCR-I model for the period 2005–2022.

Types of Insurance	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Accident Insurance	0.716	0.523	0.397	0.913	0.440	0.628	0.938	0.999	1	0.977	0.816	0.985	0.718	0.953	0.568	0.844	0.843	0.594
Health Insurance	0.651	0.564	0.436	0.841	0.539	0.627	1	1	1	1	1	1	1	0.906	0.857	0.991	0.965	0.855
Motor Vehicle Insurance	0.795	0.681	0.467	0.962	0.523	1	1	0.946	1	0.884	0.895	0.844	0.946	1	1	1	1	1
Rail Vehicle Insurance	1	1	1	0.477	1	1	1	1	0.889	1	1	1	1	1	0.526	1	0.837	0.571
Aircraft Insurance	0.584	0.329	0.152	0.229	0.181	0.108	0.214	0.616	0.668	0.640	0.325	0.234	0.127	0.191	0.141	0.540	0.233	0.271
Vessel Insurance	0.352	0.240	0.149	0.390	0.230	0.292	0.358	0.379	0.324	0.481	0.526	0.463	0.437	0.515	0.466	0.725	0.638	0.617
Cargo Insurance	0.815	0.644	0.476	0.902	0.371	0.617	1	1	1	1	0.774	0.866	0.673	0.784	0.593	0.668	0.786	0.691
Fire and Natural Disaster Insurance	0.537	0.388	0.324	0.578	0.314	0.391	0.609	0.598	0.583	0.562	0.561	0.669	0.501	0.635	0.526	0.578	0.537	0.525
Other Property Insurance	0.692	0.559	0.410	0.821	0.415	0.485	0.782	0.738	0.696	0.635	0.714	0.664	0.647	0.763	0.683	0.766	0.771	0.760
Motor Vehicle Liability Insurance	0.800	0.679	0.504	1	1	1	0.921	0.946	0.990	0.892	0.860	0.932	0.725	0.872	0.780	0.872	0.965	0.863
Aircraft Liability Insurance	0.255	0.132	0.872	1	0.333	1	1	0.288	0.606	1	0.383	0.139	0.159	0.317	0.190	0.572	0.475	0.514

Vessel Liability Insurance	0.430	0.354	0.263	0.485	0.217	0.350	0.487	0.683	0.801	0.708	0.646	0.307	0.545	0.659	0.559	0.806	0.920	0.770
Other Liability Insurance	0.507	0.373	0.256	0.495	0.335	0.406	0.641	0.712	0.737	0.635	0.649	0.754	0.640	0.815	0.689	0.867	0.838	0.728
Credit Insurance	0.598	0.563	0.538	0.695	0.454	0.822	0.875	0.942	0.642	0.710	0.540	1	0.872	1	0.535	0.848	0.832	0.453
Surety Insurance	1	0.686	0.537	1	0.533	0.450	0.890	0.699	0.661	0.835	1	1	1	0.844	0.641	0.936	1	1
Miscellaneous Financial Loss Insurance	0.583	0.375	0.379	0.679	0.326	0.384	0.577	0.593	0.527	0.758	0.603	0.761	0.522	0.737	0.603	0.866	0.720	0.668
Legal Expenses Insurance	1	1	0.708	0.379	1	0.467	0.521	1	1	1	1	1	1	1	1	1	1	1
Assistance Insurance	0.869	0.380	0.559	0.503	0.251	0.438	0.620	0.871	0.980	0.845	0.695	0.983	0.762	0.967	0.833	1	0.953	0.897
Average Efficiency	0.663	0.526	0.468	0.686	0.460	0.581	0.746	0.778	0.784	0.809	0.703	0.755	0.682	0.775	0.622	0.827	0.795	0.710

Source: HANFA data (processed by author)

Table 4. Efficiency results in the BCC-I model for the period 2005–2022.

Types of Insurance	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Accident Insurance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Health Insurance	0.809	0.887	0.862	0.962	1	0.929	1	1	1	1	1	1	1	1	1	1	1	0.943
Motor Vehicle Insurance	0.993	1	0.927	0.962	0.994	1	1	1	1	1	1	1	1	1	1	1	1	1
Rail Vehicle Insurance	1	1	1	0.719	1	1	1	1	1	1	1	1	1	1	0.628	1	1	1
Aircraft Insurance	1	0.617	0.174	0.250	0.113	0.199	0.315	1	1	0.865	0.556	0.486	0.707	0.665	0.478	0.617	0.478	0.391
Vessel Insurance	0.536	0.434	0.304	0.424	0.422	0.457	0.362	0.383	0.324	0.516	0.609	0.516	0.460	0.524	0.488	0.734	0.646	0.654
Cargo Insurance	1	1	1	1	0.685	0.891	1	1	1	1	0.915	1	0.707	1	0.733	0.828	0.851	0.835
Fire and Natural Disaster Insurance	0.726	0.662	0.757	0.650	0.661	0.627	0.644	0.602	0.602	0.606	0.637	0.676	0.694	0.761	0.682	0.580	0.538	0.709
Other Property Insurance	0.863	0.851	0.811	0.821	0.783	0.740	0.798	0.773	0.819	0.797	0.808	0.716	0.715	0.791	0.769	0.777	0.780	0.820
Motor Vehicle Liability Insurance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aircraft Liability Insurance	1	1	1	1	0.534	1	1	1	1	1	1	0.828	1	1	1	1	1	0.989
Vessel Liability Insurance	0.665	0.926	0.856	0.685	0.835	0.770	0.597	0.718	0.930	0.779	0.790	0.307	0.706	0.788	0.738	0.965	0.976	1
Other Liability Insurance	0.628	0.607	0.590	0.593	0.701	0.644	0.678	0.723	0.737	0.668	0.848	0.831	0.837	1	0.904	0.914	0.899	0.906
Credit Insurance	1	1	1	0.755	0.834	1	0.880	0.944	0.643	1	0.642	1	1	1	0.882	1	1	1
Surety Insurance	1	0.968	1	1	0.879	0.900	1	1	0.705	1	1	1	1	0.844	0.685	1	1	1
Miscellaneous Financial Loss Insurance	0.739	0.608	0.867	0.852	0.715	0.706	0.671	0.666	0.542	0.844	0.809	0.768	0.680	0.787	0.828	0.961	0.740	0.936

Legal Expenses Insurance	1		1	1		0.470	1		0.581	0.567	1		1	1	1	1	1	1	1	1
Assistance Insurance	0.984	0.424	1	1		0.660	1		0.898	1		0.982	0.879	0.835	0.990	0.983	1	1	1	0.962	1
Average Efficiency	0.886	0.832	0.842	0.786		0.768	0.802		0.800	0.878		0.849	0.886	0.858	0.840	0.861	0.897	0.823	0.910	0.882	0.899

Source: HANFA data (processed by author)

Table 5. Average efficiencies by BCC-I and CCR-I models

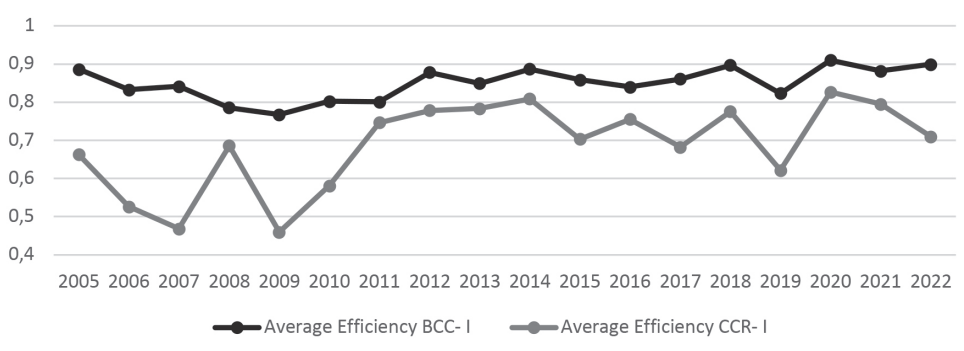
Types of Insurance	BCC-I Average Efficiency	CCR-I Average Efficiency
Accident Insurance	1	0.7696
Health Insurance	0.9654	0.8462
Motor Vehicle Insurance	0.9931	0.8857
Rail Vehicle Insurance	0.9637	0.9055
Aircraft Insurance	0.5506	0.2932
Vessel Insurance	0.4885	0.4212
Cargo Insurance	0.9137	0.7588
Fire and Natural Disaster Insurance	0.6563	0.5231
Other Property Insurance	0.7908	0.6666
Motor Vehicle Liability Insurance	1	0.8668
Aircraft Liability Insurance	0.9639	0.4988
Vessel Liability Insurance	0.7796	0.5550
Other Liability Insurance	0.7615	0.6153
Credit Insurance	0.9211	0.7178
Surety Insurance	0.9434	0.8173
Miscellaneous Financial Loss Insurance	0.7621	0.5922
Legal Expenses Insurance	0.9232	0.8930
Assistance Insurance	0.9220	0.7448

Source: HANFA data (processed by author)

The comparison of average efficiency results between the CCR and BCC models reveals several significant conclusions. First, it is evident that the BCC model generally shows higher efficiency values compared to the CCR model for all types of insurance. This difference arises from the fundamental assumptions of the models, where the BCC model, considering variable returns to scale, allows for a more flexible assessment of efficiency that better corresponds to real business conditions in the insurance market. It is particularly noticeable that certain types of insurance show a significantly

greater difference between the results obtained by different models, suggesting that scale effects play an important role in their efficiency.

Graph 1. Trends in average efficiency by BCC-I and CCR-I models for the period 2005–2022.



Source: HANFA data (processed by author)

Analyzing the trends in average annual efficiency over time, we can observe certain trends and changes in the efficiency of non-life insurance. The time series shows that efficiency according to both models varied during the observed period, but with different intensities and patterns. The time analysis shows that the global financial crisis of 2008 had an impact on the efficiency of non-life insurance, which can be seen through changes in efficiency during that period. However, most types of insurance showed the ability to recover and adapt to new market conditions. The period from 2015 to 2019 is characterized by relative stability in the efficiency of most types of insurance, suggesting that the non-life insurance market in Croatia has reached a certain level of maturity and stability. However, the emergence of the COVID-19 pandemic in 2020 brought new challenges and changes in the efficiency of non-life insurance.

Analyzing by types of insurance, it is observed that accident insurance shows complete efficiency according to the BCC model throughout the observed period, while according to the CCR model, it shows an average efficiency of 0.77. This difference suggests that this type of insurance is optimally organized when variable returns to scale are taken into account, but there is opportunities for improvement when considered in the context of constant returns to scale. Health insurance shows high average efficiency according to the BCC model of 0.97 and slightly lower according to the CCR model. This indicates good business organization but also potential for further improvements in resource management at higher levels of operation. Motor vehicle insurance also shows very high efficiency of 0.99 according to the BCC model and slightly lower efficiency of 0.89 according to the CCR model. This type of insurance shows consistently high results according to both models, suggesting good resource management regardless of the scale of operations. Motor vehicle liability

insurance shows complete efficiency according to the BCC model and high efficiency of 0.87 according to the CCR model, indicating very well-organized operations in this segment of the insurance market.

Significant differences in efficiency can be observed in aircraft insurance, where the BCC model shows an average efficiency of 0.55, while the CCR model shows significantly lower efficiency of 0.29. This difference suggests that this type of insurance is particularly sensitive to the effects of scale and could significantly improve its efficiency through optimization of operation size. Vessel insurance also shows relatively low levels of efficiency according to both models of 0.49 according to the BCC and 0.42 according to the CCR, indicating the need for significant improvements in operational efficiency in this segment, regardless of the approach to measuring efficiency. Fire and natural disaster insurance shows moderate efficiency according to both models of 0.66 according to the BCC and 0.52 according to the CCR, suggesting significant potential for improvement in operational efficiency in this segment.

Surety insurance and credit insurance show relatively high levels of efficiency according to the BCC model of 0.94 and 0.92, but significantly lower of 0.82 and 0.72 according to the CCR model. This difference suggests that these types of insurance are particularly sensitive to the effects of scale and could achieve better efficiency through optimization of operation size. Assistance insurance shows good efficiency according to the BCC model of 0.94 and slightly lower according to the CCR model of 0.74, indicating well-organized operations but also opportunities for improvement when considered in the context of constant returns to scale. Other property insurance and other liability insurance show moderate levels of efficiency according to both models, suggesting the need for significant improvements in operational efficiency in these segments.

The analysis of trends during the observed period shows that certain types of insurance have experienced significant changes in efficiency. Some types of insurance show a trend of improving efficiency over time, while others show stable or even declining trends. This suggests that different types of insurance respond differently to changes in market conditions and regulatory environment. It is particularly interesting to note that types of insurance that are traditionally important for the Croatian market, such as motor vehicle liability insurance and motor vehicle insurance, show consistently high levels of efficiency according to both models. This suggests that long-term experience in these segments has resulted in optimized business processes and good resource management. On the other hand, some specific types of insurance, such as aircraft and vessel insurance, show lower levels of efficiency, which may be due to a smaller market and specific challenges in risk management in these segments.

Differences in results between the BCC and CCR models are particularly important for understanding the impact of scale on the efficiency of different types of insurance. Greater differences between the results of the two models suggest that the efficiency of a particular type of insurance is significantly conditioned by the scale of operations, while smaller differences indicate that efficiency is less dependent on

the scale of operations. Observing the results over time, we can see that most types of insurance have shown a certain level of resilience to external shocks, although some segments were more affected than others. This is particularly evident in periods of economic crises and during the COVID-19 pandemic. The analysis also reveals that there is a significant difference in the volatility of efficiency between different types of insurance. Some types of insurance show stable levels of efficiency over time, while others show significant fluctuations. This may be related to various factors, including changes in market conditions, regulatory changes, and changes in the competitive environment.

It is important to note that higher efficiency values according to the BCC model compared to the CCR model do not necessarily mean that the BCC model is "better" or "more accurate." Instead, this difference reflects different model assumptions and provides complementary insights into the efficiency of insurance companies' operations. The analysis results also suggest that there is potential for improving efficiency in many segments of non-life insurance in Croatia. This particularly applies to types of insurance that show lower levels of efficiency according to both models. Improvements could include optimizing business processes, better resource management, and adapting strategies to different market conditions.

Observing the results in the context of the development of the Croatian insurance market, we can conclude that the non-life insurance sector has shown significant ability to adapt to changing market conditions. However, the existence of significant differences in efficiency between different types of insurance suggests that there is potential for further development and optimization of operations in certain segments. The analysis also highlights the importance of continuous monitoring and evaluation of the efficiency of different types of insurance to identify areas for improvement and optimize business processes. Using both the CCR and BCC models provides a more comprehensive insight into operational efficiency and allows for a better understanding of the impact of scale on the efficiency of different types of insurance.

In the context of the future development of the insurance market in Croatia, the results of this analysis can serve as a basis for strategic planning and decision-making on resource allocation. Special attention should be paid to types of insurance that show lower levels of efficiency to identify the causes of inefficiency and develop strategies to overcome them. The analysis of non-life insurance efficiency in Croatia using the DEA method provides important insights into the performance of different types of insurance and identifies areas for potential improvements. The results suggest that, although most types of insurance show satisfactory levels of efficiency, there is significant opportunities for optimizing operations in certain segments of the non-life insurance market.

5. CONCLUSION

The conducted analysis of the efficiency of the non-life insurance market in the Republic of Croatia using the DEA method provided a comprehensive insight into the performance of different types of insurance in the observed period from 2005 to 2022. The use of the CCR and BCC models enabled a detailed comparison of efficiency by types of insurance, taking into account different assumptions about returns to scale. The comparison of average efficiency results between the BCC and CCR models clearly indicated differences in efficiency assessment. The BCC model, which takes into account variable returns to scale, generally showed higher efficiency values compared to the CCR model, which assumes constant returns. This difference indicates that scale effects play a significant role in the efficiency of different types of insurance.

The analysis by groups of non-life insurance revealed new scientific findings. Accident insurance, health insurance, and motor vehicle insurance, showed very high levels of efficiency according to both models, indicating good business organization and efficient resource management. On the other hand, aircraft insurance, vessel insurance, and fire insurance, showed relatively lower levels of efficiency, especially according to the CCR model, suggesting that these types of insurance are more sensitive to to business volume effects.

The analysis of efficiency trends over time revealed that most types of insurance showed a certain level of resilience to external shocks, such as the global financial crisis of 2008 and the COVID-19 pandemic. However, certain types of insurance experienced more significant changes in efficiency over time, indicating different abilities to adapt to changing market conditions.

The analysis results also suggest that there is opportunities for improving efficiency in many segments of non-life insurance in Croatia. Types of insurance with lower levels of efficiency according to both models, such as aircraft insurance, vessel insurance, and fire insurance, represent areas where measures could be taken to optimize business processes, better manage resources, and adapt strategies to different market conditions.

Differences in results between the BCC and CCR models are particularly important for understanding the impact of scale on the efficiency of different types of insurance. Greater differences between the results of the two models suggest that the efficiency of a particular type of insurance is significantly conditioned by the scale of operations, while smaller differences indicate that efficiency is less dependent on the scale of operations. This analysis provides important implications for policymakers, regulators, and insurance company managers. The results can serve as a basis for strategic planning and decision-making on resource allocation, with a special focus on types of insurance that show lower levels of efficiency. Continuous monitoring and evaluation of the efficiency of different types of insurance are crucial for identifying areas for improvement and optimizing business processes. Future research in this area could focus on further analysis of factors affecting efficiency, such as the impact of

technological innovations, regulatory changes, and market competition. Additionally, integrating DEA analysis with other methods could provide further insights into the dynamics of efficiency changes over time.

6. RESEARCH LIMITATIONS AND RECOMMENDATIONS

Limitations in research represent an important aspect of scientific transparency and critical reflection on the conducted study. Although the DEA methodology is widely accepted in scientific literature and provides robust results in the analysis of relative efficiency, it is important to highlight several limitations that may have influenced the research results. The limitations arise from the structure of the DEA methodology which, despite its strength in efficiency analysis, has limitations due to the lack of statistical tests that would allow for a more precise assessment of the statistical significance of the obtained results. The DEA model is also sensitive to the selection of input and output variables, which constitutes a methodological limitation. The selection of variables in this research was thoroughly considered and based on relevant literature, but every selection has a certain degree of bias and can influence on the research.

The limitation related to the research concerns the assumption of homogeneity of the analyzed units. In the context of the Croatian non-life insurance market, this assumption may be present given the different sizes of insurance companies, their business models, and market strategies. The time dimension of the research, covering the period from 2005 to 2022, may also include a potential limitation. The analyzed period is relatively long and includes different phases of the economic cycle, including the global financial crisis and the COVID-19 pandemic period, but the dynamic nature of the insurance market opens up the possibility that newer trends and changes may not be fully covered in the analysis.

The integration of the DEA methodology with other analytical approaches also represents a challenge and a possible limitation. Although DEA provides a robust framework for efficiency analysis, combining it with other methods, such as econometric analysis or qualitative research approaches, could provide additional information on efficiency and the factors influencing it. However, such integration carries its methodological challenges and was not the focus of this research.

The mentioned limitations do not diminish the value and contribution of the conducted research but serve as guidelines for interpreting the results and planning future research. Understanding these limitations also opens up space for methodological improvements and the expansion of the research focus in future research of efficiency in the insurance market.

REFERENCES

Adams, M., & Buckle, M. (2003). The determinants of corporate financial performance in the Bermuda insurance market. *Applied Financial Economics*, *13*(2), 133-143. https://doi.org/10.1080/096031002101050 30

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092. https://doi.org/10.1287/mnsc.30.9.1078

Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European journal of operational research*, *98*(2), 175-212. https://doi.org/10.1016/S0377-2217(96)00342-6

Biener, C., & Eling, M. (2012). Organization and efficiency in the international insurance industry: A cross-frontier analysis. *European Journal of Operational Research*, *221*(2), 454-468. https://doi.org/10.1016/j.ejor.2012.03.037

Bowlin, W. F. (1998). Measuring performance: An introduction to dana envelopment analysis (DEA). *The Journal of Cost Analysis*, *15*(2), 3-27. https://doi.org/10.1080/08823871.1998.10462318

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1-4. https://doi.org/10.1016/j.omega.2013.09.004

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-Solver software*. Springer Science & Business Media. https://doi.org/10.1007/978-0-387-45283-8

Cummins, J. D., & Xie, X. (2016). Efficiency and Productivity in the US Property-Liability Insurance Industry: Ownership Structure, Product and Distribution Strategies. In J. Zhu (Ed.), *Data envelopment analysis: A handbook of empirical studies and applications* (pp.113-163.). New York: Springer. https://doi.org/10.1007/978-1-4899-7684-0_6

Cummins, J. D., & Weiss, M. A. (1993). Measuring cost efficiency in the property-liability insurance industry. *Journal of Banking & Finance*, *17*(2-3), 463-481. https://doi.org/10.1016/0378-4266(93)90046-G

Cummins, J. D., & Weiss, M. A. (2013). Analyzing firm performance in the insurance industry using frontier efficiency methods. In G. Dionne (Ed.), *Handbook of insurance* (pp. 795-861). Springer. https://doi.org/10.1007/978-1-4614-0155-1_28

Cummins, J. D., & Xie, X. (2008). Mergers and acquisitions in the US property-liability insurance industry: Productivity and efficiency effects. *Journal of Banking & Finance*, *32*(1), 30-55. https://doi.org/10.1016/j.jbankfin.2007.09.003

Cummins, J. D., & Zi, H. (1998). Comparison of frontier efficiency methods: An application to the US life insurance industry. *Journal of Productivity Analysis*, *10*(2), 131-152. https://doi.org/10.1023/A:1026402922367

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., & Shale, E. A. (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research*, *132*(2), 245-259. https://doi.org/10.1016/S0377-2217(00)00149-1

Eling, M., & Luhnen, M. (2010a). Efficiency in the international insurance industry: A cross-country comparison. *Journal of Banking & Finance*, *34*(7), 1497-1509. https://doi.org/10.1016/j.jbankfin.2009.08.026

Eling, M., & Luhnen, M. (2010b). Frontier efficiency methodologies to measure performance in the insurance industry: Overview, systematization, and recent developments. *The Geneva Papers on Risk and Insurance-Issues and Practice*, *35*(2), 217-265. https://doi.org/10.1057/gpp.2010.1

Eling, M., & Schaper, P. (2017). Under pressure: How the business environment affects productivity and efficiency of European life insurance companies. *European Journal of Operational Research*, *258*(3), 1082-1094. https://doi.org/10.1016/j.ejor.2016.08.070

Fenn, P., Vencappa, D., Diacon, S., Klumpes, P., & O'Brien, C. (2008). Market structure and the efficiency of European insurance companies: A stochastic frontier analysis. *Journal of Banking & Finance*, *32*(1), 86-100. https://doi.org/10.1016/j.jbankfin.2007.09.005

Gardner, L. A., & Grace, M. F. (1993). X-efficiency in the US life insurance industry. *Journal of Banking & Finance*, *17*(2-3), 497-510. https://doi.org/10.1016/0378-4266(93)90048-I

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega*, *17*(3), 237-250. https://doi.org/10.1016/0305-0483(89)90029-7

HANFA - Croatian Financial Services Supervisory Agency - Statistics [available at: www.hanfa.hr/statistika/drustva-za-osiguranje-i-drustva-za-reosiguranje/ access May 10, 2024]

Hollingsworth, B. (2003). Non-parametric and parametric applications measuring efficiency in health care. *Health care management science*, *6*(4), 203-218. https://doi.org/10.1023/A:1026255523228

Jurčević, B., & Žaja, M. M. (2013). Banks and insurance companies efficiency indicators in the period of financial crisis: The case of the Republic of Croatia. *Economic research-Ekonomska istraživanja, 26*(1), 203-224. https://doi.org/10.1080/1331677X.2013.11517598

Kao, C., & Hwang, S. N. (2008). Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan. *European Journal of Operational Research*, *185*(1), 418-429. https://doi.org/10.1016/j.ejor.2006.11.041

Klumpes, P. J. M. (2004). Performance benchmarking in financial services: Evidence from the UK life insurance industry. *The Journal of Business, 77*(2), 257–273. https://doi.org/10.1086/381281

Liebenberg, A. P., & Sommer, D. W. (2008). Effects of corporate diversification: Evidence from the property–liability insurance industry. *Journal of Risk and Insurance*, *75*(4), 893-919. https://doi.org/10.1111/j.1539-6975.2008.00290.x

Medved, D., & Kavčič, S. (2012). An empirical study of efficiency in Croatia and Slovenia insurance markets. *Economic research – Ekonomska istraživanja*, *25*(1), 87-98. https://doi.org/10.1080/1331677X.2012.11517496

Mihelja Žaja, M., Anđelović, M., & Gardijan Kedžo, M. (2018). Analiza učinkovitosti poslovanja osigurateljne industrije u Europskoj uniji. In M. Ćurković, J. Krišto & D. Zorić (Eds.), *Zbornik radova sa međunarodne znanstveno-stručne konferencije - Hrvatski dani osiguranja 2018* (pp. 29-41.). Zagreb: Hrvatski ured za osiguranje. https://huo.hr/upload_data/site_files/zbornik-2018-web.pdf

Paradi, J. C., & Zhu, H. (2013). A survey on bank branch efficiency and performance research with data envelopment analysis. *Omega*, *41*(1), 61-79. https://doi.org/10.1016/j.omega.2011.08.010

Pavić Kramarić, T., Pervan, M., & Ćurak, M. (2022). Determinants of Croatian Non-Life Insurance Companies' Efficiency. *Croatian Operational Research Review, 13*(2), 149-160. https://doi.org/10.17535/crorr.2022.0011

Pervan, M., Ćurak, M., & Pavić Kramarić, T. (2021). Has Accession to the European Union Affected the Efficiency of Croatian Insurance Companies? *International Review of Economics & Business*, *24*(1), 67-98. https://doi.org/10.2478/zireb-2021-0004

Ray, S. C. (2004). *Data envelopment analysis: Theory and techniques for economics and operations research*. Cambridge University Press. https://doi.org/10.1017/CBO9780511606731

Rees, R., & Kessner, E. (1999). Regulation and efficiency in European insurance markets. *Economic Policy*, *14*(29), 363-397. https://doi.org/10.1111/1468-0327.00053

Simar, L., & Wilson, P. W. (2000). Statistical inference in nonparametric frontier models: The state of the art. *Journal of Productivity Analysis*, *13*(1), 49-78. https://doi.org/10.1023/A:1007864806704

Škrinjarić, T. (2017). Analiza relativne efikasnosti industrije osiguranja europskih zemalja korištenjem analize omeđivanja podataka. *Ekonomski pregled*, *67*(1), 3-26. https://hrcak.srce.hr/154691

Thanassoulis, E. (2001). *Introduction to the theory and application of data envelopment analysis: A foundation text with integrated software*. Springer Science & Business Media. https://doi.org/10.1007/978-1-4615-1407-7

Thanassoulis, E., Portela, M. C. S., & Allen, R. (2004). Incorporating value judgments in DEA. In W. W. Cooper, L. M. Seiford, J. Zhu (Eds.), *Handbook on data envelopment analysis* (pp. 99-138). Springer. https://doi.org/10.1007/1-4020-7798-X_4

Učkar, D., & Petrović, D. (2022). Efficiency of insurance companies in Croatia. *Ekonomska misao i praksa*, *31*(1), 49-79. https://doi.org/10.17818/EMIP/2022/1.3