Ing. Iveta Palečková
Silesian University in Opava, School of Business Administration in Karvina
paleckova@opf.slu.cz
orcid.org/0000-0003-2381-0738
Lenka Přečková
Silesian University in Opava, School of Business Administration in Karvina
preckova@opf.slu.cz
orcid.org/0000-0002-1973-3293
DOI: https://doi.org/10.14195/2183-203X_61_4

Measuring Efficiency and Productivity Change of Insurance Companies in the European Union

Avaliação da Evolução da Eficiência e da Produtividade das Companhias de Seguros na União Europeia

Ing. Iveta Palečková
Lenka Přečková

Received for publication: August 31, 2025
Revision accepted for publication: November 9, 2025

ABSTRACT
This article analyses the efficiency of European insurance companies (composite, life and non-life) in 27 EU countries over the period 2014–2023. Using Data Envelopment Analysis and the Malmquist index, the study examines the impact of technological change and input–output management. The results reveal efficiency differences between countries and positive productivity trends in most of them. Life insurers were the most efficient, although their efficiency declined during 2021–2022. Composite insurers were less efficient than life and non-life insurers, the latter of which significantly improved their performance in 2022–2023. Overall, efficiency growth depends both on process improvements and on technological innovations.
Keywords: insurance efficiency, life insurer, non-life insurer, composite insurer, technological innovation

JEL Codes: G22

RESUMO
Este artigo analisa a eficiência das empresas de seguros europeias (compostas, de vida e não vida) em 27 países da UE durante o período de 2014-2023. Recorrendo ao método Data

Envelopment Analysis e ao índice de Malmquist, o estudo examina o impacto da mudança tecnológica e da gestão dos inputs e outputs. Os resultados revelam diferenças de eficiência entre países e tendências positivas de produtividade na maioria deles. As seguradoras de vida são as mais eficientes, embora a sua eficiência tenha diminuído em 2021-2022. As seguradoras compostas apresentaram menor eficiência do que as seguradoras de vida e não vida, sendo que estas últimas melhoraram significativamente o seu desempenho em 2022-2023. Em geral, o crescimento da eficiência depende tanto das melhorias nos processos como das inovações tecnológicas.

Acknowledgements: Publication of this paper was supported by the Student Grant Competition Project SGS/22/2024: "Impact of COVID-19 and digitalization on selected areas of banks and insurance companies"

1. Introduction

The insurance market represents a vital part of the economy, with its growth significantly influencing a nation's economic progress. The insurance industry plays a crucial role in the stability and growth of the economy. It contributes to growth of the real economy and helps maintain financial stability by reducing the impact of losses on businesses and households through risk-sharing (Časta et al. 2021). In the European Union (EU), where the insurance market is both diverse and highly regulated, understanding the efficiency of insurers is essential for ensuring competitiveness, resilience, and sustainable growth. This need has become even more pronounced in the wake of the COVID-19 pandemic, which has accelerated digital transformation and reshaped operational dynamics within the industry.

The COVID-19 pandemic has accelerated the digital transformation of insurance companies, turning it from a strategic choice to an essential requirement. Before the pandemic, the insurance industry lagged behind the banking sector in adopting digital technologies (Puschmann 2017; Stoeckli et al. 2018). Today, rapid changes are reshaping the insurance sector. Companies are adopting measures to become more customer-focused, improve their offerings, and boost efficiency (Pauch and Bera 2022).

Despite this growing importance, there is still a limited number of empirical studies analysing how digital transformation and technological change affect the efficiency of insurance companies across the European Union. Most previous research has focused on individual markets or on the period before the pandemic, leaving a research gap in understanding post-pandemic efficiency dynamics. Moreover, existing studies rarely compare different types of insurers (life, non-life, and composite) within a single analytical framework, which limits insights into how specialization influences performance.

This study therefore aims to fill this gap by providing an updated, EU-wide assessment of insurers' efficiency and productivity in the context of accelerating digital transformation. Specifically, it conducts a comparative efficiency analysis of 1,823 insurance companies operating in 27 EU countries over the period 2014–2023. By applying the Data Envelopment Analysis (DEA) and the Malmquist index, the study aims to capture both efficiency and productivity changes in the context of technological progress and digital transformation.

Based on the literature review and the identified research gap, this paper formulates two main hypotheses. First, technological change, accelerated by digital transformation, is expected to positively influence the efficiency of European insurers. Second, efficiency and productivity dynamics are assumed to differ across life, non-life, and composite insurers due to their distinct business models and risk structures.

Accordingly, the paper empirically examines whether the observed efficiency improvements in the European insurance market are driven primarily by technological progress or by better management of inputs and outputs. In line with these objectives, the paper assesses how efficiency and productivity evolved in the EU insurance market between 2014 and 2023. The Data Envelopment Analysis (DEA) and the Malmquist index are applied to evaluate insurance efficiency. In line with the aim of the paper, we stated the following research questions: *Is the increase in efficiency of European insurance companies driven by technological change? Does efficiency and productivity (as measured by the Malmquist index) differ across insurance specializations (life, non-life, and composite)?* These questions allow us to link technological development with

operational performance and to explore whether specialization shapes efficiency patterns in the European insurance industry.

The structure of the paper is as follows. The literature review in the second section highlights prior research and gaps addressed by this study. Section 3 presents the data and methodology; Section 4 discusses the results and efficiency trends across EU countries. The final section concludes with key findings, policy implications, and directions for future research.

2. Literature Review

2.1. Digitalization of the insurance industry

Digitalisation fundamentally transforms insurance markets, offering a variety of opportunities and challenges. Modern information technology (IT) solutions increase the efficiency of processes such as selling insurance policies, reporting insurance claims or financial reporting, leading to better customer service and significant operational streamlining (Novović-Burić and Stojanović 2022).

The authors Chojan et al. (2022) focused on efficiency and identified the importance of trends such as automation and point out that the automation of processes accelerates service delivery and reduces the number of manual errors, contributing to cost savings. The key benefits of digitalisation are accuracy, transparency, and timeliness in financial management. The possibilities of real-time data analysis and automated reporting support better planning and decision making in real time, as stated by Novović-Burić and Stojanović (2022). Digital platforms enable service personalization and strengthen customer relationships, while artificial intelligence enhances the user experience (Cappiello 2018; Chojan et al. 2022). Digital tools also increase the revenues of insurance intermediaries and support the growth of insurance contracts and the increase in written premiums (Köhne and Köhne 2024).

However, digitalisation brings risks. The main issues include IT outsourcing, system incompatibility, and growing concerns about data security, which can negatively impact customer trust (Chojan et al. 2022). Another risk lies in the potential loss of personal contact between insurance companies and clients, which could affect relationships and long-term loyalty, as noted by Cappiello (2018). Furthermore, digital stress is emerging among employees, which can hinder their performance if not properly managed (Köhne and Köhne 2024).

For full utilisation of the potential of digitalisation, strategic adaptation to market demands, proactive innovation, and effective problem solving are essential. Key priorities include a deep understanding of markets, technological development, product innovation, and the importance of cost management (Cappiello 2018).

Technological progress in insurance sector has led to increased efficiency through digital transformation, improving data collection and analysis, optimizing underwriting, and customer services (Ostagar 2018). The introduction of mobile and online platforms expanded the market, leading to higher gross written premiums (Nepochatenko et al. 2023; Grigorie and Tălăban 2024). Automation and advanced analytics optimized risk assessment and claim processing, improving the technical results of insurance accounts (Monkiewicz and Monkiewicz 2023). However, technology has also brought complex challenges, including

regulatory issues and adverse effects in some cases, indicating the need for careful adaptation by insurers (Grigorie and Tălăban 2024; Nepochatenko et al. 2023). Research by Cappiello (2020) highlights that technological development, such as Big Data and digital communication methods, significantly impacts the insurance value chain, increasing customer engagement and operational efficiency. The ongoing process of digitalization is crucial for traditional insurers to adapt and remain competitive in the rapidly changing, technology-driven market. InsurTech solutions enable better risk management and customer engagement, leading to higher efficiency and profitability for insurers.

2.2. Measurement of insurance efficiency

The efficiency of the insurance companies was measured in several studies, especially the Data Envelopment Analysis method was used. Although, Kaffash and Marra (2017) showed that US, Taiwan and China have the largest number of papers on the application of DEA in the insurance industry in case of geographical distribution of insurance group. Several studies evaluate the efficiency of insurance companies in European Union countries. These studies were mostly focused on the period covered the global financial crisis. E.g. Cummins and Rubio-Misas (2022) using the Data Envelopment Analysis evaluated 10 EU life insurance markets over the period 1998–2014 and found the convergence in cost/revenue technology gap among these markets, suggesting that industries become more technologically homogeneous during the 1998-2014. However, the global financial crisis has led to a slowdown in the progress of integration and convergence in efficiency and technology gap of EU life insurance markets in terms of cost efficiency but not in terms of revenue efficiency. Eling and Schaper (2017) applied DEA on a sample of 970 life insurance companies from 14 European countries. The authors found no technical change in the European life insurance sector, and they nonetheless observe an efficiency increase in 2002–2013 that leads to an increase in total factor productivity; these trends can be explained by more challenging business conditions in the 2000s.

Eling and Luhnen (2009) measured the efficiency of 6462 insurers from 36 countries considering life and non-life insurers. The authors found a steady technical and cost efficiency growth in international insurance markets from 2002 to 2006, with large differences across countries. From the European countries, Denmark has the highest average efficiency. Kasman and Turgutlu (2011) analyzed the cost efficiency in the European insurance market over the period 1995–2005. They found that all insurance systems display significant levels of cost inefficiency and their analyses suggest similar results for major EU countries, new members and the candidate.

Kaffash et al. (2020) provided a review of 132 data envelopment analysis studies in the insurance industry and supposed that the Malmquist index has been widely adopted in studies. The Malmquist index has its advantages when estimating the changes in the total factor of productivity. Moreover, Bertoni and Croce (2011) applied DEA and Malmquist index to a panel of 602 life insurance companies in five countries (Germany, France, Italy, Spain and U.K.) between 1997 and 2004. The authors found that efficiency increased that was mostly due to innovation in best-practices. Their results indicated that innovation of best-practices

was attributable to technological change and new technologies were more flexible. Nektarios and Barros (2010) applied the Malmquist index on the Greek insurance industry and found that the life sector experienced highest average annual productivity growth and the lowest growth was in the group of mixed insurance companies.

From the literature is visible that the studies about the insurance efficiency of the European Union countries in recent period are rare. Therefore, this paper can fill the existing knowledge gap.

3. Methodology and Data

The Data Envelopment Analysis is a widely used methodology to evaluate the performance/efficiency of different organizational systems. DEA is a nonparametric or mathematical programming technique used to evaluate the relative efficiencies of a set of decision-making units (Bruni et al. 2009). In this paper the decision-making units (DMUs) are commercial insurance companies. DEA measures the relative efficiency; the methodology consists in compares DMUs with a frontier of efficiency.

The DEA originated from the work of Charnes et al. (1978). The CCR (Charnes, Cooper and Rhodes) model assumes constant returns to scale (CRS) and evaluates overall technical efficiency without considering the scale of operations. This model posits that inputs and outputs increase proportionally. The CRS assumption is valid only when all DMUs function at optimal scales. However, in practice, DMUs may experience either economies or diseconomies of scale. Therefore, applying the CRS assumption incorrectly can distort technical efficiency measurements by incorporating scale efficiencies. Banker et al. (1984) advanced the CCR model by introducing variable returns to scale (VRS) with the BCC (Banker, Charnes and Cooper) model. The BCC model, which accounts for varying marginal benefits, is more appropriate for practical evaluations of insurance efficiency. Therefore, in this paper, the model with variable return to scale is used.

DEA initiates with a fractional programming framework. It is posited that there exist n DMUs for assessment. DMU_j utilizes x_{ij} quantities of input to generate y_{rj} quantities of output. It is presumed that inputs, x_{ij}, and outputs, y_{rj}, are non-negative, with each DMU possessing at least one positive input and output. The efficiency of a DMU can be expressed as

$$h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

In this equation, u and v denotes the weights for inputs and outputs. DEA employs mathematical programming techniques to optimally assigns the weights subject to the following constraints. The weights for each DMU are constrained to ensure no other DMU has efficiency greater than 1 if it uses the same weights, implying that efficient DMUs will have a ratio value of 1. The objective function of DMU is the ratio of the total weighted output divided by the total weighted input:

$$\max h0(u, v) = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1,\ j = 1, 2, \ldots, j0, \ldots, n,$$

$$u_r \geq 0, \qquad r = 1, 2, \ldots, s,$$

$$v_i \geq 0, \qquad i = 1, 2, \ldots, m,$$

where h_0 is the technical efficiency of DMU_0 to be estimated, u_r and v_i are weights to be optimized, y_{rj} is the observed amount of output of the r^{th} type for the j^{th} DMU, x_{ij} is the observed amount of input of the i^{th} type for the j^{th} DMU, r indicates the s different outputs, i denotes the m different inputs and j indicates the n different DMU_s.

Conditions of BCC model:

$$\max h_0 = \sum_{r=1}^{s} u_r y_{r0} + u_0,$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1,$$

$$\sum_{r=1}^{s} u_r y_{r0} - \sum_{i=1}^{m} v_i x_{i0} + u_0 \leq 0,$$

$$v_i \geq 0,\ u_r \geq 0, \qquad j = 1, 2, \ldots, n, \qquad i = 1, 2, \ldots, m, \qquad r = 1, 2, \ldots, s,$$

where index $_0$ shows DMU, which efficiency is estimated, x_s denotes inputs, y_s denotes outputs, v_s is value of efficiency of the DMU, n shows number of DMU, m in number of inputs, s is number of outputs, u_0 denotes return to scale.

In classical DEA literature, the Malmquist index (MI) and window analysis are the unique methods of DEA that can analyse the change in efficiency over the time (Sanchez, 2018). Window DEA extends the traditional DEA model by evaluating the performance of DMUs over multiple time periods or windows. This method is useful for tracking changes in efficiency over time. In this paper, the Malmquist index will be used because it can be divided into two parts: efficiency change and technological change. The Malmquist index measures the relative efficiency change of a DMU in multiple time period and is an example in comparative statistics analysis (Cooper et al. 2007). The Malmquist index was introduced by Caves et al. (1982) and developed further by Färe et al. (1992) and Färe et al. (1994). The index is usually applied to the measurement of efficiency change over time and can be multiplicatively decomposed into an efficiency change index and a technological change index (Shahverdi and Ebrahimnejad 2014). One of the primary advantages of Malmquist index is that it would not involve the producer's behavior optimization assumptions, and these units can be deficient (Khosravi et al. 2015). When $MI > 1$ the DMU has improvement

on productivity or efficiency and once $MI < 1$ the DMU experiences a decrease on efficiency (Khosravi et al. 2015).

Färe et al. (1994) use the DEA to construct an input-based MI between period t (the base period) and period s:

$$M_I(y^s,x^s,y^t,x^t) = \left[\frac{D_I^t(y^s,x^s)}{D_I^t(y^t,x^t)} * \frac{D_I^s(y^s,x^s)}{D_I^s(y^t,x^t)}\right]^{\frac{1}{2}},$$

where $M_I(\cdot)$ is the input-oriented MI, $D_I^t(y^s,x^s)$ is the distance function showing a maximal proportional reduction of the observed period s inputs under the period t technology. The distance function is defined as follows:

$$D_I^t(y^s,x^s) = \min_{\theta,\lambda} \theta,$$

subject to

$$y_{is} \leq \lambda Y^t,$$

$$\theta x_{is} \geq \lambda X^t,$$

$$\lambda_i \geq 0, i = 1, ..., n,$$

where θ is a scalar and λ is a vector of constants. The value of θ obtained is the component score of the i-th company. X and Y are input and output vectors, and the amounts of the i^{th} input consumed and output generated by the DMU_0, are denoted by x and y.

Assumption that $D_I^t(y^t,x^t)$ and $D_I^s(y^t,x^t)$ should equal to one, and allowing for technical inefficiency, Färe et al. (1992) decompose the Malmquist index into two components:

$$M_I = \left[\frac{D_I^t(y^s,x^s)}{D_I^t(y^t,x^t)} * \frac{D_I^s(y^s,x^s)}{D_I^s(y^t,x^t)}\right]^{\frac{1}{2}} = \frac{D_I^s(y^s,x^s)}{D_I^t(y^t,x^t)}\left[\frac{D_I^t(y^s,x^s)}{D_I^s(y^s,x^s)} * \frac{D_I^t(y^t,x^t)}{D_I^s(y^t,x^t)}\right]^{\frac{1}{2}}.$$

The first component $EC = \frac{D_I^s(y^s,x^s)}{D_I^t(y^t,x^t)}$ measures the change in technical efficiency (efficiency change, EC). The second component $TC = \left[\frac{D_I^t(y^s,x^s)}{D_I^s(y^s,x^s)} * \frac{D_I^t(y^t,x^t)}{D_I^s(y^t,x^t)}\right]^{\frac{1}{2}}$ measures the technology frontier shift (technological change, TC) between time period t and s. Färe et al. (1992, 1994) point out that a value of $TC > 1$ indicates a positive shift or technical progress, a value of $TC < 1$ indicates a negative shift or technical regress, and value of $TC = 1$ indicates no shift in technology frontier.

The data set utilized in this paper was obtained from the Moody's Analytics Orbis during the period 2014-2023. We consider insurance companies across 27 European Union member countries. All the data is reported on an unconsolidated basis. An unbalanced panel data was used with the sample of 1823 commercial insurance companies. Because DEA measures relative efficiency with respect to other entities in the sample, we distinguish between life, non-life and composite insurance companies. We covered the sample of 375 composite insurance companies, 464 life and 984 non-life insurance companies in 27 European Union countries during the period 2014-2023. All monetary variables were downloaded in euros, any currency conversion is performed within the Orbis database.

The data set included 27 European Union countries: Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE).

To conduct DEA-Malmquist analysis, the specification of inputs and outputs is essential. We used three inputs: total investment (TI), total underwriting expenses (TUE) and total gross insurance provisions (TGIP) and three outputs: gross premiums written (GPW), earned premiums (EP) and balance on combined technical account (BCTA). The input–output set follows common practice in DEA studies of insurers. Underwriting expenses and technical provisions are standard inputs reflecting operating effort and risk-bearing capacity, while investments proxy the financial capital deployed. On the output side, written and earned premiums capture production and realized insurance services; the combined technical account summarizes underwriting performance. Similar configurations are used across European samples and life/non-life settings (e.g., Eling and Schaper, 2017; Bertoni and Croce, 2011; Nektarios and Barros, 2010 or Kaffash et al., 2020).

The total investment indicates the foundational capital of the insurance company, highlighting financial management's impact on insurer efficiency. It also signifies the capital dedicated to traditional and digital operations that improve efficiency and customer satisfaction. Total underwriting expenses represent the costs linked to evaluating, pricing, and issuing insurance policies, playing a critical role in assessing operational efficiency and profitability. Effective management of these expenses is vital for maintaining competitive advantage, while digitalization can enhance underwriting efficiency and reduce costs. Gross insurance provisions, encompassing reserves for future claims, are essential inputs within the insurance sector. They signify the anticipated liabilities of the insurer, and their efficient management is key to ensuring solvency and financial stability.

Gross premiums written denote the total revenue accrued from sold insurance policies within a defined timeframe, reflecting the insurer's market appeal and demand for its offerings, which are vital for operational success. Earned premiums correspond to the premiums related to the insurance coverage provided during the period, serving as a direct indicator of the insurer's income generation relative to its risk exposure. The balance on the combined technical account illustrates the overall underwriting outcome after accounting for claims, reinsurance, and operational costs. This metric serves as a holistic assessment of the insurer's efficiency and profitability in managing underwriting and claims.

Table 1 Descriptive Statistics of input and output variables

	TI	TUE	TGIP	GPW	EP	BCTA
Mean	8142139	1113827	7356370	966851.8	975780.5	56403.69
Median	299159.9	68426.22	254237	78390	65222	2551
St.Dev.	42987761	5305604	38811823	4410806	4530230	1041280
Min	0.00001	-7.1E+07	-16395	-78171	-1780491	-2.9E+07
Max	9.73E+08	1.15E+08	9.05E+08	99852000	91337000	87128000

Source: Authors' calculations.

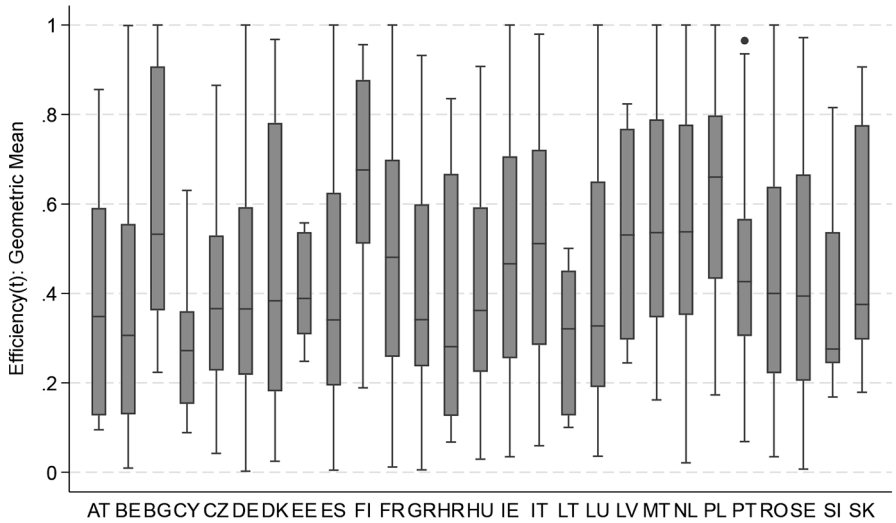
4. Research Results and Discussion

The empirical analysis of this study focuses on evaluating the efficiency of insurance companies in the European Union using Data Envelopment Analysis and the Malmquist index. We used the slack-based (non-oriented) measured model with variable return to scale.

Because DEA frontiers are sensitive to extremes, we used the super-efficiency analysis. An efficient DMU with a very high super-efficiency score is likely an outlier and we removed these outlier observations from our results.

In Figure 1 the results showed that there are significant differences in insurance efficiency between individual countries in 27 European Union countries. The EIOPA report (2024b) highlights significant differences in the level of technological development between EU countries in the insurance sector. Digitalization is still in its early stages, and progress varies by country. The adoption of new technologies such as artificial intelligence, blockchain, and the Internet of Things presents new opportunities for insurers, distributors, and consumers. The European Commission supports the digitalization of financial services and, in 2020, adopted the Digital Finance Package, which includes initiatives like the Data Act and the Digital Markets Act. EIOPA focuses on promoting the digital transformation of insurance and responds flexibly to rapid technological advances to minimize risks and harness the opportunities associated with digitalization. Moreover, Bayar et al. (2023) supported that internet penetration has a significant positive influence on insurance sector growth in 10 EU new EU member countries. This result can support the significant digitalization in insurance industry, in addition countries with higher ICT penetration tend to perform better in insurance development.

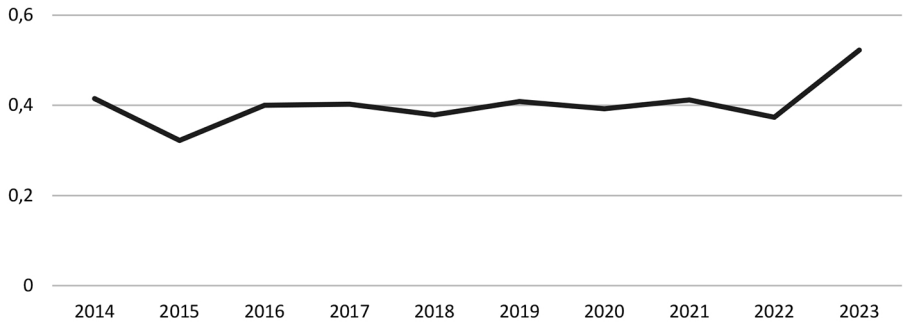
Figure 1. Box plot of insurance efficiency during the period 2014-2023 in EU countries



Source: Authors' calculations.

Technological advances in European insurance industry between 2014 and 2023 have led to slight improvements in efficiency, stability, and consumer protection. During the observed period, differences in efficiency development can be observed, which are related to technological progress (see Figure 2). The development of the insurance efficiency was almost stable during the analysed period, slight decrease was visible in year 2015 and 2021, but during the period 2022-2023 is visible increase in efficiency.

Figure 2. Insurance efficiency development in European Union during the period 2014-2023



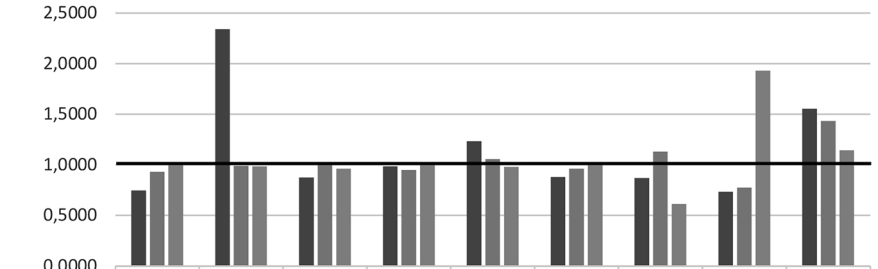
Source: Authors' calculations.

The 2014-2015 period, despite the absence of major technological breakthroughs, was crucial to the preparation of Solvency II. As noted by EIOPA (2024a), it involved the modernization of data infrastructures, the introduction of advanced risk management mechanisms and analytical tools. These preparatory steps improved transparency and efficiency, and their full impact became evident after 2016. In some countries, early experiments with cloud technologies emerged, laying the foundation for greater flexibility, more efficient data management, and cost reduction (Czech Statistical Office, 2024). Since 2010, the development of client service digitalization and the implementation of self-service portals have been observable. Digital technologies have begun to be used in all stages of insurance products, including design, distribution, and policy administration.

The EIOPA Annual Report (2016) highlights that the Solvency II regime, implemented in 2016, brought technological innovations and improved the efficiency of insurers. EIOPA provides significant assessments regarding the introduction of Solvency II in 2016. The implementation of Solvency II modernized capital requirements and risk management, supported digitalization, leveraged big data, and improved data transparency and quality. The regulatory framework allowed for better supervision, more efficient risk management, and operational processes. A major milestone was the acquisition of the first complete reporting data, which promoted innovation and adaptability of insurers to new challenges. EIOPA (2021b) launched its digital transformation in 2018, focusing on technological innovations in insurance supervision, known as SupTech. These initiatives led to process automation, more efficient use of data, and strengthened supervision mechanisms.

Since 2021, the graph shows a significant increase in efficiency within European insurance industry (Figure 3). It is evident that the COVID-19 pandemic (EIOPA, 2020) accelerated insurance digitalization, including online product distribution and digitalization of client services. EIOPA had to respond to this development with a series of gradual steps in the following years. It was necessary to address the advancement of technologies and the growing technological/cyber risks. In 2021, (2021a) introduced its digital strategy, which included the development of a data ecosystem, support for artificial intelligence, ensuring financial stability, a unified market, and enhanced supervisory capabilities. In the same year, the SupTech strategy was published, emphasizing the use of technology to improve supervision and enable the early identification of risks. In 2022, the Digital Operational Resilience Act (DORA 2022) was adopted, establishing a unified framework for financial institutions' resilience to cyber threats. Strengthening IT infrastructures, improving cybersecurity, and improving insurer operational resilience. Regular financial stability reports from the European Central Bank and EIOPA (2014-2023) highlighted the crucial role of technological innovations in the stability of the financial sector and provided valuable input for policy making. These measures improved the ability to meet customer needs and increased operational efficiency. In 2023, EIOPA (2023) updated its digital strategy for the 2024-2026 period, promoting transformation in consumer services, markets, and supervision.

Figure 3. Efficiency change of insurers in European Union



	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Life	0,7480	2,3403	0,8738	0,9849	1,2343	0,8799	0,8694	0,7349	1,5533
Non-life	0,9303	0,9892	1,0064	0,9487	1,0563	0,9621	1,1323	0,7741	1,4344
Composite	1,0163	0,9859	0,9619	1,0139	0,9803	1,0174	0,6147	1,9309	1,1450

Source: Authors' calculations.

We calculated the average Malmquist index and its decompositions of the commercial insurance companies in 27 EU countries during the period 2014-2023, We measured the efficiency for life insurers, non-life insurers and composite insurers.

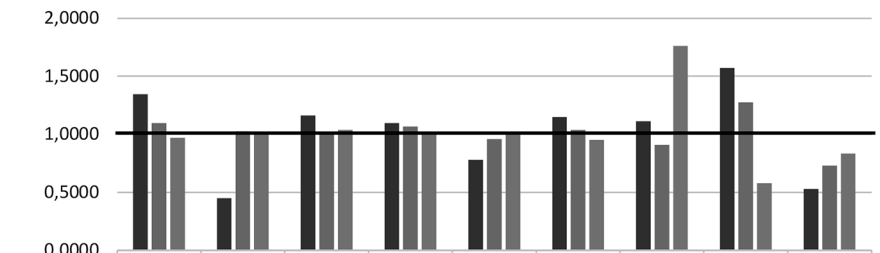
The Malmquist index (Figure 5) is higher than one during whole analysed period in non-life insurance companies. It indicates that non-life insurers in EU countries increased productivity and efficiency in these periods. In case of composite insurers, the Malmquist index is higher than one in most of periods (except the 2015-2016 and 2019-2020). The life insurance companies did not reach the value higher than one in most of periods. Over 2014–2023, the non-life segment shows a Malmquist index above 1 on average, it indicates the productivity growth, whereas the life segment records Malmquist index lower than 1 in most period. At the same time, life insurers display higher technical efficiency levels than non-life, which may be reflected in lower Malmquist index values. The Malmquist index equals catch-up (efficiency change) times frontier shift (technical change). Higher technical efficiency score in life means life insurers are close to the frontier within each year. Malmquist lower that 1 indicates that the frontier itself moved inward for life (technical change < 1) or that catch-up did not offset that inward shift. In non-life, positive technical change and/or faster catch-up pushed Malmquist higher than 1. The ability to balance efficiency and technological change remains a key success factor, with investment in innovation and process improvement playing a critical role.

If we consider the possible economic consequences in the given period, then during the period 2014–2019 it could be probably caused by fact that prolonged low rates and legacy guarantees in life increased reserving and capital intensity (it means larger inputs), depressing technical change; non-life benefited from pricing/claims digitalization and cost control (frontier shift outward). During the COVID-19 period 2020-2021 it could lead to the temporary declines in claim frequencies in key non-life lines (e.g., motor, travel) improved

productivity; life faced disruptions in distribution and investment re-pricing, keeping total factor productivity subdued. Moreover, higher inflation and rates during 2022-2023 could probably support new business economics in life but revaluation of liabilities/portfolios and distribution costs kept technical change muted. Non-life absorbed inflation via repricing and operational gains, sustaining positive frontier movement.

When we consider the efficiency change (Figure 3) and technological change (Figure 4), we found that the efficiency increased due to the better management of inputs and outputs and efficiency improvements during the years 2018-2019 and 2022-2023. In the years 2017-2018 and 2019-2022, the strong technological progress was the main factor of efficiency increasing. During the period 2018-2019 the decline in MI (especially life insurance) indicate a period of stagnation, where technological change declined and efficiency. The increased in 2020-2021 could be caused likely due to adaptation to pandemic challenges and the introduction of technological innovation. However, decrease in MI in 2022-2023 may indicate an inability to sustain previous improvements in efficiency and technological progress.

Figure 4. Technological change of insurers in European Union

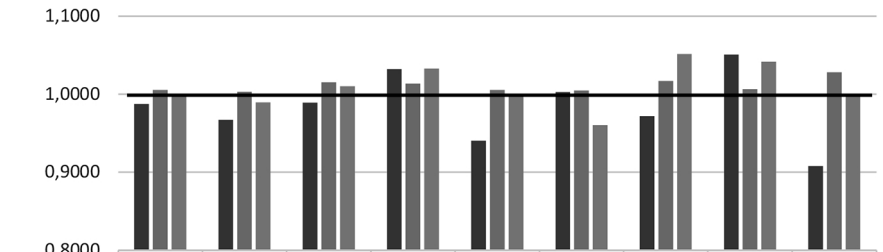


	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Life	1,3441	0,4494	1,1620	1,0961	0,7785	1,1473	1,1112	1,5708	0,5273
Non-life	1,0953	1,0233	1,0031	1,0671	0,9570	1,0368	0,9090	1,2748	0,7294
Composite	0,9702	1,0017	1,0367	1,0193	1,0147	0,9508	1,7610	0,5788	0,8348

Source: Authors' calculations.

The development of EC and TC differs during individual periods. Over 2014–2023, non-life insurers show slight efficiency (MI) growth (geometric mean MI = 1.0075), whereas life insurers are broadly flat to slightly negative (MI = 0.9938). The gap is driven mainly by technical change, the non-life frontier shifts outward on average (TC = 1.016), while the life frontier contracts in several key sub-periods (TC ≈ 0.997). Within-year efficiency (catch-up) is broadly similar across segments (EC around 1).

Figure 5. Malmquist index of insurers in European Union



	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Life	0,9875	0,9671	0,9893	1,0321	0,9403	1,0027	0,9717	1,0508	0,9079
Non-life	1,0053	1,0029	1,0153	1,0134	1,0053	1,0048	1,0168	1,0063	1,0279
Composite	1,0000	0,9894	1,0100	1,0328	1,0000	0,9605	1,0515	1,0417	1,0000

Source: Authors' calculations.

In 2015-2016 in case of life insurance there is significant increase in efficiency change but decrease in technological change, that influence also final Malmquist index. It can show that companies are rapidly catching up, while the frontier is reducing. Change during 2019-2020 and 2021-2022 the technological change in life and non-life insurance increased.

In case of life insurance, the higher level of technical efficiency, but MI often below 1, as the frontier shifted inward in several key years (TC < 1 during the years 2015-2016, 2018-2019, 2022-2023). This is consistent with pressures from guarantees, re-pricing of liabilities, and capital/interest intensity when rates change. In case of non-life insurance, we can see more stable TC ≥ 1 overall and episodes of strong efficiency change (2020-2021, 2022-2023), giving MI slightly above 1. In line with faster repricing capabilities, digitization of claims, and cost management. In composite insurance segment there is visible the mix of effects. We see technological change shocks (1.761 in 2020-2021; 0.579 in 2021-2022) and EC fluctuations. Geometric mean of Malmquist index around 1.005 shows slight growth in efficiency.

Table 2 presents the average efficiency and Malmquist index in individual insurance markets. We can see the differences between individual countries. The Malmquist index is higher than one in the most of insurance market. Therefore, in most countries, the overall productivity and efficiency of insurance companies was increasing during analysed period. This growth is the result of a combination of technological progress and changes in efficiency. However, the Malmquist index was less than 1 in Austria, Bulgaria, Germany, Denmark, Ireland, Latvia and Portugal, indicating a decrease in overall productivity/efficiency. This result may be due to either weak technological progress (Bulgaria, Denmark and Ireland), insufficient efficiency improvements (Portugal) or a combination of both factors (in case of Latvia).

The technological change is greater than 1 in only 10 countries (Austria, Finland, France, Greece, Croatia, Italy, Lithuania, Poland, Portugal and Sweden), indicating that there were technological advances in these countries that contributed to increased productivity/efficiency. These countries are likely to have invested in innovation, digitisation and process modernisation. In the other countries, technological progress has slowed down or stagnated. This may indicate limited investment in new technologies or inefficient implementation. Weak technological progress, therefore, means that insurers do not adopt or use new technologies. Therefore, low technological change in several countries suggests that efficiency depends more on efficiency, better management of inputs and outputs than on technological innovation.

Table 2. The average efficiency, Malmquist index, Technological change and efficiency change during the period 2014-2023

Country	Efficiency	Efficiency Change	Technological Change	Malmquist Index
AT	0.4035	0.9614	1.0386	0.9923
BE	0.3700	1.0631	0.9782	1.0060
BG	0.5972	1.0858	0.8591	0.9300
CY	0.2978	1.1511	0.9658	1.0509
CZ	0.3838	1.1376	0.9643	1.0508
DE	0.4143	1.0674	0.9680	0.9932
DK	0.4615	1.0661	0.9744	0.9988
EE	0.3986	1.1456	0.9440	1.0157
ES	0.4150	1.1018	0.9543	1.0036
FI	0.6611	1.0071	1.0174	1.0234
FR	0.4901	1.0039	1.0195	1.0104
GR	0.4027	1.0365	1.0448	1.0291
HR	0.3589	1.0834	1.0039	1.0725
HU	0.3942	1.1461	0.9112	1.0013
IE	0.4958	1.0448	0.9863	0.9885
IT	0.5101	1.0041	1.0098	1.0050
LT	0.3131	0.9989	1.0128	1.0073
LU	0.4085	1.1612	0.9363	1.0177
LV	0.5323	0.9784	0.9715	0.9441
MT	0.5662	1.0148	0.9973	1.0120
NL	0.5505	1.0640	0.9906	1.0185

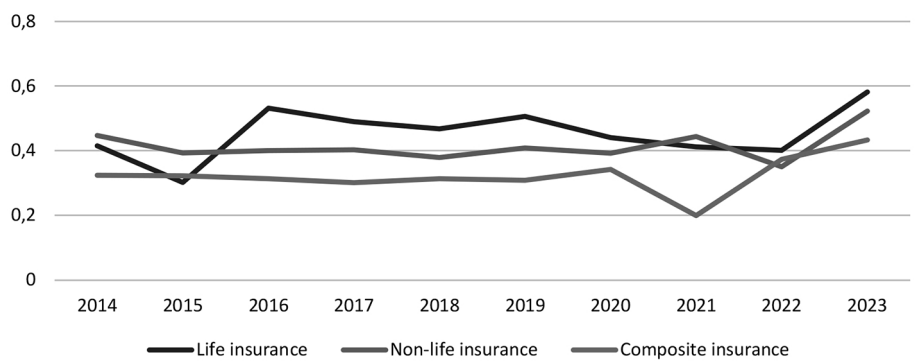
PL	0.6151	1.0065	1.0127	1.0187
PT	0.4498	0.9820	1.0220	0.9979
RO	0.4302	1.0981	0.9688	1.0324
SE	0.4361	1.0365	1.0202	1.0520
SI	0.3864	1.0511	0.9803	1.0289
SK	0.4969	1.0584	0.9944	1.0540

Source: Authors' calculations.

In summarize, the results show that overall productivity is positive in most countries, which means that insurance companies in these countries indicate growth in efficiency. However, the low technological change values in most countries suggest that growth is more dependent on efficiency improvements than on technological innovation. Moreover, DEA measures relative performance against the best observed peers in the sample. Countries with many small, specialized insurers can span the frontier, whereas large, diversified German insurers carry higher technical provisions, compliance and distribution costs, and more complex product mixes that increase measured inputs. Accordingly, for example, lower German efficiency does not imply inferior management, but rather reflects a different scale and business mix under a pooled technology.

Figure 6 showed that the life insurers were the highest efficient during the period 2016-2020 and 2022-2023, but the efficiency of life insurers slightly decreased in 2020-2022. On the other hand, the composite insurers were less efficient than the life and non-life insurers and the efficiency slightly decreased in 2021. The efficiency of non-life insurers was stable during the analysed period with slight increase in 2021 and 2023. significantly increased in 2023. We measured the efficiency of insurance companies using Malmquist index and its decomposition into efficiency and technology change.

Figure 6. Efficiency of insurance companies in EU according to the specialization



Source: Authors' calculations.

Our finding confirmed the previous studies, e.g. Witkowska (2023) concluded that the slight decline in efficiency from 2021 to 2023 could be attributed to challenges in adapting to digital transformation and maintaining cost efficiency amidst evolving consumer expectations. Moreover, non-life insurers saw a significant increase in efficiency in 2023, likely driven by technological innovations and improved risk management practices (Kumar and Kumar 2024). The ability to quickly adapt to market changes and leverage data analytics for better underwriting and claims processing has contributed to their enhanced performance (Witkowska 2023).

5. Conclusions

The paper analysed the efficiency of the commercial insurance companies in 27 European Union countries during the period 2014-2023. We applied the Data Envelopment Analysis and Malmquist index and its decomposition for empirical analysis.

The results show the significant differences in insurance efficiency across the 27 countries of the European Union. The Malmquist index highlights fluctuations in productivity within the EU insurance sector, with increases in 2016-2018 and 2021-2022, indicating successful adaptation and innovation. Conversely, there were decreases in periods such as 2018-2019 and 2022-2023 (especially in life insurance), pointing to challenges such as stagnating efficiency and slowing technological progress. Investment in innovation and process improvements plays a key role. Overall, the results show positive productivity trends in most countries, indicating that insurance companies are becoming more efficient. However, the low values of technological change in many countries suggest that this growth is more dependent on efficiency improvements than on technological innovation.

Considering the specialisation of insurance companies, life insurers were the most efficient, although their efficiency decreased slightly between 2021 and 2022. In contrast, non-life insurers experienced a slight increase in efficiency in 2021 and 2023. For insurance companies, technological change was the main driver of efficiency improvements in most of the analysed period. While better management of inputs and outputs was the main driver in 2022-2023, with technological change playing a less important role.

When we consider our research questions: *Is the increase in efficiency of European insurance companies driven by technological change?* The increase in efficiency of European insurance companies is not primarily driven by technological change. The finding indicates that while there are periods of significant technological advancements, the overall growth in efficiency is more dependent on improvements in efficiency rather than technological innovation.

Does efficiency and productivity (as measured by the Malmquist index) differ across insurance specializations (life, non-life, and composite)? There is a difference in efficiency and the Malmquist index based on the insurers' specialization. Life insurers were found to be the most efficient, although their efficiency significantly declined during 2021-2022. Moreover, technological change was more significant for non-life insurers, while efficiency improvements in life and composite insurance companies were mainly due to better management of inputs and outputs.

There are several limitations of this research. We consider the life, non-life and composite insurance companies. We used the static DEA model and Malmquist index to allow us to use an unbalanced panel and not have to remove insurers that did not work throughout the analysis period. But dynamic methods can better capture changes in efficiency. We can deeply focus on the specific inputs and outputs of the individual specialization of insurers. Moreover, since we have estimated the relative efficiency of commercial insurers in the context of other insurance companies within the sample, it is crucial to interpret the results cautiously and in light of the specific context in which they were analysed. Significant differences exist in the structure of EU economies, including factors such as the size of the economy, the productive orientation of various industries, and the overall economic environment. These structural disparities may influence the efficiency of insurance companies and should be carefully considered when drawing conclusions from the results.

The research pointed that it is very important topic and in the empirical literature is gap in this issue. Moreover, in the future research it is necessary to focus on the determinants of the insurance efficiency. We will use the two-stage DEA model, namely Bootstrap analysis to analyse the influence of the macroeconomic and insurance specific factors.

References

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

Bayar, Y.; Danuletiu, D. C.; Danuletiu, A. E.; Gavriletea, M. D. (2023) ICT penetration and insurance sector development: Evidence from the 10 new EU member states. *Electronics*, 12(4), 823. https://doi.org/10.3390/electronics12040823

Bertoni, F.; Croce, A. (2011) The productivity of European life insurers: Best-practice adoption vs. innovation. *Geneva Papers on Risk and Insurance – Issues and Practice*, 36(1), 165-185. https://doi.org/10.1057/gpp.2011.1

Bruni, M.; Conforti, D.; Beraldi, P.; Tundis, E. (2009) Probabilistically constrained models for efficiency and dominance in DEA. *International Journal of Production Economics*, 117(2), 219-228. https://doi.org/10.1016/j.ijpe.2008.10.011

Cappiello, A. (2018) Technology and insurance. In Cappiello, A.; Winter, R. (eds) *Technology and the Insurance Industry: Re-configuring the Competitive Landscape*. Cham, Palgrave Pivot, pp. 1-21.

Cappiello, A. (2020) The technological disruption of insurance industry: A review. *International Journal of Business and Social Science*, 11(1), 1-11. https://doi.org/10.30845/ijbss.v11n1p1

Caves, D. W.; Christensen, L. R.; Diewert, W. E. (1982) The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica*, 50(6), 1393-1414.

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/10.1057/palgrave.jors.2600342

Chojan, A.; Lisowski, J.; Manikowski, P. (2022) Digitalization trends in insurance and their impact on the functioning of the insurance market entities. *Wiadomości Ubezpieczeniowe*, 1(1), 1-15. https://doi.org/10.33995/wu2022.1.1

Cooper, W. W.; Seiford, L. M.; Tone, K. (2007) *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Vol. 2. New York, Springer.

Cummins, J. D.; Rubio-Misas, M. (2022) Integration and convergence in efficiency and technology of European life insurance markets. *Annals of Operations Research*, 315(1), 93-119. https://doi.org/10.1007/s10479-022-04672-w

Časta, M.; Hodula, M.; Janků, J.; Kučera, A. (2021) *What factors influence the development of the insurance sector in Europe?* Czech National Bank Blog. Available at: https://www.cnb.cz/en/about_cnb/cnblog/What-factors-influence-the-development-of-the-insurance-sector-in-Europe/

Czech Statistical Office (2024) *Digitalizace v Česku a v zemích EU*. Available at: https://csu.gov.cz/docs/107508/28fd05d2-4323-ccbc-5611-dcf8352ce994/06202624.pdf

European Union (2022) *Regulation (EU) 2022/2554 of the European Parliament and of the Council of 14 December 2022 on digital operational resilience for the financial sector (DORA)*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R2554

EIOPA (2016) *Annual report 2016*. Available at: https://www.eiopa.europa.eu/document/download/ea8c7ee6-ffeb-4b75-ae81-72d2a99e66d5_en?filename=EIOPA%20Annual%20Report%202016.pdf

EIOPA (2020) *Annual report 2020*. Available at: https://www.eiopa.europa.eu/publications/annual-report-2020_en

EIOPA (2021a) *EIOPA sets out a forward looking digital transformation strategy*. Available at: https://www.eiopa.europa.eu/eiopa-sets-out-forward-looking-digital-transformation-strategy-2021-12-10_en

EIOPA (2021b) *Suptech strategy*. Available at: https://www.eiopa.europa.eu/publications/suptech-strategy_en

EIOPA (2023) *EIOPA's digital strategy – support consumers, markets and the supervisory community through digital transformation*. Available at: https://www.eiopa.europa.eu/system/files/2023-10/EIOPA%20Digital%20Strategy.pdf

EIOPA (2024a) *Solvency II*. Available at: https://www.eiopa.europa.eu/browse/regulation-and-policy/solvency-ii_en

EIOPA (2024b) *The trend towards the increasing digitalisation of the insurance sector*. Available at: https://www.eiopa.europa.eu/publications/trend-towards-increasing-digitalisation-insurance-sector_en

Eling, M.; Luhnen, M. (2009) 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.; 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

Färe, R.; Grosskopf, S.; Lindgren, B.; Roos, P. (1992) Productivity change in Swedish pharmacies 1980–1989: A nonparametric Malmquist approach. *Journal of Productivity Analysis*, 3(1-2), 85-102. https://doi.org/10.1007/BF00158770

Färe, R.; Grosskopf, S.; Norris, M.; Zhang, A. (1994) Productivity growth, technical progress, and efficiency change in industrial countries. *American Economic Review*, 84(1), 66-83. https://www.jstor.org/stable/2117971

Grigorie, E. I.; Tălăban, C. D. (2024) How advanced technologies shape the insurance market: Statistical insights at the European Union level. In *Proceedings of the International Conference on Business Excellence*, 18(1), 2766-2775. https://doi.org/10.2478/picbe-2024-0230

Kaffash, S.; Azizi, R.; Huang, Y.; Zhu, J. (2020) A survey of data envelopment analysis applications in the insurance industry 1993–2018. *European Journal of Operational Research*, 284(3), 801-813. https://doi.org/10.1016/j.ejor.2019.07.034

Kaffash, S.; Marra, M. (2017) Data envelopment analysis in financial services: A citations network analysis of banks, insurance companies and money market funds. *Annals of Operations Research*, 253(1-2), 307-344. https://doi.org/10.1007/s10479-016-2294-1

Kasman, A.; Turgutlu, E. (2011) Performance of European insurance firms in the single insurance market. *International Review of Applied Economics*, 25(3), 363-378. https://doi.org/10.1080/02692171.2010.483470

Khosravi, A.; Najafi, S.; Rafiei, S. (2015) Productivity measurement using DEA and Malmquist index. *Management Science Letters*, 5(7), 663-668. https://doi.org/10.5267/j.msl.2015.5.007

Köhne, T.; Köhne, M. (2024) Uncovering the impact of digitalization on the performance of insurance distribution. *Risks*, 12(8), 129. https://doi.org/10.3390/risks12080129

Kumar, K. S. D.; Kumar, J. P. S. (2024) Efficiency assessment and trends in the insurance industry: A bibliometric analysis of DEA application. *Insurance Markets and Companies*, 15(1), 83-98. https://doi.org/10.21511/ins.15(1).2024.07

Monkiewicz, J.; Monkiewicz, M. (2023) Digitalisation of insurance: New values, new challenges. In Gąsiorkiewicz, L.; Monkiewicz, J. (eds) *The Digital Revolution in Banking, Insurance and Capital Markets*. London, Routledge, pp. 131-143.

Nektarios, M.; Barros, C. A. (2010) Malmquist index for the Greek insurance industry. *Geneva Papers on Risk and Insurance – Issues and Practice*, 35(2), 309-324. https://doi.org/10.1057/gpp.2010.2

Nepochatenko, O.; Bechko, P.; Ponomarenko, O. (2023) The transformation of the insurance market under the influence of financial digital technologies. *International Science Journal of Management, Economics & Finance*, 2(2), 48-55. https://doi.org/10.46299/j.isjmef.20230202.06

Novović-Burić, M.; Jakšić-Stojanović, A. (2022) Digitalization of the operations of insurance companies with special reference to the financial reporting of insurers in Montenegro. In Karabegović, I. (ed.) *New Technologies, Development and Applications V*. Cham, Springer International Publishing, pp. 1003-1010. https://doi.org/10.1007/978-3-031-07481-7_116

Ostagar, A. M. (2018) Impact of technology and innovation in insurance sector. *International Journal of Management, IT and Engineering*, 8(12), 253-258. (DOI not available)

Pauch, D.; Bera, A. (2022) Digitization in the insurance sector – challenges in the face of the Covid-19 pandemic. *Procedia Computer Science*, 207, 1677-1684. https://doi.org/10.1016/j.procs.2022.09.225

Puschmann, T. (2017) Fintech. *Business and Information Systems Engineering*, 59(1), 69-76. https://doi.org/10.1007/s12599-017-0464-6

Shahverdi, R.; Ebrahimnejad, A. (2014) DEA and Malmquist productivity indices for measuring group performance in two periods. *International Journal of Industrial and Systems Engineering*, 16(3), 382-395. https://doi.org/10.1504/IJISE.2014.060135

Sanchez, J. J. V. (2018) Malmquist index with time series to data envelopment analysis. In *Multi-Criteria Methods and Techniques Applied to Supply Chain Management*. London, IntechOpen, pp. [specific pages not available]. https://doi.org/10.5772/intechopen.74571

Stoeckli, E.; Dremel, C.; Uebernickel, F. (2018) Exploring characteristics and transformational capabilities of insurtech innovations to understand insurance value creation in a digital world. *Electronic Markets*, 28(3), 287-305. https://doi.org/10.1007/s12525-018-0304-7

Witkowska, J. (2023) The life and non-life insurance market in the European Union. *Olsztyn Economic Journal*, 18(2), 157-170. https://doi.org/10.31648/oej.10290