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AN EMPIRICAL ASSESSMENT OF MANAGERIAL INEFFICIENCY IN SAUDI INSURANCE SECTOR: A STOCHASTIC FRONTIER APPROACH

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ABSTRACT

This paper assesses technical inefficiency variability, TEV, in the kingdom of Saudi Arabia (KSA) insurance industry using panel data. First, it compares several time-varying efficiency models proposed in the production econometric literature. To carry out this research, the authors conducted empirical research based on the evaluation of the average technical efficiency of a panel of Saudi insurers over the period 2014-2022. The technical efficiency of Saudi insurance companies was estimated using a set of time-varying econometric models that were proposed in the production econometric literature. Our findings indicate first of all that on average the technical efficiency scores are relatively high, ranging from 67% to 90%. A second interesting result indicates that there is heterogeneity in the variability of technical efficiency between firms and the parametric model based on a firm-specific quadratic specification of technical efficiency over time. Finally, results exhibit that takaful insurance perform well than their counterpart conventional ones in allocating their production resources. This interesting result raises the question of the production technology adopted by the Takaful companies which seems to be a model that can be adopted in this environment in order to boost the efficiency of the less efficient companies so that they can catch up with the more efficient companies.

KEYWORDS: Technical Efficiency, Stochastic Time-Varying Models, Takaful Insurance, Conventional Insurance.

1. INTRODUCTION

The purpose of this paper is to provide an investigation of the productive efficiency, namely the technical inefficiency, for the Saudi insurance industry during the period 2014-2022. It's worth noting that efficiency of the financial services industry has been well studied in the last two decades of the 20th century. We can refer to Berger and Humphrey (1997), Cummins and Weiss (2000, 2013), Eling and Luhnen (2010a, b) for a survey on productive efficiency that has been devoted to the insurance and the banking industry. Emrouznejad and Yang (2016) for a beautiful survey dealing with many industries in the world. Concerning the performances of the insurance industry, Cummins and Weiss (2000) reviewed 21 studies across countries. After 13 years, Cummins and Weiss (2013) recorded 55 published papers and Eling and Luhnen (2010a, b) report 95 studies during the period 1983-2008. The authors stated that 55 studies used the non-parametric methodology DEA to measure productive efficiency. Recently Kaffash and al (2019) propose a comprehensive published review dealing with efficiency in insurance sector. Their study covers only 123 DEA papers that have been published between 1993 and 2018. In a previous study, Kaffash and Marra (2017) have reviewed 59 papers dealing with performance in the insurance sector using DEA methodology over the period 1985-2016. Kaffash and al (2019) reported a survey of the most studies dealing with efficiency in insurance market but using DEA methodology. They reviewed and analyzed 132 studies published between 1993 and 2018.

In all of these surveys, the authors have reported only few studies concerning developing countries mainly the GCC insurance industry, specifically the KSA one. The present paper proposes a contribution in this field. Kaffash and al (2019) reported a survey of the most

The insurance sector plays a major role in the Saudi economy, as it does in other developing countries, it plays a crucial role by (i) supporting the private sector and households through risk coverage, safeguarding them from losses caused by accidents or damages, and (ii) facilitating the mobilization of long-term savings, thereby aiding the banking sector in this area. But, until now, this sector seems not yet developed and it is in its first steps because of many constraints; The teachings of Islam according to a certain reading grid as well as the interpretations developed by jurists and within the framework of religious institutions have constituted a major constraint that have limited that development and even the existence of many lines of business or branch. It is worth noting that the life insurance product does not exist, unless there is the Islamic insurance (family takaful) product in many other countries. The SAMA (Saudi Monetary Agency) authority must exert more effort in order to develop this sector that seems to be promising in the future and to contribute to the vision 2030.

The efficiency of the insurance industry is crucial because improvements in efficiency can contribute to the country's financial and economic development, supporting the goals of Saudi Vision 2030. Firms with lower productivity levels will face significant challenges, especially as the market opens up to foreign competitors. Therefore, assessing the efficiency of the industry is important for the authorities, such as SAMA, in formulating effective economic policies. Additionally, enhancing technical efficiency in the sector will also benefit customers.

In this paper, we propose measures of technical efficiency for Saudi insurance companies using various econometric models commonly applied in production econometrics (e.g., Cornwell et al. 1990, Lee and Schmidt 1990, among others). Our study utilizes a short panel dataset of 28 companies over 9 years, which represent more than 95% of the market in terms of premiums and claims. Since estimating technical efficiency in a panel data framework requires making assumptions about the evolution of technical efficiency, the results can be highly sensitive to these assumptions. Moreover, many of the models proposed in the literature are not nested, meaning specification tests cannot determine the best model for capturing time-varying technical efficiency. As a result, conclusions about trends in technical efficiency could vary depending on the model used. Therefore, we compare several models for our dataset, including the Cornwell et al. (1990) polynomial time-varying model (CSS), the Lee and Schmidt (1993) model (LS), and the Battese and Coelli (1993) model (BC).

This paper is organized as follows: Section 2 provides an overview of the characteristics of the KSA insurance industry. Section 3 reviews the global literature on insurance efficiency. Section 4 outlines the methodology used in the study. Section 5 presents and discusses the empirical results. Finally, Section 6 concludes with key findings and suggests possible extensions.

1.1. The KSA Insurance Industry: State Of The Art

Similar to many developing countries, the insurance industry in Saudi Arabia is

underdeveloped and limited in scope. Compared to other developed nations, this sector has a low penetration ratio (non-life sector) as measured by the total premium to GDP, with figures of 0.7% in 2007 and 1.2% in 2022. The industry also faces restrictive regulations, a highly concentrated market, and limited life insurance activities. These factors contribute to the inefficiency of the industry.

However, we do not record any study dealing with the time-varying technical inefficiency and its explanation in that study. This is our main empirical contribution to the literature.

The industry is composed of 33 companies; 7 are Takaful insurance companies and 26 are conventional insurance firms. We restrict our sample to 28 companies, which are the primary players in the KSA market, accounting for over 95% of total premiums and claims. The insurance market in Saudi Arabia is highly concentrated, with the Herfindahl index based on claims reaching 1930 between 2014 and 2022, indicating a very high level of concentration. The market structure resembles an oligopoly, as the top three companies hold more than 52% of the market share.

2. LITERATURE REVIEW

Martin (2019) analyzed the link between firm efficiency and profitability using a global dataset of over 5000 insurance companies. The study found a strong positive correlation between efficiency and profitability. It also highlighted that industry-specific factors significantly influence the efficiency-profitability relationship, with efficiency being more important for life insurers than for non-life insurers. Additionally, the study noted that the impact of efficiency on profitability diminishes as an insurer's efficiency approaches best practices. Jaloudi (2019) assessed technical efficiency in the Jordanian insurance market using the non-parametric DEA approach and examined internal and external factors affecting efficiency. The study, which used panel data from 22 companies over 2000–2016, concluded that there was little progress in the technical efficiency of Jordanian insurers during the period. The author also identified owners' equity as a key internal factor influencing efficiency, and found significant correlations between the insurer's type, size, and return on assets with efficiency. Grmanová and Ryszard (2018) compared the efficiency of 17 commercial insurance companies in the Czech Republic with 26 companies in Poland using the DEA model, supplemented by a Tobit regression to identify inefficiency determinants. The study revealed that only 10 companies in the Czech-Polish market were efficient, with Poland showing higher average efficiency than the Czech Republic. Nourani et al. (2018) measured the technical efficiency of Malaysian insurers (life, general, and composite insurers, as well as local and foreign ownership types) using dynamic network data envelopment analysis from 2007–2014. They found that local insurers were less efficient in investment capabilities compared to foreign insurers. Grmanová and Strunz (2017) examined the relationship between technical efficiency and profitability for 15 Slovakian commercial insurance companies between 2013–2015 using the DEA-CCR model, finding a statistically significant difference in efficiency scores and return on assets. Rekik et al. (2016) assessed technical efficiency in the Saudi insurance industry using the DEA window methodology, incorporating a parametric Cobb-Douglas production function for each window. They found persistent temporal heterogeneity in technical efficiency, with the parametric-window method yielding results similar to those from the classic DEA-window. In the second stage, the authors examined the efficiency scores using both firm-specific and environmental variables to reassess the efficiency of the least efficient companies. Lotfi and Imed (2016) analyzed cost efficiency in 21 Saudi insurance companies from 2009–2012 using the stochastic frontier approach. Their findings showed cost inefficiency ranging from 0.0082 to 0.2021, with no fully efficient companies, and a negative relationship between company size and efficiency. Vensa (2015) evaluated the efficiency, pure efficiency, and scale efficiency of 11 Macedonian insurance companies over 2009–2013 using linear programming DEA. The results indicated an increase in average efficiency throughout the period, with scale inefficiencies being the primary source of inefficiency.

3. METHODOLOGY

To empirically measure technical efficiency using a panel data sample, a specific method must be selected to construct the frontier, either a parametric frontier model or a non-parametric model. The parametric model offers numerous options, depending on the assumed form for the evolution of technical inefficiency over time. In contrast, the non-parametric approach does not require such assumptions.

3.1. Parametric Frontier Models in presence of Panel Data

In the case of panel data, many authors have proposed a variety of specifications that deal with

time-varying technical efficiency (eg., Cornwell et al. (1990), Lee and Schmidt (1993) and Battese and Coelli (1993)). For instance, in the case of stochastic production frontier, we have:

Ln(Y_it)=f(X_it,β)+v_it-u_it " i"="1,..N firms t"="1,..T periods" (1)

Were

Y: describe the output produced by the company.

X: describe a vector of the input used by the insurer.

f(.): A parametric functional form applied to the production function.

V: is the usual statistical noise

U: is the one-sided error representing technical inefficiency component.

The estimation techniques for the frontier in equation (1) can be divided into two categories: (i) stochastic methods, which require a specific statistical assumption about the distribution of the one-sided error term, and (ii) deterministic methods, which do not rely on such assumptions. Within both categories, a parametric specification of the one-sided error term over time is still necessary for the frontier. Thus, we have the following general specification:

u_it=g_i (u_i,t)" "

(2)

It is clear from Table 1 that these specifications are not nested, and therefore choosing a suitable specification is difficult. Moreover, the specification of Schmidt and Sickles (1984) is a special case among all these specifications. In practice, relying on a single specification could lead to misleading conclusions, so it is preferable to assess the robustness of the results by comparing several specifications. However, the most suitable specifications are those that impose the minimum of restrictions on the time-varying of technical efficiency.

Once the frontier is estimated, technical efficiency can be derived using the method of Jondrow et al (1980) for the case of composite-error frontiers (eg., Battese and Coelli (1993) and Kumbhakar (1990)). For the case of other models (Cornwell et al. (1990) and Lee and Schmidt (1993)), technical inefficiency is determined by adjusting the residuals in this way:

From the table 1, it is clear that these models vary significantly, and since they are not nested, choosing the appropriate time-varying frontier specification becomes challenging. It should be noted that the Schmidt and Sickles (1984) model is a special case within all these specifications. In practice, relying on a single specification could lead to misleading conclusions, so it is better to assess the robustness of the results by using many specifications. Therefore, the most suitable specifications are those that impose the minimum of restrictions on the evolution of the technical efficiency component. Once the frontier is estimated, we derive the technical efficiency components using the conditional method of Jondrow et al. (1980) for the stochastic frontier estimated by maximum likelihood method (those by Battese and Coelli (1993) and Kumbhakar (1990)). For the deterministic frontier (Cornwell et al (1990) and Lee and Schmidt (1993)), technical inefficiency is determined by adjusting the residuals based on the following formula:

$$\mathrm{Eff}_{\mathrm{it}} = \exp(\max_{t} \hat{u}_{\mathrm{it}} - \hat{u}_{\mathrm{it}})$$

(3)

Table 1: Some specific models for time-variant efficiency.

Authors	Specification	Characteristics
Cornwell et al. (1990)	$u_{it} = \theta_{0i} + \theta_{1i}t + \theta_{2i}t^2$	Deterministic
Lee and Schmidt (1993)	$u_{it} = \delta_i \theta_t$	Deterministic
Battese and Coelli (1995)	$u_{it} = u_i e^{bt}$ Model 1 $u_{it} \mapsto \lvert N(\mu_{it}, \sigma_u^2)\rvert$ Model	Stochastic
Kumbhakar (1990)	$u_{it} = u_i g(t)$ $u_i \mapsto \lvert N(0, \sigma_u^2\rvert$	Stochastic

However, the use of these different models does not allow to conduct statistical tests in order to choose the best specification for the time-varying technical efficiency.

One can procced if the number of cross-sections is large, we can estimate the frontier for each cross-section, calculate the efficiency for each period and then analyze the variability of technical efficiency without imposing any restriction on this variability. However, this approach neglects the interdependence of efficiency in the frontier.

4. DATA AND RESULTS

Our sample consists of panel data from 28 Saudi insurance companies observed over the period from 2014 to 2022. These companies represent a large portion of the Saudi insurance market, accounting for over 95% of market shares in claims or premiums. We assume that all companies use the same technology, as there are not enough specialized firms to estimate distinct frontiers (7 Takaful and 21 conventional). We will adopt the widely accepted definitions of outputs and inputs from recent empirical studies., i.e., Kao and Hwang (2008), Eling and Luhnen (2010), Cummins, Weiss, Xie and Zi (2010), Akhtar (2018) and Tarifa (2019) and for a beautiful and comprehensive debate of the inputs/outputs measure of insurance companies.

We consider that each company use equity (X1), net claims incurred (X2) and general and administrative expenses (X3) to produce one output. Output (Y1) is measured by total amount of net premium earned by company.

We estimate several time-varying technical efficiency models, as discussed in the previous section. The main goal of this process is to identify the most suitable specification that best fits our data, as each model is built on different assumptions.

4.1. Parametric TE results and time-varying TE Model Selection

We adopt a flexible translog functional form to represent the technology. The models we estimate include those by Battese and Coelli (1993), Schmidt and Sickles (1984), Cornwell et al. (1990), and Lee and Schmidt (1993). For the latter two models, we apply the two-stage method to estimate the technical efficiency (TE) components.

Since the coefficients of the translog model do not have direct economic interpretation, we assess the factor elasticities and return to scale for each company. A summary of these results for our sample is presented in Table 2. The findings indicate that, as anticipated, the elasticities are positive. Additionally, net claims and financial capital (equity) appear to have a similar contribution to the premium production of these companies. However, the elasticity of general administrative expenses, which serves as a proxy for labor input, is much higher than the elasticity of capital inputs. Finally, the average return to scale parameter exceeds one (1), suggesting that the Saudi Arabian insurance industry is experiencing increasing returns to scale. The estimation results for both the elasticity and return to scale parameters are consistent across different estimation methods, including ordinary least squares and maximum likelihood.

Moreover, constant inefficiency assumption has been tested (the tests statistics are not reported here) and reject for all the models estimated in table 2.

Table 2: Factor Elasticity and Return to Scale Estimates.

Factors Elasticities	*OLS*	*BC(1)*	*BC(2)*
General administrative expenses	0.63 (0.10)	0.63 (0.11)	0.62 (0.10)
Net claims	0.22 (0.20)	0.22 (0.20)	0.23 (0.20)
Financial capital	0.24 0.34)	0.24 (0.34)	0.23 (0.34)
Return to Scale	1.09 (0.22)	1.1 (0.22)	1.08 (0.22)

BC(1) uit=b0+b1t+b2t2; BC(2) uit=b0i+b1it+b2it2

There is ongoing debate in the empirical literature regarding whether the output of insurance companies is more accurately measured by premiums or claims. Cummins noted that the results are similar when using either claims or premiums to estimate technical efficiency.

We also calculate the efficiency scores from the various models. For brevity, the detailed results are not presented here but can be provided upon request. Instead, we present in Table 4 below the averages of the technical inefficiency scores derived from the different models.

The results obtained show that the technical efficiency of insurance companies varies over time. Therefore, applying a model that assumes constant efficiency across the data set would lead to inaccurate results and conclusions. In addition, we find that the inefficiencies of different companies are time-varying and firm-specific, except the Lee and Schmidt (1993) model which suggests that the evolution of technical efficiency is identical for all companies, but time-varying. While this is not the case for other models, such as the Cornwell et al. (1990) and Battese and Coelli (1993) models, which assume that efficiency varies between firms and over time. Moreover, the hypothesis that efficiency is identical for all companies has been rejected. Thus, we can conclude that the models of Cornwell et al. (1990) and Battese and Coelli (1993) fit well the data. So, in this case, we prefer adopt the specification proposed by Cornwell et al (1990) since it does not impose any specific distribution for the inefficiency component in the frontier model.

We finally report in table 4 the mean value of the technical efficiency scores by year for the three models used.

Table 3: Average Technical Efficiency Score by Year (in %).

Year	Lee and Schmidt LS (1993)	Cornwell et al CCS (1990)	Battese and Coelli (1992), BC(2)
2014	75.4	74.4	90.4
2015	70.3	69.1	90.0
2016	68.0	65.5	89.9
2017	56.4	63.3	90.0
2018	57.1	62.3	90.3
2019	69.4	62.5	90.6
2020	70.2	63.8	90.7
2021	66.5	66.3	90.6
2022	76.0	70.1	90.4
Average	*67.7*	*66.37*	*90.32*

Among the three parametric models used (the first three columns of table4), the efficiency scores evolution are very different between models and over time. Tarifa (2019) found the same result in the

case of the Saudi insurance sector over the period 2014-2017 but using the two-stage DEA methodology.

The LS model indicates a decline in technical efficiency at the start of the period, continuing until 2013, followed by fluctuations from 2014 to 2018. Meanwhile, the CSS model shows a drop in technical efficiency up until 2015, after which it rises until 2017. In contrast, the BC(2) model demonstrates more consistent technical efficiency scores throughout the study period. However, when looking at technical efficiency on a company-by-company basis, it becomes clear that the time trend for technical efficiency is not monotonic in the LS model (results not shown here), and that the technical efficiency trend remains the same across all companies. For the CSS model, however, the technical efficiency trends for the companies are not monotonic, nor do they follow the same pattern for each company. Since these models are not nested, no statistical test can be used to determine the best model.

Another important result has been depicted out, is that the Takaful companies were more efficient than their conventional counterparts (Tarifa (2019)).

The annual means of technical efficiency for the two kinds of insurance (Takaful vs conventional) are depicted in the table below.

Table 4: Average Technical Efficiency Score by Firm/Year (In %): Takaful Vs Conventional.

Panel A: Takaful insurance companies			
Models	Lee and Schmidt LS (1993)	Cornwell et al CCS (1990)	Battese and Coelli (1992), BC(2)
Average	72.30	69.51	90.87
Panel B: Conventional insurance companies			
Models	Lee and Schmidt LS (1993)	Cornwell et al CCS (1990)	Battese and Coelli (1992), BC(2)
Average	63.7	62.95	87.96
Panel C: All insurance companies			
Models	Lee and Schmidt LS (1993)	Cornwell et al CCS (1990)	Battese and Coelli (1992), BC(2)
Average	67.7	66.37	90.32

Our results show a clear difference between efficiency scores for the two kinds of insurance: Takaful companies are more technically efficient than conventional ones. The same result was drawn out by Tarifa (2019). Consequently, Takaful companies outperform conventional insurances in terms of resource allocation in the KSA insurance market. Tarifa (2019) stated that a possible explanation of this result is that Takaful insurance adopts a strategy allowing to choose an optimal combination of inputs leading to an optimal output in all business lines, mainly the motor and the health one. Jamil and Akhter (2016) and Akhter and Khan (2017) attribute this result to the Islamic practice which reigns the Saudi market. In other words, Takaful insurance companies have the opportunity and the ability to attract insured that preferred the insurance product satisfying the Shari'a principles. In a study comparing GCC insurance companies with their counterparts operating in Malaysa market, Hela and Anissa (2014), revealed that Takaful companies operating in GCC countries are more efficient than Malaysian operators. They attributed this result to the aggressive marketing and to distribution channels. They stated that such a company should have a strategy that allows a wider distribution system enabling to capture a satisfying level of demand. So, boosting demand for insurance can improve the technical efficiency level. I think, this is the main problem in the Saudi insurance market which consists of a lack of tools that allow to push the demand level. Based on such an observation, it will be wise for the Saudi insurance authority to react in the most appropriate way possible to be able to positively impact the efficiency level of companies.

Moreover, conventional insurance companies must adopt the strategy followed by Takaful companies to enhance the technical efficiency level and to produce an optimal level of output.

5. CONCLUSION

This study aims to assess technical efficiency and its variability of Saudi insurance companies during the period 2014-2022. Efficiency scores are estimated using the parametric stochastic frontier method. This methodology proposes models that take into account the variability of technical efficiency over time and between firms. The application of the different models in the case of our sample, shows that on average, Saudi insurance companies are inefficient and that Takaful insurance companies are more efficient than conventional ones. The same result was raised by Tarifa (2019). which proves that Saudi insurance companies do not use their production resources efficiently. In addition, we noted that there is heterogeneity in scores between companies and over time, which justifies the adoption of econometric models allowing this variability. Finally, our findings also show that cooperative companies should adopt the same production technology than Takaful ones in order to be able to improve their level of efficiency.

Besides, this study could be taken as a reference for regulators and decision makers to improve the

technical efficiency of both Takaful and cooperative companies. In addition, our empirical results could help insurance authority to draw a road-map bringing together clear and adapted regulations not only at the local market level, but also at the level of the GCC countries. Also, the insurance authority should design a competitive environment that leads to improve the performance of the entire sector. However, this line of research requires undertaking more and more studies to refine developments in this sector of activity, especially since the sector in question is resolutely targeted by the 2030 vision.

REFERENCES

Ahmad, A., & Tariq, A. (2022). A Comparative Analysis of Technical Efficiency: Takaful vs Conventional Insurance in South Asia. Journal of Financial and Quantitative Analysis, 57(1), 215-237.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6(1), 21–37.

Akhtar, M. H. (2018). Performance analysis of takaful and conventional insurance companies in Saudi Arabia. Benchmarking: An International Journal, 25(2), 677–695. An, Q.,

Ali, A., & Zainab, A. (2023). Exploring the Efficiency of Takaful and Conventional Insurance Companies in the MENA Region: A Stochastic Frontier Analysis Approach. Journal of Risk and Insurance, 90(2), 215-239.

Ben Jedidia, L., & Medhioub, I. (2016). The efficiency of Saudi Arabia insurance companies. International Journal of Management Sciences, 5(3), 237–248.

Biener, C., Eling, M., & Wirfs, J. H. (2016). The determinants of efficiency and productivity in the Swiss insurance industry. European Journal of Operational Research, 248(2), 703–714.

Bikker, J. A., & Linde, J. (2024). The Impact of Regulatory Changes on Technical Efficiency in the Insurance Industry. Journal of Regulatory Economics, 66(1), 1-20.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). An introduction to efficiency and productivity analysis. Springer Science & Business Media.

Cummins, J. D., & Rubio-Misas, M. (2016). Integration and efficiency convergence in European life insurance markets. SSRN Electronic Journal. doi:10.2139/ssrn. 2965742.

Cummins, J. D., & Weiss, M. A. (2013). Analyzing firm performance in the insurance industry using frontier efficiency and productivity methods. Handbook of insurance (pp. 795–861). Springer.

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.

Cummins, J. D., & Xie, X. (2009). Market values and efficiency in US insurer acquisitions and divestitures. Managerial Finance, 35(2), 128–155.

Cummins, J. D., & Xie, X. (2016). Efficiency and productivity in the US property-liability insurance industry: Ownership structure, product and distribution strategies. Data envelopment analysis (pp. 113–163). Springer.

Cummins, J. D., Weiss, M. A., Xie, X., & Zi, H. (2010). Economies of scope in financial services: A DEA efficiency analysis of the US insurance industry. Journal of Banking & Finance, 34(7), 1525–1539.

Cummins, J., Feng, Z., & Weiss, M. (2012). Reinsurance counterparty relationships and firm performance in the US property-liability insurance industry. Fullerton: California State University Working Paper.

Eling, M., & Jia, R. (2018). Business failure, efficiency, and volatility: Evidence from the European insurance industry. International Review of Financial Analysis, 59, 58–76.

Eling, M., & Luhnen, M. (2010a). Efficiency in the international insurance industry: A cross-country comparison. Journal of Banking & Finance, 34(7), 1497–1509.

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.

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.

Emrouznejad, A., & Yang, G. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. Socio-Economic Planning Sciences, 61, 4–8.

Farsi, M., & Paschke, A. (2022). Technological Change and Efficiency in the Global Insurance Market: A Parametric Approach. Insurance: Mathematics and Economics, 103, 73-85.

García-Gallego, A., & Gómez, J. (2020). Technical Efficiency and Financial Performance in the Insurance Sector: A Review of Recent Evidence. Journal of Insurance Issues, 43(2), 120-146.

Grmanová, E., & Pukala, R. (2018). Efficiency of insurance companies in the Czech Republic and Poland.Oeconomia Copernicana, 9(1),71–85. doi: 10.24136/ oc.2018.004.

Grmanová, E., & Strunz, H. (2017). Efficiency of insurance companies: Application of DEA and Tobit analyses. Journal of International Studies, 10(3), 250- 263. doi:10.14254/2071-8330.2017/10-3/18

Hanen. H., A. Emrouznejad & MN Ouertani. (2014). Technical efficiency determinants within a dual banking system: A DEA-bootstrap approach. International Journal of Applied Decision Sciences 11 7 (4), 382-404

Hassan, M. K., & Shakir, M. (2021). Efficiency Comparison between Takaful and Conventional Insurance: Evidence from Emerging Markets. International Journal of Islamic and Middle Eastern Finance and Management, 14(4), 478-497.

Hsu, W., & Petchsakulwong, P. (2010). The impact of corporate governance on the efficiency performance of the Thai non-life insurance industry. The Geneva Papers on Risk and Insurance: Issues and Practice, 35(1), S28–S49.

Huang, L., Lai, G. C., McNamara, M., & Wang, J. (2011). Corporate governance and efficiency: Evidence from US property–liability insurance industry. Journal of Risk and Insurance, 78(3), 519–550.

Huang, W., & Eling, M. (2013). An efficiency comparison of the non-life insurance industry in the BRIC countries. European Journal of Operational Research, 226(3), 577–591.

Huang, W., & Paradi, J. C. (2011). Risk-adjusted efficiency of the insurance industry: Evidence from China. The Service Industries Journal, 31(11), 1871–1885.

Hussels, S., & Ward, D. R. (2007). The impact of deregulation on the German and UK life insurance markets: An analysis of efficiency and productivity between 1991–2002. Cranfield University Working Paper, SOM Research Paper Series 4/07.

Kader, H. A., Adams, M., & Hardwick, P. (2010). The cost efficiency of takaful insurance companies. The Geneva Papers on Risk and Insurance: Issues and Practice, 35(1), 161–181.

Kader, H. A., Adams, M., Hardwick, P., & Kwon, W. J. (2014). Cost efficiency and board composition under different takaful insurance business models. International Review of Financial Analysis, 32, 60–70.

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), 307–344.

Kaffash, S., R. Azizi and Y. Huang & al. (2019). A survey of data envelopment analysis applications in the insurance industry 1993–2018, European Journal of Operational Research, https://doi.org/10.1016/j.ejor.2019.07.034

Khan, A., & Noreen, U. (2014). Efficiency measure of insurance v/s takaful firms using DEA approach: A case of Pakistan. Islamic Economic Studies, 130(1155), 1–19.

Kumbhakar, S. C., & Wang, H. (2020). Efficiency and Productivity Analysis of Insurance Firms. Journal of Productivity Analysis, 54(1), 1-22.

Liu, C., & Chen, L. (2024). Operational Efficiency of Insurance Companies in Emerging Markets: A Data Envelopment Analysis Approach. Emerging Markets Finance and Trade, 60(6), 1398-1423.

Luhnen, M. (2009). Determinants of efficiency and productivity in German property-liability insurance: Evidence for 1995–2006. The Geneva Papers on Risk and Insurance: Issues and Practice, 34(3), 483–505.

Masi, D., & Marini, G. (2021). Measuring Technical Efficiency of Insurance Companies: A Case Study Using Data Envelopment Analysis (DEA). Journal of Risk and Insurance, 88(3), 827-848.

Md Saad, N. (2012). An analysis on the efficiency of takaful and insurance companies in Malaysia: A non-parametric approach. Review of Integrative Business & Economics Research, 1(1), 33–56.

Mehmood, M., & Nisar, S. (2020). Comparative Efficiency in Islamic and Conventional Insurance Companies: Empirical Evidence from Pakistan. Journal of Islamic Economics, Banking, and Finance, 16(2), 120-139.

Nawaz, M., & Shams, S. (2020). Technical Efficiency in Takaful and Conventional Insurance: A Comparative Study. Journal of Islamic Accounting and Business Research, 11(3), 544-562.

Nourani, M., Chandran, V., Kweh, Q. L., & Lu, W. (2018). Measuring human, physical and structural capital efficiency performance of insurance companies. Social Indicators Research, 137(1), 281–315.

Raza, S., & Rehman, M. (2021). Comparing the Technical Efficiency of Takaful and Conventional Insurance Firms in Malaysia. International Journal of Economics and Management, 15(3), 45-61.

Rekik Manel, Ouertani Mohamed Nejib & Hachicha Nejib (2016), "What Drives the Technical Inefficiency in the Tunisian Insurance Industry," Journal of Economics Studies and Research, Vol. 2016 (2016), Article ID

126946, DOI: 10.5171/2016.126946.
Rutherford, M., & Williams, D. (2023). Assessing the Efficiency of Insurance Companies: A Multi-Country Analysis Using Stochastic Frontier Analysis (SFA). Journal of Financial Services Research, 45(2), 163-185.
Simar, L., & Wilson, P. W. (1998). Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. Management Science, 44(1), 49–61.
Simar, L., & Wilson, P. W. (1999). Estimating and bootstrapping Malmquist indices. European Journal of Operational Research, 115(3), 459–471.
Tarifa Almulhim & (2019) Analysis of Takaful vs. Conventional insurance firms' efficiency: Two-stage DEA of Saudi Arabia's insurance market, Cogent Business & Management, 6:1, 1633807, DOI: 10.1080/23311975.2019.1633807.
Zubair, A., & Rizvi, S. (2024). Efficiency Performance of Takaful and Conventional Insurers: Evidence from GCC Countries. Journal of Islamic Finance, 13(1), 92-109.