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RESEARCH ARTICLE

Data Envelopment Analysis to Study Efficiency and Productivity Change of Public and Private General Insurance Sector

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ABSTRACT

This study aims to analyze and compare the efficiency and productivity changes of India's public and private non-life insurance companies from 2015 to 2022. The study will use Data Envelopment Analysis (DEA) to examine the technical, pure technical, and scale efficiencies of both sectors and Malmquist Index methods to explore the Total Factor Productivity (TFP) changes of the general insurance companies. The analysis data shows that the private general insurance sector is making more effort Than the Public Sector, and private companies or more efficient than the public Sector. Based on the analysis of the data provided, the study will provide a useful reference for policy makers and industry stakeholders interested in improving the insurance sector's Performance in India. The study is expected to contribute to the existing literature on insurance efficiency and productivity by providing a comparative analysis of the public and private sector non-life insurance companies in India. The study's results will provide valuable insightsintothePerformanceofthepublicandprivateSectornon-lifeinsurancecompanies in India. Itwillhelpidentifythefactorsthatcontributetotheirefficiencyandproductivity. Originality the data indicates that all four companies, ICICI, Bajaj, United, and Oriental, have shown varying levels of efficiency in the insurance sector from2015-2022.Overall, the data provides a glimpse into the efficiency and productivity of the fournon-life insurance companies in India, based on the DEA and Malmquist Index methods.

Keywords: Data Envelopment Analysis (DEA), Total Factor Productivity (TFP),Malmqui

INTRODUCTION

The insurance industry plays a significant role in economic development; (Ug- wuanyim, 2021). Any sector, for that matter, needs a lot of strategies and plans to establish its considerable impact on society. This paper aims to discuss or identify the factors which influence the Performance of general insurance in private and public Sectors. On-life insurance in India plays a very significant role in mitigating risk for many industrial sectors. In the non-life insurance business, India is ranked 14th in the world, which is an improvement of one rank compared to last year. The country also holds a 0.77% share of the global non-life insurance market. During 2020, the non-life insurance premium in India decreased by 1.3%, while the global non-life insurance premium increased by 2.8%. This highlights an efficiency and productivity gap in the general insurance industry(S, 2021). The general insurance industry recorded a total direct premium of 1.99 crores in India for 2020-21 against 1.89 crores in 2019-20 (ANNUAL REPORTS OF THE AUTHORITY, no date). There is a growth rate of 5.19%, but compared to last year, it was 11.49, so evidently proving that there is d-growth in 2020-21 over the previous year from the Public Sector, but in the private Sector, there is a tremendous growth rate of 8.1% registered. And if we see the penetration and density of general insurance compared to life insurance, penetration is 1% compared to 3.20 in life insurance. As well as, if we see the thickness of general insurance is 19% compared to 59% of life insurance (Mahapatra, 2017), although general insurance is mandatory in India, there has been a notable decline in both its penetration and density. This indicates a weakness in the development of the general insurance industry.

Additionally, when comparing the Performance of public and private insurers, the private insurers seem to be doing better. It's worth noting that private insurers have only recently been granted permission to operate. (Silver and Com, 2020) The study will use Data Envelopment Analysis (DEA) (Mandal and Dastidar, 2014; Zhao *et al.*, 2021)to examine the technical, pure technical, and scale efficiencies of both sectors and Malmquist Index methods to explore the Total Factor Productivity (TFP) change of the general insurance companies. Overall, the data provides a glimpse into the efficiency and productivity of the four non-life insurance companies in India, based on the DEA and Malmquist Index methods (Lovell, 2003; Barros *et al.*, 2005; Chakraborty, 2018). The study results will provide valuable insights into the Performance of the public and private Sector non-life insurance companies in India and will help identify the factors that contribute to their efficiency and productivity. Additionally, the study will provide a valuable reference for policymakers and industry stakeholders interested in improving India's insurance sector's performance. The study is expected to contribute to the existing literature on insurance efficiency and productivity by providing a comparative analysis of India's public and private Sector non-life insurance companies.

REVIEW LITERATURE

This study is a novel and groundbreaking comparison of the efficiency and productivity changes of India's public and private non-life insurance companies. We are not aware of any previous research that has examined this particular aspect of the industry. The findings of this study will address an essential gap in the literature, providing valuable Insights into the Performance of India's public and private non-life insurance sectors. These results will be of great significance to policymakers and industry stakeholders- ers, as they will offer guidance on ways to improve the efficiency and productivity of the insurance sector in India. This research represents a significant advance in our comprehension of the Performance of the insurance industry in India. It will be a crucial reference point for future studies in this area. Following will be the summary of research related to the studies DEA: Data Envelopment Analysis (DEA) model measures how well an organization utilises its available resources to produce output. In the insurance sector, technical efficiency can be calculated for an insurance company by using the DEA model to compare the company's actual work to the potential output that could be achieved if the company was operating at its maximum efficiency. (Oppong *et al.*, 2019; Li *et al.*, 2020; Lim *et al.*, 2021).

In a CRS model, the inputs and outputs of a DMU are assumed to be related by a fixed constant so that the relationship between inputs and outputs remains the same, regardless of the scale of production. This means that as the DMU increases its production levels, the ratio of inputs to outputs will remain constant. (Chakraborty, 2016;

Benyoussef and Hemrit, 2019; Pervan *et al.*, 2021). In contrast, a VRS model allows for the possibility that the relationship between inputs and outputs may change as the scale of production changes. This means that the ratio of inputs to outputs may not be constant and may vary depending on the production level. (Luhnen, 2009)(Luhnen, 2009)

The Malmquist index is a productivity measure used in Data Envelopment Analysis (DEA) to assess changes in the efficiency of a set of decision-making units (DMUs) over time (Lovell, 2003; Chakraborty, 2018). The index is calculated based on two periods, and it captures changes in both the technological frontier and shifts in the Efficiency of individual DMUs over time (Cummins and Weiss, 2013; Cummins and Xie, 2016)

Technical Change: Technical change captures the change in the distance between the DMUs and the efficient frontier due to improvements in technology or other external factors. It reflects the shift in the efficient frontier over time and is calculated by Comparing the distance of DMUs to the efficient frontier between the two periods. (; Ndlovu, 2021a) (Cummins and Weiss, 2013; Biener *et al.*, 2016; Cummins and Xie, 2016; Chakraborty, 2016,?; Ilyas and Rajasekaran, 2020).

Pure Technical Efficiency Change: Pure technical efficiency change measures the change in the relative Efficiency of the DMUs in the same technology environment. It captures the change in the Efficiency of each DMU independent of changes in the production technology. It is calculated by dividing the distance to the efficient frontier of the second period by the product of the distance to the frontier of the first period and the technical change.

Scale Efficiency: Scale efficiency change reflects the change in the optimal scale of production. It captures the efficiency change resulting from changes in the scale of operations, which may lead to economies or diseconomies of scale. It is calculated by dividing the ratio of the distance to the efficient frontier between the two periods by the technical change. (Barros, Barroso and Borges, 2005; Luhnen, 2009; Chakraborty, 2018; Ilyas and Rajasekaran, 2019; Ndlovu, 2021).

OBJECTIVE OF THE STUDY

I. TO EXAMINE AND COMPARE THE TECHNICAL EFFICIENCY, PURE TECHNICAL EFFICIENCY AND SCALE EFFICIENCIES OF THE PUBLIC and PRIVATE SECTOR OF GENERAL INSURANCE COMPANIES IN INDIA FOR THE PERIOD FROM 2015-2022

II. TO EXAMINE THE TFP (TOTAL FACTOR PRODUCTIVITY) CHANGES OF THE GENERAL INSURANCE COMPANIES

HYPOTHESIS OF THE STUDY

1. H_0 = No significant difference in efficiency between public and private.
2. H_{01} = There is no significant change. In between the total factor of productivity among public and private general insurance companies

METHODOLOGY AND DATA

Data and Methodology Research Tools

The non-parametric Data Envelopment Analysis (DEA) model was employed to determine the relative efficiency scores of both the public and private non-life insurance firms in India. The output-oriented DEA approach was adopted in this study, using an input-output framework. In addition, the Malmquist index was utilized as an extension to the DEA model to evaluate the productivity changes of the public sector non-life insurers during the study period. (Brockett, 2007; Sinha, 2015; Yu, 2021; Zhao *et al.*, 2021) the value-based approach of data envelopment analysis (DEA) is used in common in that risk pooling and bearing (to decide on input and output) refer to the ways in which risk is managed and shared among the decision-making units (DMUs) being analyzed(; J. Chakraborty, 2016, 2018) (Cummins and Weiss, 2013; Cummins and Xie, 2016; Chakraborty, 2016)

DATA SOURCES

The data used in this study was obtained from the IRDA Annual Reports spanning the period of 2015-2022 and was further supplemented by the annual reports of individual companies for each respective year. In order to conduct the TFP (Total Factor Productivity) analysis, two private and two public general insurance companies were selected as the sample for this study. Summary of Input-Output Variables Used Table 2.

RESULTS AND DISCUSSION

Efficiency Analysis of the Sample Firms

The data utilized in this study comprises a correlation matrix, which quantifies the degree of linear association between various variables. The values in this matrix range from -1 to 1 and indicate the strength of the relationship between the variables. A value of 1 represents a perfect positive relationship, while a value of -1 indicates a perfect negative relationship. A value of 0 signifies no correlation between the variables. From the matrix, we can see that there is a strong positive relationship between Operating Expenses and Net Premiums (0.85), as well as between Investments and Income from Investments (0.98). There is a moderate positive relationship between Operating Expenses and Investments (0.82) and between Net Premiums and Income from Investments (0.86). In conclusion, the data suggest that there is a strong association between Operating Expenses and Net Premiums, as well as between Investments and Income from Investments. However, the association between Operating Expenses and Investments and Net Premiums and Income from Investments is moderate. Table 3 The data provided is a descriptive statistics table for multiple variables for different years. The variables are Operating Expenses, Investments, Net Premiums, and Income from Investments. The statistics provided are mean, standard deviation (SD), minimum, and maximum.

Descriptive Statistics of inputs and Outputs variables. Note: Figures are in Rs000

we can see that the mean value of Operating Expenses has increased over the years, while the standard deviation has remained relatively stable. The mean value of Investments has also increased over the years, while the standard deviation has been more volatile. The mean value of Net Premiums has also increased over the years, while the standard deviation has remained relatively stable. The mean value of Income from Investments has increased over the years, while the standard deviation has been more volatile. In conclusion, the data shows that the mean values of all variables have increased over the years, indicating growth in the respective areas. The standard deviation of Investments and Income from Investments has been more volatile than the other variables, indicating a higher degree of variability in these areas.

Table 5 displays the technical efficiency scores of four non-life insurance companies (ICICI, Bajaj, United, and Oriental) for the period 2015-16 to 2021-22. The technical efficiency score measures how efficiently a company uses its inputs to produce outputs. A score of 1 indicates that the company uses its inputs to the maximum possible extent to produce outputs. In contrast, a score less than 1 indicates that the company has room for improvement in terms of efficiency. The scores in the table are calculated using the Constant Return to Scale (CCR) output orientation approach. This approach assumes that a company's inputs and outputs are linearly related and that an increase in inputs leads to proportional outputs. In this approach, the focus is on the outputs produced by the company and how efficiently the inputs are being used to produce those outputs. The table also shows the number of efficient and inefficient DMUs A DMU is considered efficient if its technical efficiency score is equal to 1, meaning that it uses its inputs to the maximum possible extent to produce outputs. A DMU is considered inefficient if its score is less than 1, indicating that it has room for improvement in terms of efficiency.

Here's an interpretation of the data:

- Based on the technical efficiency scores, ICICI has an average score of 0.96494437 over the period from 2015-16 to 2021-22, indicating that the company has been using its inputs efficiently to produce outputs. However, there have been some fluctuations in its efficiency score over the years.

- Bajaj has an average technical efficiency score of 0.969744741, which is higher than ICICI's score, indicating that Bajaj has been consistently efficient in using its inputs to produce outputs over the entire period.
- United has an average technical efficiency score of 0.932797841, which is lower than the scores of ICICI and Bajaj. This indicates that United has not been as efficient in using its inputs to produce outputs as the other two companies. However, it has improved its efficiency score over the years.
- Oriental has an average technical efficiency score of 0.943754351, which is higher than United's score but lower than the scores of ICICI and Bajaj. This indicates that Oriental has been relatively efficient in using its inputs to produce outputs but still has room for improvement.
- The table also shows that there have been fluctuations in the number of efficient and inefficient DMUs over the years. At different times, there have been two to three efficient DMUs, while there have been one to four inefficient DMUs.

Overall, the data suggest that Bajaj has been the most efficient of the four companies in using its inputs to produce outputs over the period from 2015-16 to 2021-22, while United has the least efficiency. Under VRS, the average technical efficiency score for ICICI was 0.9891 and ranked 3rd among the four insurers. ICICI scored 1 in 2015-16, 2017-18, 2018-19, 2020-21, and 2021-22, indicating that it was technically efficient in those years. However, it scored 0.971 in 2016-17, indicating that it was technically inefficient. Bajaj had an average technical efficiency score of 0.993 under VRS and was ranked 2nd among the four insurers. Bajaj scored 1 in all the years except 2020-21, when it had a score of 0.955, indicating that it was technically inefficient. United had an average technical efficiency score of 0.995 under VRS and was ranked 1st among the four insurers. United scored 1 in all the years except 2021-22, when it scored 0.967, indicating that it was technically inefficient. Oriental had an average technical efficiency score of 0.979 under VRS and was ranked 4th among the four insurers. Oriental scored 1 in 2015-16, 2017-18, 2018-19, 2019-20, and 2021-22, indicating that it was technically efficient in those years.

Comparison of CRS and VRS

- The average technical efficiency score for all the insurers is higher under VRS as compared to CRS.
- The ranking of the insurers is different in both models. For example, Bajaj is ranked 2nd in VRS but 1st in CRS.
- The scores of the insurers show that most of the insurers were technically efficient in VRS compared to CRS.

The scale efficiency scores under the VRS model (Table 6) tell us about each non-life insurance company's ability to produce a given output level using the minimum number of inputs (scale efficiency). The average TE SE (2015-2022) gives us the average level of scale efficiency over time. The rank compares the companies in terms of their scale efficiency.

Based on the data, it can be seen that

- Bajaj and ICICI have consistently been among the top performers in scale efficiency.
- Oriental has also had a good level of scale efficiency over the years.
- United has had the lowest average scale efficiency over the period.

Hypothesis H0= Null hypothesis is rejected due to a significant change in efficiency between the Public Sector and Private Sector; above are the data indicating the details of the significant changes. This data suggests that the companies could focus on improving their scale efficiency by using their inputs more efficiently, improving their processes, and increasing their out- put while minimizing the use of inputs. Additionally, they could consider expanding their operations to increase their economies of scale, which could improve scale efficiency.

TOTAL FACTOR OF PRODUCTIVITY (MALMQUIST INDEX

the Malmquist Index is a valuable tool for measuring productivity growth in the insurance sector and guiding insurance companies in their efforts to improve their competitiveness and Performance. In the insurance sector, TFP can be a valuable tool for evaluating the Performance of different insurance companies and identifying areas for improvement. The index provides a comprehensive picture of how each company is performing, taking into account both technical efficiency and technological advancements.

MALMQUIST INDEX SUMMARY OF FIRM MEANS

The above data shows the Total Factor Productivity (TFP) changes for the four non-life insurance companies ICICI, Bajaj, United, and Oriental Insurance. The data indicates the changes in technical efficiency, technological change, pure technical efficiency change, scale efficiency change, and overall TFP changes. Based on the data, ICICI has the highest increase in TFP at 1.17, followed by Bajaj at 1.085, United at 1.05, and Oriental Insurance at 0.976 The average TFP change is 1.068. To improve TFP, companies can focus on improving their technical efficiency, - embracing technological changes, increasing their scale of operation, and improving their management practices. Companies can also focus on increasing their operational efficiency, improving customer service, and finding new market opportunities to grow their business. It's important to note that this is just a general suggestion, and the best approach for each company may vary based on their specific circumstances and goals. Further analysis and data would be needed to make more specific recommendations. Hypothesis H01 = Null hypothesis is rejected because there is a significant change in TOTAL FACTOR PRODUCTIVITY between the Public Sector and Private Sector; above are the data indicating the details of the significant changes.

Year-Wise Malmquist Index Summary of Annual Means

The above table represents the Total Factor Productivity (TFP) change in the insurance sector from 2016-17 to 2021-22. The TFP change is calculated using the Malmquist Index, which considers both technical and scale efficiency changes. The data shows that the average TFP change over the period is 1.068, which indicates that the overall productivity of the Sector has increased slightly over this time. However, there is some variability in the TFP change from year to year, with the highest increase of 1.175 observed in 2016-17, and the lowest increase of 0.977 observed in 2021-22. When analyzing the different components of TFP change, it is seen that technical change has an average value of 1.064, which suggests that the companies in the Sector have improved their processes and operations, leading to higher efficiency. (PTEC)Technological change, on the other hand, has an average value of 1, indicating that no major technological breakthroughs have significantly impacted the Sector. In terms of (TEC)technical efficiency change, the average value of 1.004 suggests that there has been a slight improvement in the way resources are utilized by the companies in the Sector. However, scale efficiency change, with an average value of 1.004, indicates that there has been a more significant improvement in the way the companies are managing their economies of scale.

Based on this data, I would suggest that companies in the insurance sector continue to focus on improving their processes and operations and utilizing their resources effectively to maintain or increase their productivity in the future. Additionally, it may be beneficial for companies to consider adopting new technologies and finding ways to manage their economies of scale better to remain competitive in a rapidly changing industry.

CONCLUSION

From the above data, it's clearly concluded that the private general insurance sector is making more effort Than the public sector and private companies or more efficient than the public Sector. Based on the data analysis, it can be concluded that all four companies, ICICI, Bajaj, United, and Oriental, have shown varying levels of efficiency in the insurance Sector from 2015-2022. According to the fourth table, the technical efficiency change of these companies has fluctuated over the years, with the highest chance of 1.175 in 2016-17 and the lowest of 0.977 in 2021-22. The technological change has also shown variation, with a highest value of 1.163 in 2020-21 and a lowest value of 0.96 in 2019-20.

In the fifth table, the VRS model shows that Bajaj has the highest average TE score of 0.975874, while United has the lowest average TE score of 0.936545. The remaining companies, ICICI and Oriental, have average TE scores of 0.974719 and 0.964136, respectively. In the seventh table, the Malmquist Index reflects the companies' Total Factor

Productivity (TFP) change. The highest TFP change was seen in 2016-17 with 1.175, and the lowest in 2020-21 with 1.03. The overall TFP change has fluctuated from 2015-2022, with a mean TFP change of 1.068. In conclusion, all four companies have shown some level of efficiency over the years. Still, there is room for improvement regarding technical and scale efficiency, technological change and total factor productivity. The companies can focus on improving these aspects in order to be more competitive in the insurance sector.

LIMITATIONS

The above data provide information about the efficiency of the companies in the insurance Sector. However, the data only provides limited information and does not consider other factors that can impact the efficiency of a company. The data only considers technical Efficiency, technological change, pure technical Efficiency, scale efficiency, and total factor productivity (TFP). It does not consider other factors such as financial performance, market conditions, competition, regulatory environment, and other internal and external factors. Therefore, the data should be viewed as a starting point for understanding the efficiency of these companies and not as a comprehensive analysis. It is essential to consider other factors and gather more information before making any decisions or conclusions about the efficiency of these companies

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Table 1. Inputs and outputs: from the review literature

Author	Method	Units	Inputs	Output
(Pervan, Pavić Kramarić and Ćurak, 2021)	DEA	34	Operative expenses	Net premium and investment.
(Mandal and Ghosh Dastidar, 2014)	DEA	12	Operative expenses equity and share capital.	Premium claim processed
(Kaffash *et al.*, 2020)	DEA	Systematic review literature.	NA	NA
(Ilyas and S. Rajasekaran, 2022a)	DEA	15	Operating expenses equity and debt.	Net claims investment.
(Abdin, Mahelan Prabantarikso, *et al.*, 2022)	DEA	18	Capital expenses.	Premium. Gross investment
(Chakraborty, 2016)	DEA	4	Operating expenses	Net premium income from investment.
(Alhassan and Biekpe, 2015a)	DEA	80	Equity capital.	Income from investment.
(Cummins and Xie, 2016)	DEA	45	Labour financial capital material.	Premium investment on return.
(Chakraborty, 2018)	DEA/MI	12	Operating expenses investment	Net premium income from investment.
(Grmanová and Strunz, 2017)	DEW/TOBIT	15	Claims income operating expenses	Premium earned income from investment.
(Kozak, 2018)	SFA	29	Claims incurred operating expenses.	Premium earned income from investment
(Lim, Lee and Har, 2021)	RBCR	5	Labour business services material and capital.	Investment claims and PRIMIUM
(Alhassan and Biekpe, 2015a)	DEA	35	Management epenses to liquidity total average.	Changes net premium climbing income from investment.
(Barros, Barroso and Borges, 2005)	DEA	27	Wages capital Investment.	Claims profit

(Chawla and Sharma, 2017)	DEA	30	LABOUR COST commission broker financial capital.	TOTAL LOSS
(Huang and Eling, 2013)	DEA	BIBLOMATRIC ANALYSIS	NA	NA
(Luhnen, 2009)	DEA	295	LABOUR equity and debt.	Claims total investment.
(Eling and Luhnen, 2010)	DEA	52	LABOUR equity and debt.	Claims total investment.
(Lee *et al.*, 2019)	DEA	34	Number of employees, Total premium written	Net profit, Claims paid
(Krishnamurthy *et al.*, 2005)	DEA	45	Number of employees, Total premium written	Underwriting profit, Investment return
(J. chakjoy@gmail. com Chakraborty and Basu, 2018)	DEA	54	Number of policies issued; Total investments made	Claims ratio, Operating expenses ratio
(Garg and Garg, 2020a)	DEA	23	Number of claims processed, Total administrative expenses	Return on assets, Combined ratio
(Garg and Garg, 2020b)	SFA	34	Market share, Total assets	Return on equity, Loss ratio
(J. Chakraborty and Basu, 2018)	DEA	24	Premium growth rate, Total liabilities	Investment yield, Expense ratio
(Chakraborty and Sengupta, 2014)	DEA	5	Investment income, Underwriting expenses	Net income, Loss and expense ratio
(Yu *et al.*, 2021)	DEA	7	Premium earned, Total expenses	Policyholder surplus, Operating ratio
(Sinha, 2015)	DEA	8	Customer satisfaction, Customer retention rate	Risk-adjusted return on capital, Capital adequacy ratio
(Bakhouche *et al.*, 2020)	DEA	7	Underwriting risk, Investment risk	Average claim cost, Loss development factor
(Ghosh and Dey, 2018)	DEA	4	Claims frequency, Claims severity	Market power, Premium adequacy
(Brockett *et al.*, 2007)	DEA	12	Market concentration, Premium per policy	Overall profit margin, Gross written premium
(Sinha, 2017)	DEA	12	Underwriting profit margin, Investment profit margin	Reinsurance recoveries, Net reinsurance expense ratio
(Nourani *et al.*, 2022)	DEA	32	Loss adjustment expenses, Reinsurance expenses	Settlement rate, Claims settlement efficiency
(Alhassan and Biekpe, 2015b)	DEA	12	Claims processing time, Average settlement amount	Sales productivity, Expense per employee
(Eling and Jia, 2019)	DEA	10	Sales commission, Premium per employee	Customer retention rate, Customer acquisition efficiency

(Siddiqui, 2020)	SFA	10	Customer acquisition cost, Customer lifetime value	Expense ratio, Policy acquisition cost
(Parida and Acharya, 2016)	SFA	9	Expense per policy, Premium per policy	Expense ratio, Combined ratio
(Al-Amri, Gattoufi and Al-Muharrami, 2012)	DEA	9	Loss adjustment expense ratio, Underwriting expense ratio	Revenue diversification, Market diversification
(Abdin, Prabantarikso, *et al.*, 2022)	DEA	8	Product diversity, Distribution channel diversity	Market segmentation, Target market penetration
(Peng and Lian, 2021)	DEA	14	Product diversity, Distribution channel diversity	Revenue diversification, Market diversification
(Medved and Kavčič, 2012)	DEA	13	Customer demographics, Product pricing	Market segmentation, Target market penetration
(Barros and Wanke, 2016)	DEA	15	Investment portfolio diversification, Investment portfolio performance	Investment portfolio yield, Investment portfolio volatility
(Leverty and Grace, 2010)	DEA	14	Claims severity distribution, Claims frequency distribution	Aggregate claims distribution, Loss distribution shape
(Hardwick, Adams and Zou, 2011)	DEA	18	Fraud detection rate, Fraud detection cost	Fraud detection efficiency, Fraud loss ratio
(Sinha, 2021)	DEA	17	Underwriting guidelines, Claims handling guidelines	Compliance rate, Regulatory fines
(Suvvari, 2019)	DEA	21	Risk exposure, Risk mitigation strategies	Risk management effectiveness, Risk appetite
(Alhassan and Biekpe, 2016)	DEA	31	Industry benchmarking, company benchmarking	Performance relative to industry, Performance relative to peers
(Savitha, Banerjee and Shetty, 2019)	DEA	41	Market competition, Product differentiation	Competitive advantage, Price elasticity of demand
(Biener and Eling, 2012)	DEA	12	Capital allocation, Capital utilization	Return on capital employed, Capital efficiency
(Bhatia and Mahendru, 2022)	DEA	6	Premium per customer, Loss per customer	Customer lifetime value, Customer profitability
(Naushad, Faridi and Faisal, 2020)	DEA	8	Sales volume, Marketing spends	Return on marketing investment, Market share growth rate

(Yuengert, 1993)	DEA	14	Claims severity trend, Claims frequency trend	Loss trend, Reserve adequacy
(Bansal and Singh, 2021)	DEA	24	Premium pricing, Underwriting standards	Underwriting margin, Premium adequacy
(Tone and Sahoo, 2005)	DEA	45	Customer loyalty, Customer advocacy	Net promoter score, Referral rate
(Modi, 2008)	DEA	66	Customer service quality, Customer complaint ratio	Customer satisfaction, Customer loyalty
(Dutta, 2013)	DEA	7	Market growth rate, Market penetration rate	Revenue growth rate, Market share growth rate
(Ilyas and S Rajasekaran, 2022)	DEA	75	Customer lifetime value, Customer acquisition cost	Customer retention rate, Customer acquisition efficiency
(Anandarao, Durai and Goyari, 2019)	DEA	77	Claims frequency, Claims severity	Average claim cost, Loss development factor
(Ohene-Asare, Asare and Turkson, 2019)	DEA	74	Market concentration, Premium per policy	Market power, Premium adequacy
(Chen, Liu and Kweh, 2014)	DEA	47	Underwriting profit margin, Investment profit margin	Overall profit margin, Gross written premium
(Rahmani*et al.*, 2014)	DEA	44	Loss adjustment expenses, Reinsurance expenses	Reinsurance recoveries, Net reinsurance expense ratio
(Shetty and Basri, 2020)	DEA	32	Claims processing time, Average settlement amount	Settlement rate, Claims settlement efficiency
(Kuo*et al.*, 2017)	DEA	43	Sales commission, Premium per employee	Sales productivity, Expense per employee
(Akhtar, 2018)	DEA	11	Expense per policy, Premium per policy	Expense ratio, Policy acquisition cost
(Kasman and Turgutlu, 2011)	DEA	11	Loss adjustment expense ratio, Underwriting expense ratio	Expense ratio, Combined ratio
(Biener and Eling, 2011)	DEA	22	Product diversity, Distribution channel diversity	Revenue diversification, Market diversification
(Sahoo and Tone, 2022)	DEA	33	Customer demographics, Product pricing	Market segmentation, Target market penetration
(Ilyas and S. Rajasekaran, 2022b)	DEA	12	Investment portfolio diversification, Investment portfolio performance	Investment portfolio yield, Investment portfolio volatility

(Ghose and Kumar, 2019)	DEA	12	Claims severity distribution, Claims frequency distribution	Aggregate claims distribution, Loss distribution shape
(Varma, 2007)	DEA	33	Fraud detection rate, Fraud detection cost	Fraud detection efficiency, Fraud loss ratio
(sreedevi k, 2016)	DEA		Underwriting guidelines, Claims handling guidelines	Compliance rate, Regulatory fines

Table 2 Summary of Input-Output

VARIABLES USED	INPUT/OUTPUT
Operating Expenses	Input
Investments	Input
Net Premiums	Output
Income from Investments	Output

Table 3 Correlation Metric Between Inputs and Outputs.

	Operating Expenses	Investments	Net Premiums	Income from Investments
Operating Expenses	1	0.824038	0.853467	0.985218
Investments	0.824038	1	0.610702	0.828762
Net Premiums	0.853467	0.610702	1	0.860429
Income from Investments	0.985218	0.828762	0.860429	1

Table 4. Descriptive Statistics of inputs and Outputs variables. Note: Figures are in Rs 000

		Operating Expenses	Investments	Net Premiums	Income from Investments
2015-16	MEAN	20890185	115625186	70663935	12816240
	SD	8125055	67043980	27336709	5990849
	MIN	11407097	89346369	45723819	6201791
	MEAN	29240700	232382395	107145600	18226800
2016-17	MEAN	22834615	188197835	86161383	15437516
	SD	7528384	75693852	35506054	7910137
	MIN	13614489	102727526	53008839	7374934
	MAX	29691200	271252752	133464800	23256800
2017-18	MEAN	22019474	212930912	92489979	20963615
	SD	5890249	68093015	25020343	12666941
	MIN	14051321	139906917	67325358	8837656
	MAX	26929900	298151002	123904700	32923300

2018-19	MAX	26929900	298151002	123904700	32923300
	MEAN	23365023	239206871	104877169	20902768
	SD	5548349	61855360	25371849	11236114
	MIN	18071090	167864429	77744606	9298583
2019-20	MAX	30594100	316566721	137924600	31844800
	MEAN	28722281	233088323	105963423	22005396
	SD	6531231	45628411	24226897	9773587
	MIN	22931019	183045594	80159624	11964950
2020-21	MAX	34425350	279307452	137400200	31787576
	MEAN	29361967	278216154	19146613	19146613
	SD	7669719	54786746	5931396	5931396
	MIN	20597713	224774302	11932977	11932977
2021-22	MAX	39080200	339320662	24103134	24103134
	MEAN	33539140	315507609	117471731	21528175
	SD	8908516	68812486	27123563	5385689
	MIN	21648278	242279567	77628213	13830525

TABLE 5

TECHNICAL EFFICIENCY SCORES UNDER CRS

DMUs/Non-Life Insurers	TE CRS 2015-16	TE CRS 2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Avg. Te (15-22)	RANK
ICICI	1	0.95	0.964	1	1	0.91	0.92	0.96	2
BAJAJ	1	1	1	0.94	0.93	0.91	1	0.96	1
UNITED	0.93	1	1	0.97	1	0.84	0.77	0.93	4
ORIENTAL	0.79	0.86	1	1	1	0.96	0.97	0.94	3
Number of EfficientD-MUs	2	2	3	2	3		1		
Number of Inefficient-	2	2	1	2	1	4	3	4	

TABLE 6

TECHNICAL EFFICIENCY SCORES UNDER VRS

DMUs/Non-Life Insurers	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	avg. TE	RANK
ICICI	1	0.971	0.982	1	1	0.975	1	0.9891	3
BAJAJ	1	1	1	1	1	0.955	1	0.993	2
UNITED	1	1	1	1	1	1	0.967	0.995	1
ORIENTAL	1	0.880	1	1	1	0.973	1	0.979	4
Number of EfficientDMUs	4	3	3	4	4	1	3		
Number of InefficientDMUs	NIL	1	1				1		
Number of Efficient DMUsExhibiting CRS	2	2	3	3	4	1	3		
Number of EfficientDMUs Exhibiting IRS	2	1	NIL	1					
Number of Efficient DMU Exhibiting DRS		1	1			3	1		

Table 7.

SCALE EFFICIENCY SCORES UNDER VRS

DMUs/Non-Life Insurers	TE SE 2015-16	TE SE 2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	avg. TE (15-22)	RANK
ICICI	1	0.98	0.98	1	1	0.93	0.92	0.97	2
BAJAJ	1	1	1	0.94	0.93	0.95	1	0.97	1
UNITED	0.93	1	1	0.97	0.84	0.79		0.93	5
ORIENTAL	0.79	0.97	1	1	1	0.99	0.97	0.96	3
MEAN	0.93	0.98	0.99	0.98	0.98	0.93	0.92	0.. 96	4
Number of SCALE efficient DMus	2	2	3	3	3	NIL	1		

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Table 8. technical efficiency and technological advancements

DMUs/	TEC	TC	PTEC	SEC	TFPC	Ranks(TFP)
ICICI	0.965	1.212	1	0.965	1.17	1
BAJAJ	1	1.085	1	1	1.085	2
UNITED	1.035	1.015	1	1.035	1.05	3
OrientalInsurance	1.016	0.961	1	1.016	0.976	4
Means	1.004	1.064	1	1.004	1.068	
Increase(in %)	0.4	0.64	0	0.004	0.68	
Decrease(in %)						

Table 9

Year ofOperation	TEC	TC	PTEC	SEC	TFPC
2016-17	1.026	1.145	1	1.026	1.175
2017-18	1.074	1.063	1	1.074	1.141
2018-19	1.008	1.035	1	1.008	1.043
2019-20	1.076	0.96	1	1.076	1.033
2020-21	0.885	1.163	1	0.885	1.03
2021-22	0.966	1.032	1	0.966	0.977
Means	1.004	1.064	1	1.004	1.068

Year-Wise Malmquist Index Summary of Annual Means

$$MI^{t_1,t_2} = \left[\overbrace{\frac{D^{t_2}_{CRS}(x^{t_2},y^{t_2})}{D^{t_1}_{CRS}(x^{t_1},y^{t_1})}}^{TEC}\right] \times \left[\overbrace{\frac{D^{t_1}_{CRS}(x^{t_2},y^{t_2})}{D^{t_2}_{CRS}(x^{t_2},y^{t_2})} \times \frac{D^{t_1}_{CRS}(x^{t_1},y^{t_1})}{D^{t_2}_{CRS}(x^{t_2},y^{t_2})}}^{TC}\right]^{1/2}$$

Figure 1:

$$MI^{t_1,t_2} = TC^{t_1,t_2}(x^{t_2},y^{t_2}) \times TEC^{t_1,t_2}(x^{t_2},y^{t_2},x^{t_1},y^{t_1}) \times SEC^{t_1,t_2}(x^{t_1},y^{t_2},y^{t_1}) \times IMEC^{t_1,t_2}(x^{t_2},x^{t_1},y^{t_2})$$

Figure 2

$$MI^{t_1,t_2} = \left[\overbrace{\frac{D^{t_2}_{VRS}(x^{t_2},y^{t_2})}{D^{t_1}_{VRS}(x^{t_1},y^{t_1})}}^{PTEC}\right] \times \left[\overbrace{\frac{D^{t_2}_{CRS}(x^{t_2},y^{t_2})/D^{t_2}_{VRS}(x^{t_2},y^{t_2})}{D^{t_1}_{CRS}(x^{t_1},y^{t_1})/D^{t_1}_{VRS}(x^{t_1},y^{t_1})}}^{SEC}\right] \times \left[\overbrace{\frac{D^{t_1}_{CRS}(x^{t_2},y^{t_2})}{D^{t_2}_{CRS}(x^{t_2},y^{t_2})} \times \frac{D^{t_1}_{CRS}(x^{t_1},y^{t_1})}{D^{t_2}_{CRS}(x^{t_1},y^{t_1})}}^{TC}\right]$$

Figure 3:

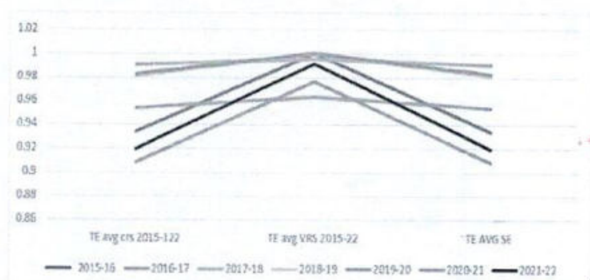

Chart 1. Total factor of productivity (malmquist index)