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THE DETERMINANTS AND EFFICIENCY ESTIMATION OF OIL AND GAS EXPLORATION AND PRODUCTION COMPANIES: EVIDENCE FROM PAKISTAN

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ABSTRACT

This study examined the total factor productivity change and determinants of inefficiency in oil and gas exploration and production companies in Pakistan, utilizing panel data spanning 15 years. Malmquist Data Envelopment Analysis was used to estimate the total factor productivity change and the Stochastic Frontier Analysis (SFA) was used to explore the determinants of inefficiency of these companies. Leverage has been found to exert a positive and significant impact on inefficiency, whereas liquidity, firm size, and firm age are negatively related to the inefficiency of firms. Financial debt should be in a reasonable amount to decrease the inefficiency of these firms.

Keywords: *Efficiency, Malmquist DEA, SFA, Oil and Gas Exploration and Production Companies.*

INTRODUCTION

Energy sector plays an important role in the development of an economy. Due to its significant role considerable importance is being given to this sector all over the world. Oil and gas are two important and major sources of energy in the world. Natural gas is becoming more and more important as a source of energy in contemporary era. Like any other country in the world, natural gas and oil are two most important components of energy zone in Pakistan. Pakistan is blessed with natural gas profoundly and its oil production is minimal as compare to the gas. However, the stagnant oil production started to increase recently. In Pakistan, the share of oil production is 29.5% approximately and gas constitutes about 34.2% of the 86.1 million TOE (Ton of Oil Equivalent) of energy provisions during the year 2022-2023 whereas nuclear and coal contribute by approximately 2.8% and 17.3%, respectively. The gas consumption is high in Pakistan as it constitutes 44% share of the sources of energy consumption in Pakistan whereas oil holds 29% share in means of energy consumption. In energy consumption sources LPG (liquid petroleum gas), and coal hold 3.2%, 17.3% respectively (Hydrocarbon Development Institute of Pakistan, 2023).

Oil and Gas Development Company started working as a public sector corporation in 1961. Mostly it is indulged in the exploration activities as it possesses largest exploration land in the country. Oil & Gas Development Company Limited covers 49% of total exploration land in the year 2022-2023. In 2022, it was estimated that OGDCL possessed highest oil and natural gas reserves of 49% and 25%, respectively (Oil & Gas Development Company Limited, 2023). Mari Petroleum Company possesses second highest gas reserves at Mari Field in District Ghotki. It is one of the largest exploration and production companies of Pakistan. It is listed on all the stock exchanges of the country. Mari Gas Field was found in Daharki, Sindh in 1957. It is involved in production, exploration and development

activities of crude oil, natural gas, and LPG (Liquid Petroleum Gas) of the country (MPCL, 2022). Pakistan Oilfields Limited (POL) started working in 1950 as a subsidiary of Attock Oil Company Limited (AOL). Pakistan Oilfields Limited is primarily engaged in the production, exploration and drilling activities of gas and crude oil. However, Pakistan Oilfields Limited acquired the charge of production and exploration activities of Attock Oil Company Limited in 1978 (POL, 2023).

Pakistan Petroleum Limited started working in 1951. It is primarily engaged in the supply of natural gas, as it constitutes 20% of the total natural gas production of the country along with crude oil, natural gas and liquefied petroleum gas production. On the daily basis, Pakistan Petroleum Limited produces one billion cubic feet (bcf) of gas by the means of its own operations and by joint venture operating fields (PPL, 2013). This study aims to estimate the efficiency scores, Technical efficiency change and total factor productivity change over the time. This study aims to explore the determinants of inefficiency of firms.

Methodology:

Panel data of four oil and gas exploration and production companies for 15 years has been taken from the annual reports of these companies and Financial Statements Analysis of Companies (Non-Financial) Listed at Karachi Stock Exchange published by State Bank of Pakistan. At first stage, both output oriented Malmquist Data Envelopment Analysis and Stochastic Frontier Analysis techniques were used for the measurement of efficiency scores by using profit before tax as output variable whereas input variables were cost of sales, cost of operating fixed assets and administrative and other expenditures. Profit before tax is the profit generated by the firm before exclusion of any taxes. Cost of sales includes direct production costs of goods and items that a company produces and sells. It also includes material cost that is used in production process and cost of labor employed by the company to create goods. Cost of operating fixed assets has been used after deducting accumulated depreciation from it. General, administrative and other expenses include salaries, benefits, and travel facility expenses of administrators, employees and sales persons. Expenditures of advertisement and publicity are also included in these expenses. At second stage of the study determinants of inefficiency of oil and gas exploration and production companies were estimated through technical efficiency (TE) Effects Model of Stochastic Frontier Analysis (SFA) by employing dependent variable inefficiency score (ε) which took the values between (0 to 1) and independent variables were leverage (It can be computed as Debt equity ratio = (Current Liabilities + Non-Current Liabilities)/ shareholder's equity), liquidity (It can be calculated as liquidity = current assets/ total assets), size of firm (it can be measured as the total assets of the firm consisting on current and non-current assets) ; where non-current assets were operating fixed assets after deducting accumulated depreciation. , age of firm (it can be measured as the number of years of establishment of the firm) and sales growth (It can be calculated as Sales Growth = (Current Year's Sales - Last Year's Sales)/ (last year's sales) × 100).

Data Envelopment Analysis (DEA)

Data Envelopment Analysis is a non-parametric technique that calculates efficiency scores of firms, organizations, financial and non-financial institutions on the basis of linear programming technique. DEA is a non-parametric method that recognizes finest application among vast variety of practices and concentrates on estimation of efficiency of firms, units and financial or non-financial groups (SCRC, 1997). This methodology was first suggested by Charnes et al. (1978), and then prolonged by Banker et al. (1984). Charnes et al. contributed their efforts to the work of Farrell's input and output technique for estimation of efficiency.

Panel data can be handled by linear programming method through DEA model to examine productivity change. A Malmquist Index is selected as it easily deals multi-input and multi-output production, and it clearly combines the effect of scale economies on productivity change (Hollas et al., 2002). Fare et al. (1994) presented an output oriented Malmquist total factor productivity change index as below:

$$m_0(Y_{t+1},\ X_{t+1},\ X_t,\ Y_t) = \left[\frac{d_0^t(X_{t+1},\ Y_{t+1})}{d_0^t(X_t, Y_t)} \times \frac{d_0^{t+1}(X_{t+1},\ Y_{t+1})}{d_0^{t+1}(X_t, Y_t)}\right]^{1/2}$$

The above equation shows the productivity of production point (Y_{t+1}, X_{t+1}) relative to production point (X_t, Y_t). If its value is greater than one it will show positive total factor productivity improvement from current period (t) to the next period $(t+1)$. The value of Malmquist productivity index for a particular DMU can be <, =, or > 1. If its value is > 1it shows productivity growth; if it is = 1 it shows no change in productivity whereas if its value is < 1 it shows productivity deterioration. Malmquist DEA is a non-parametric index where total factor productivity change can be calculated which is further divided into technical efficiency change and technological change. The technical efficiency change can be further split into two components named as scale efficiency change and pure efficiency change.

Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis is a parametric technique to measure the efficiency of firms, corporations, organizations and financial or non-financial companies (Shehzadi and Wetzel, 2024). It assumes the functional relationship among variables. At the start, stochastic production functions were proposed for the measurement of technical efficiency. Now these can be used with certain alterations to measure the size or capacity utilization. A possible advantage of the stochastic production frontier method over the non-parametric technique Data Envelopment Analysis is that unsystematic disparities can be handled in this technique. Therefore, it is more reliable and consistent in nature as compare to the non-parametric technique DEA (Paul, Johnson and Frengley, 2000).

At first a Cobb- Douglas production function was supposed. The form of that Cobb- Douglas production function was as under.

$$Profit = \beta_0 Cos^{\beta 1} Cof^{\beta 2} Ae^{\beta 3}$$

This is a non-linear function, so, variables of this model were logged to make it a linear function. Then, it took the form as under:

$$\log(Profit_{it}) = \log(\beta_o) + \beta_1 \log(Cos_{it}) + \beta_2 \log(Cof_{it}) + \beta_3 \log(Ae_{it}) + \mu_{it}$$

where profit (before tax) was the output and β's were estimated parameters, Cos is cost of sales, Cof is cost of operating fixed assets, Ae is administrative and other expenditures and μ is error term of the model.

TE Effect Model of SFA estimation is made by maximum likelihood estimators (MLE). The method of maximum likelihood is proposed for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects (Battese and Coelli, 1995).

The following equation was estimated through TE effects model of SFA

$$\varepsilon_{it} = \delta_0 + \delta_1 Lev_{it} + \delta_2 Liq_{it} + \delta_3 Siz_{it} + \delta_4 Age_{it} + \delta_5 Sgr_{it} + \mu_{it}$$

In this equation, ε (dependent variable) is inefficiency score which was measured, and following are the independent variables Liq = liquidity, Lev = leverage, Sgr = Sales growth, Siz = size of firm (log of total assets), Age = age of firm and μ is error term.

Results and Discussion

a) Malmquist Indices of Individual Firms over the Time

The results of the above table 1 suggest that technical efficiency of Oil & Gas Development Company Limited was stagnant for consecutive seven years starting from year 1 up to the year 7. This constant technical efficiency of the firm was merely due to the no change in its pure technical efficiency and scale efficiency in those seven consecutive years. In year 8, though, there was change in technical efficiency of Oil & Gas Development Company Limited but it declined by 29.9% because its scale efficiency decreased by same percent in that year; the reason behind is that profit of Oil & Gas Development Company Limited decreased in that year only. In next year, the technical efficiency of Oil & Gas Development Company Limited increased by 42.7% and this rise in technical efficiency was the consequence of 42.7% increase in pure efficiency. The profits of Oil & Gas Development Company Limited increased by more than double as compare to that of year 8 that's why its technical efficiency increased significantly in year 9. This was the only year in which the technical efficiency of the firm rose. In year 10, the technical efficiency of Oil &

Gas Development Company Limited demonstrated no change. This process of no change in technical efficiency of Oil & Gas Development Company Limited continued up to the year 14 as a result of no change in pure technical efficiency and scale efficiency throughout from the year 1 to year 14.

Where OGDCL is Oil & Gas Development Company Limited, MPCL is Mari Petroleum Company Limited, POL is Pakistan Oilfields Limited and PPL is Pakistan Petroleum Limited.

Table 1: Malmquist Index Summary of Oil & Gas Development Company Limited

Year	Effch	techch	Pech	Sech	Tfpch
Year 1	1.000	2.160	1.000	1.000	2.160
Year 2	1.000	1.445	1.000	1.000	1.445
Year 3	1.000	1.085	1.000	1.000	1.085
Year 4	1.000	0.802	1.000	1.000	0.802
Year 5	1.000	1.094	1.000	1.000	1.094
Year 6	1.000	1.062	1.000	1.000	1.062
Year 7	1.000	1.166	1.000	1.000	1.166
Year 8	0.701	0.803	1.000	0.701	0.563
Year 9	1.427	1.621	1.000	1.427	2.313
Year 10	1.000	1.175	1.000	1.000	1.175
Year 11	1.000	1.087	1.000	1.000	1.087
Year 12	1.000	0.926	1.000	1.000	0.926
Year 13	1.000	1.254	1.000	1.000	1.254
Year 14	1.000	0.377	1.000	1.000	0.377

Source: Author's own calculations

In year 4, total factor productivity of Oil & Gas Development Company Limited decreased by 19.8% because of same percent decrease in technology. The total factor productivity of Oil & Gas Development Company Limited upturned by 116% in year 1 and this improvement was merely the result of technological progress of 116% for the firm. In years 2 and 3the total factor productivity growth of Oil & Gas Development Company Limited was 44.5% and 8.5%, respectively, and this improvement of total factor productivity was the consequence of technological gain of the firm in these years and increase in profit.

According to the findings of Malmquist DEA, Oil & Gas Development Company Limited showed stable performance regarding its technical efficiency change which remained constant during whole study period except in two years in-between as the technical efficiency of Oil & Gas Development Company Limited remained stagnant on average. On the other hand, total factor productivity progress showed somewhat different patterns as it increased in most of the years with different magnitudes while it decreased in four years during the study period.

The results of the table 2 demonstrate that technical efficiency of Mari Petroleum Company Limited decreased by 82.2% and 36% in year 1 and 2, respectively. The technical efficiency of Mari Petroleum Company Limited decreased due to the decrease in both pure technical efficiency and scale efficiency in year 11 and in year 12 it was declined only due to the decrease in scale efficiency as pure technical efficiency improved in later year. In next year the technical efficiency of Mari Petroleum Company Limited increased significantly, it improved by 152.5% and was completely attributable to scale efficiency improvement of 152.5%. However, there was decrease in technical efficiency of Mari Petroleum Company Limited for the years 6 and 7 by 29.2% and 50.5%, respectively, because of same percent decrease in scale efficiency in these two years whereas pure technical efficiency remained same

Table 2: Malmquist Index Summary of Mari Petroleum Company Limited (MPCL)

Year	effch	Techch	Pech	sech	Tfpch
Year 1	0.172	4.809	0.180	0.955	0.829
Year 2	0.640	1.753	5.541	0.115	1.122
Year 3	2.525	0.369	1.000	2.525	0.933
Year 4	1.084	1.016	1.000	1.084	1.101
Year 5	1.083	1.001	1.000	1.083	1.084
Year 6	0.708	1.566	1.000	0.708	1.109
Year 7	0.495	1.315	1.000	0.495	0.651
Year 8	2.199	1.011	1.000	2.199	2.224
Year 9	1.794	1.584	1.000	1.794	2.842
Year 10	2.213	1.611	1.000	2.213	3.565
Year 11	0.969	0.638	1.000	0.969	0.618
Year 12	1.032	1.446	1.000	1.032	1.492
Year 13	0.648	0.738	1.000	0.648	0.478
Year 14	1.544	0.943	1.000	1.544	1.456

Source: Author's own calculations

The profits of Mari Petroleum Company Limited decreased significantly in year 6, that's why it faced significant decline in its technical efficiency; however, there was minor decrease in its profits in year 7 but technical efficiency declined considerably. According to the results the total factor productivity of Mari Petroleum Company Limited decreased by 17.1% in year 11 and it was mainly due to its technical efficiency decrease of 82.8%. In next year total factor productivity increased by 12.2% and it was only due to its technological progress. The total factor productivity of Mari Petroleum Company Limited is increased by 122.4%, 184.2% and 256.5% in year 8, year 9 and year 10 respectively as a result of technological improvement. Mari Petroleum Company Limited demonstrated fluctuations regarding its technical efficiency change and total factor productivity change over the time. So it was attributable to the huge fluctuations in its profits during the complete study period. The results of table 3 suggest that there was no improvement in technical efficiency of Pakistan Oilfields Limited for consecutive four years starting from year 1 up to the year 4 and this was due to no increase in its pure technical efficiency and scale efficiency.

Table 3: Malmquist Index Summary of Pakistan Oilfields Limited (POL)

year	effch	techch	Pech	Sech	Tfpch
Year 1	1.000	3.136	1.000	1.000	3.136
Year 2	1.000	1.778	1.000	1.000	1.778
Year 3	1.000	0.373	1.000	1.000	0.373
Year 4	1.000	1.097	1.000	1.000	1.097
Year 5	0.961	1.037	1.000	0.961	0.997
Year 6	0.795	1.344	1.000	0.795	1.069
Year 7	1.082	1.136	1.000	1.082	1.229
Year 8	1.209	0.671	1.000	1.209	0.811
Year 9	0.817	1.260	1.000	0.817	1.030
Year 10	1.223	1.406	1.000	1.223	1.720
Year 11	0.750	1.015	1.000	0.750	0.761
Year 12	1.334	1.022	1.000	1.334	1.364
Year 13	1.000	1.101	1.000	1.000	1.101
Year 14	0.765	0.291	1.000	0.765	0.223

Source: Author's own calculations

This was also because profits of Pakistan Oilfields Limited increased reasonably during these years. According to the results, the technical efficiency of Pakistan Oilfields Limited decreased in year 5 and year 6 by 3.9% and 20.5%, respectively, as a result of decrease in scale efficiency in both years as pure technical efficiency was stagnant. The results of table 4.3 demonstrate that Pakistan Oilfields Limited achieved total factor productivity growth of 213.6% in year 1 and it was completely grounded on technological progress of 13.6% as technical efficiency was not changed. The total factor productivity of Pakistan Oilfields Limited is decreased by 62.7% in year 3 which was the result of same percent decrease in technology. In next year, Pakistan Oilfields Limited showed improvement in total factor productivity by 9.7% as a result of technological progress of same percent. However, the technical efficiency was constant. Total factor productivity of Pakistan Oilfields Limited is decreased by 0.3% in year 5, because the technical efficiency is decreased in that year due to decline in its profits, however, technological progress occurred in that period. In year 14, Pakistan Oilfields Limited showed decrease in total factor productivity by 77.7% which was due to consequence of deterioration in both the technical efficiency and technology; and decrease in profit also contributed to this total factor productivity reduction.

Pakistan Oilfields Limited depicted somewhat stable performance regarding technical efficiency change in early years of the study because of reasonable improvement in its profits; however, it demonstrated fluctuations with regard to the technical efficiency in later years depending on the fluctuations of profits.

Table 4: Malmquist index summary of Pakistan Petroleum Limited (PPL)

year	effch	techch	Pech	Sech	Tfpch
Year 1	1.000	1.062	1.000	1.000	1.062
Year 2	1.000	1.028	1.000	1.000	1.028
Year 3	1.000	1.155	1.000	1.000	1.155
Year 4	1.000	0.976	1.000	1.000	0.976
Year 5	1.000	1.293	1.000	1.000	1.293
Year 6	1.000	1.255	1.000	1.000	1.255
Year 7	1.000	1.146	1.000	1.000	1.146
Year 8	1.000	0.728	1.000	1.000	0.728
Year 9	1.000	1.390	1.000	1.000	1.390
Year 10	1.000	1.043	1.000	1.000	1.043
Year 11	1.000	0.903	1.000	1.000	0.903
Year 12	1.000	1.041	1.000	1.000	1.041
Year 13	1.000	1.050	1.000	1.000	1.050
Year 14	1.000	0.726	1.000	1.000	0.726

Source: Author's own calculations

According to the results of table 4, Pakistan Petroleum Limited demonstrated no progress in technical efficiency throughout the study period. Technical efficiency of Pakistan Petroleum Limited remained unchanged every year starting from year 1 to the year 14. The stagnant technical efficiency of Pakistan Petroleum Limited was the result of no change in its technical and scale efficiency throughout the period. This stability of technical efficiency of Pakistan Petroleum Limited was the consequence of stable increase in its profits during whole study period except in year 11 and year 14; where profits declined but technical efficiency remained unchanged. Pakistan Petroleum Limited demonstrated consistency in its total factor productivity change over the time as it was consistent in its profit gains. The total factor

productivity of Pakistan Petroleum Limited increased by 6.2%, 2.8% and 15.5% in years 1, year 2 and year 3, respectively; and this improvement was only due to the same percent increase in technology during these three years. In year 4, the total factor productivity of Pakistan Petroleum Limited is decreased by 2.4% and it was due to the same percent decrease in technology. According to the results of the above table Pakistan Petroleum Limited depicted total factor productivity decrease of 27.4% in year 14 which was the result of same percent decrease of technology and also due to the decrease in profit as technical efficiency was stagnant in that year. On the whole the technical efficiency of Pakistan Petroleum Limited demonstrated no change; it neither improved, nor decreased throughout the study period because of stable improvement in its profits throughout the study period. Pakistan Petroleum Limited depicted stable patterns of total factor productivity change over the time. It increased in most of the years with not very diverse magnitudes; as it was consistent because of its consistent profit gains.

b) **Malmquist index summary of annual means**

According to the above table 5, the mean technical efficiency of all firms decreased in first two years by 35.6% and 10.6%, respectively; in year 1 it decreased because of reduction in both mean pure technical efficiency and scale efficiency; however, in year 2 it decreased as a result of decrease in average scale efficiency of all firms as mean pure technical efficiency increased in that year. The mean technical efficiency of all firms increased in next three consecutive years as a result of increase in mean scale efficiency of these firms during these years. The technical efficiency of these companies increased 4.2% on average in year 14 as a consequence of mean scale efficiency improvement of firms. However, on average, the technical efficiency of oil and gas exploration and production companies decreased slightly and this decrease was 0.5%. The average total factor productivity of firms increased in year 1 and year 2 by 56.3% and 31.2% because of mean technological improvement of all firms in these two years. On average, the total factor productivity of all companies decreased in next two years; it declined due to the mean technological deterioration in both years. On average, the total factor productivity of all companies decreased in year 13 and year 14 by 8.7% and 45.4%, respectively; it declined due to the decrease in mean technical efficiency of firms in year 13 whereas in year 14, it declined due to the decrease in technology on average. However, the total factor productivity of oil and gas exploration and production companies increased on average. The average improvement of total factor productivity of these firms was reasonable as it averaged at 7.4%.

Table 5: Malmquist Index Summary of Annual Means

Year	effch	Techch	Pech	sech	Tfpch
Year 1	0.644	2.425	0.652	0.989	1.563
Year 2	0.894	1.467	1.534	0.583	1.312
Year 3	1.261	0.645	1.000	1.261	0.813
Year 4	1.020	0.966	1.000	1.020	0.986
Year 5	1.010	1.101	1.000	1.010	1.112
Year 6	0.866	1.294	1.000	0.866	1.121
Year 7	0.855	1.188	1.000	0.855	1.017
Year 8	1.168	0.794	1.000	1.168	0.927
Year 9	1.203	1.456	1.000	1.203	1.751
Year 10	1.283	1.291	1.000	1.283	1.656
Year 11	0.923	0.893	1.000	0.923	0.824
Year 12	1.083	1.093	1.000	1.083	1.183
Year 13	0.897	1.017	1.000	0.897	0.913
Year 14	1.042	0.524	1.000	1.042	0.546
mean	0.995	1.079	1.000	0.995	1.074

Source: Author's own calculations

c)

d) Malmquist Index Summary of Firm means

According to the table 6 the mean technical efficiency change for Oil and Gas Development Company Limited is 1.000; showing that on average there was no change in technical efficiency of Oil & Gas Development Company Limited during the whole study period, because of stagnant average pure technical efficiency and scale efficiency of Oil & Gas Development Company Limited (Batool et al., 2024). Similarly, the average technical efficiency of Mari Petroleum Company Limited demonstrated no change due to the unchanged average pure technical efficiency and scale efficiency during the analysis period. Pakistan Oilfields Limited depicted decline in its average technical efficiency by 1.9% as a result of same percent decrease in its mean scale efficiency. On average, the technical efficiency of Pakistan Petroleum Limited remained unchanged because of stagnant mean pure technical efficiency and scale efficiency during the analysis period. Overall, the technical efficiency of all firms decreased slightly on average. The mean technical efficiency of all firms decreased by 0.5% on average because of same percent decline of mean scale efficiency of all firms.

On average, the total factor productivity of Oil & Gas Development Company Limited increased by 7.3% and it was entirely attributable to its mean technological improvement. Similarly, the mean total factor productivity of Mari Petroleum Company Limited increased by 18.5% as a result of same percent increase in its mean technology. Pakistan Oilfields Limited demonstrated slight improvement in its total factor productivity by 0.6% on average due to the mean technological progress; however, its technical efficiency demonstrated deterioration on average. Pakistan Petroleum Limited also showed improvement of 4% regarding its total factor productivity change on average and it was completely due to the increase in its technology on average as its mean technical efficiency change was stagnant. Overall, the total factor productivity of all firms increased by 7.4% on average as a result of technological progress of these companies on average.

So, overall, the technical efficiency of oil and gas exploration and production companies decreased slightly whereas the total factor productivity of this sector increased to a reasonable extent on average.

Table 6: Malmquist Index Summary of Firm Means

Firm	effch	techch	pech	Sech	Tfpch
OGDCL	1.000	1.073	1.000	1.000	1.073
MPCL	1.000	1.185	1.000	1.000	1.185
POL	0.981	1.026	1.000	0.981	1.006
PPL	1.000	1.040	1.000	1.000	1.040
mean	0.995	1.079	1.000	0.995	1.074

Source: Author's own calculations

e)

f) SFA Efficiency Estimates

Results in table 7 show that efficiency of each firm is increasing over time. The efficiency estimates of Oil & Gas Development Company Limited are showing improvement in every year when compared with previous one. Although, that increase is minor over time, however, it shows improvement in firm's performance. As the efficiency score of Oil & Gas Development Company Limited in year 1 was 0.770012 and in year 2 was 0.776224 and in next year it was 0.782295. Oil & Gas Development Company Limited depicts same trend throughout from year 1 to year 14. The average efficiency score of Oil & Gas Development Company Limited for 15 years was 0.809359 which is close to 1 and it indicates good

Table 7: SFA Efficiency Estimates

years	Firms				Average
	OGDCL	MPCL	POL	PPL	
Year 1	0.770012	0.279951	0.813413	0.917706	0.69527
Year 2	0.776224	0.291177	0.818587	0.920115	0.701526
Year 3	0.782295	0.302485	0.823634	0.922458	0.707718
Year 4	0.788224	0.313864	0.828557	0.924735	0.713845
Year 5	0.794016	0.325301	0.833358	0.926949	0.719906
Year 6	0.79967	0.336781	0.838039	0.929102	0.725897
Year 7	0.80519	0.348294	0.842602	0.931194	0.731819
Year 8	0.810577	0.359828	0.847049	0.933227	0.73767
Year 9	0.815834	0.371369	0.851383	0.935203	0.743447
Year 10	0.820962	0.382908	0.855605	0.937123	0.749149
Year 11	0.825963	0.394432	0.859719	0.938988	0.754775
Year 12	0.83084	0.405932	0.863725	0.940801	0.760324
Year 13	0.835596	0.417396	0.867626	0.942562	0.765794
Year 14	0.840231	0.428815	0.871425	0.944272	0.771185
Year 15	0.844748	0.44018	0.875124	0.945934	0.776496
average	0.809359	0.359914	0.846591	0.932691	

Source: Author's own calculations

performance of the company over the whole time period. Same is the case with Mari Petroleum Company Limited; it also showed improvement in every next year when compared with last year. It continued progress until year 14 without any decrease in efficiency even in a single year. The average efficiency score of Mari Petroleum Company Limited was 0.359 over the complete study period. Pakistan Oilfields Limited depicted attained 0.813413 efficiency score in year 1 and in the very next year it achieved improvement by taking 0.818587 efficiency score. Pakistan Oilfields Limited shows improvement in its performance by showing increase in its efficiency during every passing year of the analysis.

The average efficiency score of Pakistan Oilfields Limited was 0.846591 showing good position of firm's performance over the time as average efficiency score was close to 1. The efficiency score of Pakistan Petroleum Limited in year 1 was 0.917706 and it rose in year 2 as at 0.920115 efficiency score; this process continued up to the year 14 by taking 0.945934 efficiency score. The results show that Pakistan Petroleum Limited possesses highest efficiency scores among all firms in each year of the study. It also achieved the highest average value of efficiency score when compared with its counterparts. It means as time passes firms are becoming more efficient as compare to the previous years. Depending on the year by year efficiency estimates Pakistan Petroleum Limited was the most efficient firm having 0.932691 average efficiency score whereas Mari Petroleum Company Limited was the least efficient

firm among all firms having 0.359914 average efficiency score.

The average efficiency score of all firms in year 1 was 0.69527 and it was raised in the very next year as 0.701526. The value of average efficiency score of oil and gas exploration and production companies continued to increase by every passing year and ultimately it increased up to 0.776496 by the year 14. This continuous increase of average efficiency of firms depicted the improvement of firms' performance and a sign of proper utilization of their available resources. According to the Stochastic Frontier Analysis results Pakistan Petroleum Limited was the most efficient oil and gas exploration and production company in Pakistan when compared with other three firms of the same field whereas Mari Petroleum Company Limited found to be the least efficient company among its counterparts (Liaqat et al., 2024).

Table 8: TE EFFECTS MODEL Results

Variables	Coefficient	SE	t-ratio
C	0.0165	0.3259	0.0508
Cost of sales	0.5886	0.1020	5.7654
Cost of operating fixed assets	0.2137	0.2388	0.8950
Administrative and other expenditures	0.3052	0.1208	2.5271

Source: Author's own calculations

a) TE Effects Model Results

The results of table 8 suggest that coefficient of cost of sales is positively and significantly attached to profit. It shows that as cost of sales increases the profit of oil and gas exploration and production companies increases. The variable cost of sales is statistically significant at 1% level of significance. As cost of sales represents production costs, so, as it increases the production of oil and gas exploration and production companies increases which leads to the increase in profit.

The coefficient of cost of operating fixed assets is positive but insignificantly related to profit. According to the results of above table the coefficient of administrative and other expenditures is positive and statistically significant at 5% level of significance showing that as administrative and other expenditures increase the profit of the firms increases. So, increase in expenditures on administrators, employees, selling and distribution, postage, travelling and other items brings increase in profit.

The results of table 9 depict that coefficient of leverage is positively and significantly related with the inefficiency of firms showing that as the value of leverage increases the inefficiency of oil and gas exploration and production companies increases as reported by (Riaz et al., 2013). So, null hypothesis of insignificant impact is rejected and leverage is statistically significant at 1% level of significance. So, it is an important determinant of inefficiency of these firms. The reason behind is that higher financial debt can affect the value of the stock if the stockholders become conscious; it might drop considerably if the stockholders get concerned. Similarly, the more liability in the capital structures of the company, the greater the financial risk to the creditor. This causes the company to pay higher average interest rates. So as debt to equity ratio increases, the inefficiency of the firm increases; as more leverage causes more interest burden on the company; so it has to pay huge amount in return and causes inefficiency to increase.

f) Determinants of Inefficiency

The coefficient of liquidity is negatively related to inefficiency scores depicting as liquidity of a firm increases its inefficiency decreases. Liquidity is negatively and statistically significant at 5% and 10% level of significance showing that null hypothesis of insignificant impact is rejected against alternative hypothesis of significant impact showing itself as an important determining factor of inefficiency of oil and gas exploration and production companies The positive and significant impact of liquidity on firm's efficiency was also reported by (Cormier and Magnan, 2002; Mubashar et al., 2012; Riaz et al., 2013; Shehzadi, 2023). Liquidity is the ease with which assets can be converted into cash, the more liquid assets a firm possesses the more it becomes easy to use its assets for business transactions. Moreover, if a firm owns good amount of liquidity, it requires to have less need for financial debt; so as a firm's liquidity increases its inefficiency decreases.

Table 9: Determinants of inefficiency

Variables	Coefficient	standard-error	t-ratio
C	4.1454	0.5979	6.9321
Leverage	0.0039	0.0005	7.2761
Liquidity	-1.5711	0.7677	-2.0464
Size	-0.4293	0.0973	-4.4120
Age	-0.0267	0.0051	-5.2406
Sales Growth	-0.0088	0.0009	-0.9247

Source: Author's own calculations

The coefficient of log size is negatively and significantly associated with the inefficiency of these firms; null hypothesis of insignificant impact is rejected and it depicts that as total assets of these firms' increase inefficiency decreases, it is consistent with the findings of (Shehzadi and Wetzel, 2024). The variable log size is significant at 1% level of significance showing itself as an important determinant of inefficiency of these companies. The reason behind is that generally, assets provide the business a means to keep up with debt in times of uncertain or unpredictable business profit. As business usually relies on loans and debt to promote and expand the business activities. When a business applies for loan, the lender parties usually look at the financial positions; particularly, lenders want to see whether the business is in position to pay back the debt. So, good amount of assets could lead business towards expansion of activities relying on its own assets as well as through receiving loans. The variable age of firm has significant and negative effect on the inefficiency of firms. It is significant at 1% level of significance so, null hypothesis of insignificant impact is rejected against the alternative hypothesis of significant impact of age on inefficiency. The negative coefficient of age describes that as the age of firm increases the inefficiency of the firm decreases because as age of the firm increases; with every passing year the firm gains more experience and hence, learns various ways to increase its efficiency. According to the results of above table the coefficient of sales growth has insignificant impact on inefficiency of oil and gas exploration and production companies in Pakistan.

Conclusion

All the firms demonstrated stable performance regarding technical efficiency change except Pakistan Oilfields Limited whose technical efficiency decreased slightly. However, all the companies confirmed total productivity improvement over the time. Mari Petroleum Company was the least efficient firm among all the firms according to the efficiency estimates calculated by Stochastic Frontier Analysis due to being highly leveraged as compared to other companies. On the other hand, Pakistan Petroleum Limited was the most efficient firm because it utilized reasonable amount of debt throughout the study period and experienced higher profits. Leverage was positively and significantly related with the inefficiency of the oil and gas exploration and production companies. Liquidity was negatively and significantly associated with the inefficiency of these companies; Size was proved to be an important determinant of inefficiency because it was inversely and significantly associated with inefficiency. Age of the firm was an important determining factor of inefficiency. It was negatively and significantly related with the inefficiency. As age of the firm increases it causes inefficiency to decline because with every passing year, the firm gains more experience and learns various ways to increase its efficiency.

There are various steps that can be taken to improve the efficiency of oil and gas exploration and production companies. Some of the suggestions are given below.

Oil and gas exploration and production companies need to increase their production in order to achieve the higher profits by the utilization of given inputs in order to become efficient. The amount of loan used in business should be in reasonable quantity as higher ratio of loan increases the interest rates and hence interest payments burden; which business has to pay in return and consequently causes the efficiency of the firm to decrease. So, it is important to use financial debt in reasonable amount to avoid some of these restrictions. Oil and gas exploration and production companies should increase their liquidity ratio in order to become efficient. Higher

liquidity ratio of a firm positively contributes to its performance because higher liquidity ratio means more current assets are possessed by the firm and it can utilize these assets in time of need as liquid assets can readily be converted into cash. Oil and gas exploration and production companies should utilize the available resources properly as the misallocation of resources could lead to them towards the poor performance and inefficiencies.

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. http://dx.doi.org/10.1287/mnsc.30.9.1078

Barros, C. P., & Assaf, A. (2009). Bootstrapped efficiency measures of oil blocks in Angola. Energy Policy, 37(10), 4098-4103.

Battese, G. E. & Coelli, T. G. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics, 20, 325-332.

Bozec, R., & Dia, M. (2007). Board structure and firm technical efficiency: Evidence from Canadian state-owned enterprises. European Journal of Operational Research, 177(3), 1734-1750.

Btool, Z., Riaz, M. F., Ali, S., & Shehzadi, A. (2024). Estimating The Effect of Macroeconomic Volatility on Different Types of FDI. *Journal of Contemporary Macroeconomic Issues*, *5*, 142-157.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. Omega, 44, 1-4.

Cormier, D., & Magnan, M. (2002). Performance reporting by oil and gas firms: contractual and value implications. Journal of International Accounting, Auditing and Taxation, 11(2), 131-153.

Eller, S. L., Hartley, P. R., & Medlock III, K. B. (2011). Empirical evidence on the operational efficiency of National Oil Companies. Empirical Economics, 40(3), 623–643. doi:10.1007/s00181-010-0349-8

Fare, R., Grosskopf, S., & Lovell, C. A. K. (1994). Production Frontiers. Cambridge University Press.

Hollas, D. R., Macleod, K. R., & Stansell, S. R. (2002). A Data Envelopment Analysis of Gas Utilities' Efficiency. Journal of Economics and Finance, 26(2), 123-137.

Hydrocarbon Development Institute of Pakistan. (2023). *Pakistan energy yearbook 2023*. Ministry of Energy.

Liaqat, M., Qaiser, I., & Shehzadi, A. (2024). Brain Drain, Key Factors Determining Student's Return Intention from Abroad: Evidence from Pakistan. *Forman Journal of Economic Studies*, *20*(02), 33-53.

Mubashar, A., Raheman, A., & Zulfiqar, B. (2012). Co-alignment among corporate strategy, Financial Structure and Firm Performance in Non-Financial sector of Pakistan. Journal of Basic and Applied Scientific Research, 2(7), 7107-7114.

Oil & Gas Development Company Limited. (2023). *Annual report 2022-23*. Retrieved from: https://www.ogdcl.com/Investors-Relation/Annual-Reports

Paul, C. J. M., Johnson, W. E., & Frengley, G. A. G. (2000). Efficiency in New Zealand Sheep and Beef Farming: The Impacts of Regulatory Reform. Review of Economics and Statistics, 82(2), 325-337.

Riaz, k., khan, I., Qayyum, A., & Khan, A. (2013). Technical Efficiency of Asian Energy Firms: A Bootstrapped DEA Approach. Journal of Basic and Applied Scientific Research, 3(5), 844-852.

Saleem, M. (2005). Technical Efficiency in Electricity Generation Sector of Pakistan: The impact of Private and Public ownership. The journal of Econometrics, 3, 325-332.

Shehzadi, A. (2023). Energy efficiency and productivity in emerging and developing Asian countries: A firm level analysis. *Journal of Asian Economics*, *88*(C).

Shehzadi, A., & Wetzel, H. (2024). Self-generation and outage losses: A firm-level analysis for emerging and developing Asian countries. *Energy Reports*, *11*, 2832-2840.

Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. Journal of econometrics, 136(1), 31-64.

Steering Committee for the Review of Commonwealth (SCRC)/State Service Provision. (1997). Data Envelopment Analysis: A technique for measuring the efficiency of government service delivery. AGPS, Canberra