“Green investment in South Africa: A perception of overinvestment or underinvestment in energy and mining firms”

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GREEN INVESTMENT IN SOUTH AFRICA: A PERCEPTION OF OVERINVESTMENT OR UNDERINVESTMENT IN ENERGY AND MINING FIRMS

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Abstract

This paper investigates green investments in energy and mining firms in South Africa to determine the efficiency level in terms of overinvestment and underinvestment. The general Richardson residual measurement model is employed, and an enhanced model is created by including variables that influence green investment, such as political connections and pollutant emissions. Data from 17 companies (5 energy and 12 mining) were used because of the significant effects of their operations on the environment over the period between 2015 and 2022. The study findings show that, in comparison to the estimated optimal investment level, South African energy and mining firms are not consistent regarding their investment level. It interplays between underinvestment and overinvestment. However, both firms demonstrated the tendency to green investment inefficiency due to underinvestment recorded in the latter years of the sample period. The study provides understanding as regards green investment levels of energy and mining firms and hence recommends adequate oversight and formulation of environmental policy by the government to ensure green investment efficiency in line with both national and international policies and regulations to facilitate a sustainable environment.

Keywords green investment, overinvestment, underinvestment, energy and mining firms, Richardson model, sustainable environment

JEL Classification Q56, R53

Conflict of interest statement:
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INTRODUCTION

Economic development may be hindered by diverse factors, like resource and environmental constraints. Some of the underlying causes of environmental constraints may be pollution surrounding three structural issues confronting an economy: energy pollution, industrial pollution, and traffic pollution. Thus, effective environmental protection efforts through green investment by these respective sectors are arguably considered a critical measure of tackling pollution of the environment (Liu et al., 2022). Green investments help in dealing with environmental issues while also providing important opportunities to participate in new forms of international initiatives. South Africa is the world's eighth-largest emission source of greenhouse gases and one significant opportunity to attend to pollution is to transition from burning coal to generating the majority of its electricity from clean energy technologies (BusinessTech, 2021). The country is planning a green investment plan worth $500 million (R7.9 billion). The Climate Investment Funds (CIF) would contribute at least $200 million (R2.9 billion) to this project, including a grant of $1 million for the plan's development. Ideally, the Clean Technology Fund's preparatory sum can influence extra mixed finance from development banks with a three-

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or four-to-one multiplier (BusinessTech, 2021). Eskom Holdings, the country's primary power generator and one of the world's largest sulfur dioxide emitters, is fundamental to the government's investment strategy, which also includes a hydrogen strategy and electric vehicles, however, with the state-owned utility losing money and being saddled with unfeasible debt, more funding will be needed for the nation to make the change. It has been estimated that R400 billion ($27 billion) will be required to build generators to replace coal-fired power plants, along with transmission and distribution infrastructure (BusinessTech, 2021).

From the aforementioned, the state of commitment of relevant stakeholders to ensure environmental sustainability need to be examined. This will assist in a critical scientific assessment of the effectiveness of green investments. Also, statistical evidence is scarce regarding the analysis of firm-level panel data samples on the effectiveness of green investments which is essential in helping policymakers, energy, and mining companies based on whether they signify over-investment or under-investment. This will ensure future resources are allocated to guarantee environmental sustainability. The questions therefore are: 1) What is the green investment efficiency at the energy and mining companies' year-by-year? and 2) How does green investment efficiency show firms' heterogeneity? This study will provide answers to these questions by examining the efficiency of investments in ecological sustainability in energy and mining firms in South Africa.

1. LITERATURE REVIEW

1.1. Examining the efficiency of green investment

In literature, investment efficiency is a subject that has become essential because it considers how profitable free cash flow is, which is the primary element that determines a firm's operations. According to Modigliani and Miller (1958), as relates to a perfect market, capital is allotted in a manner to permits its minimal output to stay constant in all economic projects. Tobin's Q, which indicates a company's investment opportunities, determines the profitability of an investment at the firm level (Hubbard, 1997; Tobin, 1969). This hypothesis serves as a groundwork for corporate investment, nevertheless, due to various frictions and distorting effects, a considerable disparity between real and maximum investments has been found.

Numerous studies have evaluated the sensitivity of investment to determine the discrepancy between actual and optimum investment, often known as investment efficiency (Biddle et al., 2009; Fazzari et al., 1988; Kaplan & Zingales, 1997; Kaplan & Zingales, 2000; Richardson, 2006; Whited, 1992). This approach has been extended by more recent studies to incorporate other viewpoints. For example, to assess the correctness of financial reporting, Yiwei et al. (2019) examined the variation of investment efficaciousness about shocks; ineffective corporate investment was explored by Chen et al. (2011) from the standpoint of state intervention; García Lara et al. (2016) examined whether the use of more cautious accounting techniques can increase a firm's investment efficiency, while Han and Zhang (2016) looked at the effectiveness of investment in the context of accommodative exchange-rate policy. There is, nonetheless, a paucity of studies that specifically examine how effective green investments are. Instead, an analysis of the aftermaths of green investment programs has been done (Czakó, 2012; Karásek & Pavlica, 2016; Korppoo, 2003); investigations into the factors and methods that affect green investments (Du et al., 2019; Eyraud et al., 2013), and Heinkel et al. (2001), Mielke and Steudle (2018) used simulations of the interplay between environmentally friendly investments and other variables from a game theory perspective. The effectiveness of green investments, however, must still be assessed at the micro level because types of investments can be essentially distinct from one another. Therefore, this paper will examine the efficiency of green investment as it relates to over and under-investment, hence the following hypothesis is proposed:

H1: Green investment in energy and mining firms is above or below the optimal level.

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1.2. Factors affecting the efficiency of green investment

When it comes to the factors that influence investment efficiency, the literature has two major stances. The first viewpoint focuses on investments made under constrained circumstances, which prevent a company from allocating funds to projects with net present values that are positive due to the high costs of raising investment capital. The effect of this can be underinvestment due to the abandonment of projects with positive net present value, hence, a decrease in the level of actual investment (Hubbard, 1997; Verdi, 2006). The second viewpoint has to do with choosing investments – investment opportunities. Making an investment decision that is both accurate and effective is not always attainable (Verdi, 2006). Political ties (Krueger, 1974; Liu, 2013; Ming et al., 2014; Xiong & Yang, 2016) and information asymmetry (Aboody & Lev, 2000; Myers & Majluf, 1984; Verdi, 2006) are two factors that may have an impact on investment decisions.

With only minimal modifications, the two viewpoints also hold when looking at the factors that affect the efficiency of green investments. First, governmental environmental policies are countered by investment constraints. Companies enforcing environmental rules must satisfy emission criteria, which are solely accomplished by spending money on pollution-control tools and infrastructure (Liao & Shi, 2018); this contrasts with mechanisms determining general investment efficiency. Companies desire to minimize emissions at the lowest possible cost under sound economic decisions Simon (1979) while hoping they will lead to green investment efficiency. Environmental regulations also promote the deployment of low-carbon emission technologies, which lower the costs associated with emission reduction, further enhancing the efficiency of green investments (Iyer et al., 2015; Liao & Shi, 2018). In terms of the second viewpoint, political connections can have an impact on general investment decisions; similar impacts applicable to decisions on green investment. Numerous studies since Krueger's (1974) initial investigation on the effects of political connections have centered on how such relations affect various facets of a company's activities (Bliss et al., 2012; SaeedBelghitar & Clark, 2015; Yu et al., 2020). For instance, it has been demonstrated that politically linked companies have a higher degree of receiving government financial assistance, consisting of lower costs (Bliss et al., 2012; Boubakri et al., 2012), higher returns (Cooper et al., 2010; Goldman et al., 2008), simpler loan approvals (Houston et al., 2014), tax reductions (Kim & Zhang, 2016), and subventions (Jin & Zhang, 2019). As a result, firms with connections to the political system can raise enough money to enable them to make larger investments in clean-air projects (Ge et al., 2017). Therefore, in examining the efficiency of firms' green investment (over or under-investment), the effect of investment opportunity on green investment is investigated and hence the following hypothesis is formulated:

H2: Investment opportunities positively affect green investment.

2. DATA AND RESEARCH METHOD

2.1. Sample and data source

Panel data covering the period of 2015 to 2022 of energy and mining firms were used for the analysis; the choice of the period was made because of the availability of data. Energy and Mining companies' operations have a significant impact on the environment. Data are sourced from the McGregor (IRESS) and Bloomberg databases.

2.2. Variable selection

The dependent variable is the green investment by companies in energy and mining firms. Emissions control costs noted in annual reports and sustainability reports are primarily included in the investing guidelines, and the general ledger for related accounting includes expenditures for general and administrative costs, non-operating costs, ongoing construction, and development and research costs (Liu et al., 2022). The independent variable is the investment opportunity. Details of the variable description are contained in Appendix A.

2.3. Model specification

2.3.1. Green investment efficiency

Green investment efficiency in South African energy and mining firms was quantified by employing Richardson residual measurement called "Model 1". It evaluates free cash flow investment efficiency (Richardson, 2006), while also, measuring the responsiveness of investment to cash flow and determining the level of overinvestment or underinvestment. Model 1 residual illustrates the effectiveness of eco-friendly investment. The positive residual demonstrates that green investment exceeds the recommended level, which is referred to as overinvestment. The negative residual demonstrates that green investment is below the ideal amount and is categorized as underinvestment. Model 1 by Richardson (2006) and used by Liu et al. (2022) was adopted for this study. It is constructed below:

$$GIV_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it} + \beta_7 GIV_{it-1} + \sum Year + \sum Ind + \varepsilon_{it}, \quad (1)$$

where GIV_{it} is $company_i$; Green investment in $year_t$; IOP_{it} is $company_i$ investment opportunity in $year_t$; and Lev_{it} is $company_i$ leverage in $year_t$ $Cash_{it}$ is $company_i$ cash flow in $year_t$; Age_{it} is the number of years that $company_i$ have listed in $year_t$; $Size_{it}$ is $company_i$ size in $year_t$; $OpRn_{it}$ is $company_i$ operating return in $year_t$, $GIV_{it\text{-}1}$ represents a green investment in the prior year. *Year* and *Ind* denote the year and industry effects, respectively, while $\beta_{0\text{-}7}$ denote the parameters to be estimated. ε_{it} is an error term that is independently and identically distributed. The variables listed above in Model 1 range from 2015 to 2022 in South Africa.

Scale, structure, environmental impact, and technical level are all characteristics of diverse environmental-related operations firms. This can lead to varying levels of performance in terms of green investment efficiency. This study separates the sample into the energy and mining industries. The green investment efficiency for every one of these samples is represented by the residuals of Equations (2) and (3).

$$GIV - Energy_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it}\ \beta_7 GIV - Energy_{it-1} + \sum Year + \sum Ind + \varepsilon_{it}, \quad (2)$$

$$GIV - Mining_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it} + \beta_7 GIV - Mining_{it-1} \sum Year + \sum Ind + \varepsilon_{it}, \quad (3)$$

where $GI - Energy_{it}$ represents the green investment of the $company_i$ in the energy industry in $year_t$; $GI - Mining_{it}$ represents the green investment of $company_i$ in the mining industry in $year_t$. Other coefficients remain unchanged as shown above.

2.3.2. Impact of investment opportunity and other control variables on green investment

Determination of the effect of investment opportunity and other control variables on green investment was examined using a second model "Model 2". Control variables pertaining to energy and mining company operations were included in Model 1. Estimating the efficiency of green investments was accomplished using Model 1 from the standpoint of all investments. While there are some similarities between green investments and conventional ones, there are also some crucial differences. Green investments have environmental characteristics and may be impacted by additional internal and external factors. Additional factors that were incorporated into Model 2 may have an impact on green investments, and the predicted green investment efficiency may offer empirical data that offer new insight into the potency of green investments in the energy and mining industries. The second group of control variables examined in Section 3.2 may have an impact on the evaluation of the efficiency of green investments in energy and mining companies. Model 2 was subsequently developed, which incorporated two control variables relevant to green investments, to adapt to the features of green investments and assure the reliability of the results. In Model 2, two sets of matching control variables were introduced, and their effects were

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separated from any other conceivably overwhelming effects. Political connections and pollutant emissions were the two control variables. Model 2 is stated as follows:

$$GIV_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it} + \beta_7 PEM_{it} + \beta_8 PC_{it} + \sum Year + \sum Ind + \varepsilon_{it}, \tag{4}$$

$$GIV - ENERGY_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it} + \beta_7 SOO_{it} + \beta_8 PC_{it} + \sum Year + \sum Ind + \varepsilon_{it}, \tag{5}$$

$$GIV - MINING_{it} = \beta_0 + \beta_1 IOP_{it} + \beta_2 Lev_{it} + \beta_3 Cash_{it} + \beta_4 Age_{it} + \beta_5 Size_{it} + \beta_6 OpRn_{it} + \beta_7 PEM_{it} + \beta_8 PC_{it} + \sum Year + \sum Ind + \varepsilon_{it}, \tag{6}$$

where $PCit$ stands for the political connections of $company_i$ in $year_t$ and PEM_{it} represents the pollution emissions of $company_i$ in $year_t$.

3. EMPIRICAL METHODOLOGY

After determining the investment efficiencies in the energy and the mining firms under research, this subsection outlines the empirical tests performed in the study to evaluate the influence of the investment determinants' variables and other control variables on green investment using Generalized Lease Square (GLS) estimation. Fixed Effects and Random Effects models are commonly used in panel data. This paper estimated both the fixed effects and random effects and performed the Hausman test to determine the appropriate technique to choose. The test suggested a random effects model. To further ensure the suitability of the estimate, more tests – the modified Wald test for groupwise heteroskedasticity and the Wooldridge test for autocorrelation in panel data – were conducted. The results suggested the presence of heteroskedasticity, while serial autocorrelation was not pronounced. This necessitated the estimation of GLS, which is more robust and controls for heteroskedasticity and serial autocorrelation.

3.1. Empirical results

3.1.1. *Descriptive statistics*

The descriptive statistics for the samples on green investment efficiency are shown in Table 1 for the sample period of 2015 to 2022. The descriptive statistics included the values for the mean, standard deviation, median, minimum, and maximum for each variable in the panel data. The green investment (GIV) had a mean value of –0.025, which indicated that GIV in proportion to a firm's total assets was small, therefore, there is room for improvement in firms' corporate social responsibility. Investment opportunity (IOP) had a mean value of 0.056, a minimum value of –1.336, and a maximum value of 0.978. The mean value was near the minimum, which is an indication that its effect on green investment was minimal, however, variables such as leverage(lev), operating return (OpRn), and political connection (PC) in the analyzed energy and mining firms, were generally similar, with standard deviations of 0.209, 0.212, and 0.236, respectively. In the same vein, the similarity between the standard deviation of GIV (1.326) and PEM (1.257) showed the association between them.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GIV	127	–.025	1.326	–2.194	2.818
IOP	117	.056	.257	–1.336	.978
Lev	136	.468	.209	.108	1.68
Cash	136	.089	.068	.003	.367
Size	136	7.175	.941	5.098	8.68
OpRn	136	.069	.212	–1.167	.733
PC	136	.059	.236	0	1
PEM	121	5.634	1.257	2.955	7.893

3.1.2. *Correlation matrix*

Table 2 shows the correlation analysis among the variables. The variables displayed both positive and negative relationships with the dependent variable (GIV). Generally, the analysis showed there is no multicollinearity among the variables.

Table 2. Pairwise correlations matrix

Variables	GIV	IOP	Lev	Cash	Size	OpRn	PC	PEM
GIV	1.000							
IOP	–0.435*	1.000						
	(0.000)							
Lev	0.343*	0.373*	1.000					
	(0.000)	(0.000)						
Cash	–0.157	0.198*	–0.264*	1.000				
	(0.077)	(0.022)	(0.002)					
Size	–0.887*	0.114	–0.172*	0.204*	1.000			
	(0.000)	(0.189)	(0.046)	(0.017)				
OpRn	–0.370*	0.051	–0.279*	0.393*	0.440*	1.000		
	(0.000)	(0.557)	(0.001)	(0.000)	(0.000)			
PC	0.346*	–0.085	0.343*	–0.254*	–0.351*	–0.064	1.000	
	(0.000)	(0.330)	(0.000)	(0.003)	(0.000)	(0.462)		
PEM	0.095	–0.025	0.142	0.027	–0.039	0.231*	0.466*	1.000
	(0.316)	(0.787)	(0.119)	(0.770)	(0.674)	(0.011)	(0.000)	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.1.3. Analysis of green investment efficiency

Figures 1 and 2 demonstrate, using Models 1, the green investment efficacy of the sampled energy and mining companies, year-by-year. The ideal level, as determined by the regression line, had a value of zero, meaning that the degree of real green investment exactly matches the level of anticipated investment. Underinvestment in green projects was indicated by negative green investment efficiency values, whilst overinvestment was shown by positive values. Underinvestment is the level of real green investment that is below the required level and is calculated based on a firm's internal and external circumstances. The level shows that the company is not making enough investments to match its internal capacity for eco-improvements or to satisfy the demands of its external environment. The reverse of such underinvestment is overinvestment, which is when a company makes more investments than are necessary; excessive green investment is the result of splurging cash on unproductive eco-projects. Considering the energy firms (Figure 1), the level of investment was below the optimum in 2015, however, from 2016 to 2021, the investment level improved, up to the optimum and beyond. In 2022, the investment level dropped as there was under-investment, hence, the energy firms did not achieve green investment efficiency in 2022. This was against expectations as regards the call for more investment in alternative energy as a solution to climate change problems. Considering the mining firms (Figure 2), the investment level was impressive from 2015 up to 2019 even though it was an overinvestment with some levels of efficiency, however, from 2020 to 2022, the investment level started degenerating into underinvestment. This is also against the tide regarding the corporate social responsibility of companies, especially those that have a direct influence on the environment. Overall, the study accepted the hypothesis that green investment in Energy and Mining firms is above or below the optimal level.

The trend of investment efficiency for both energy and mining firms is depicted in Figure 3. The energy firms' green investment from 2015 up to 2018 was below the optimum, showing a considerable investment efficiency, although, there was an improvement in 2019, 2020, and 2021. In 2022, however, the efficiency level slumped with the mining firms following the same direction. The investment efficiency was optimized from 2015 to 2019, but, from 2020 to 2022, the investment level dropped, showing no considerable investment efficiency in the year 2022. Therefore, hypothesis 1 that energy and mining firms are above, and below optimal levels is accepted.

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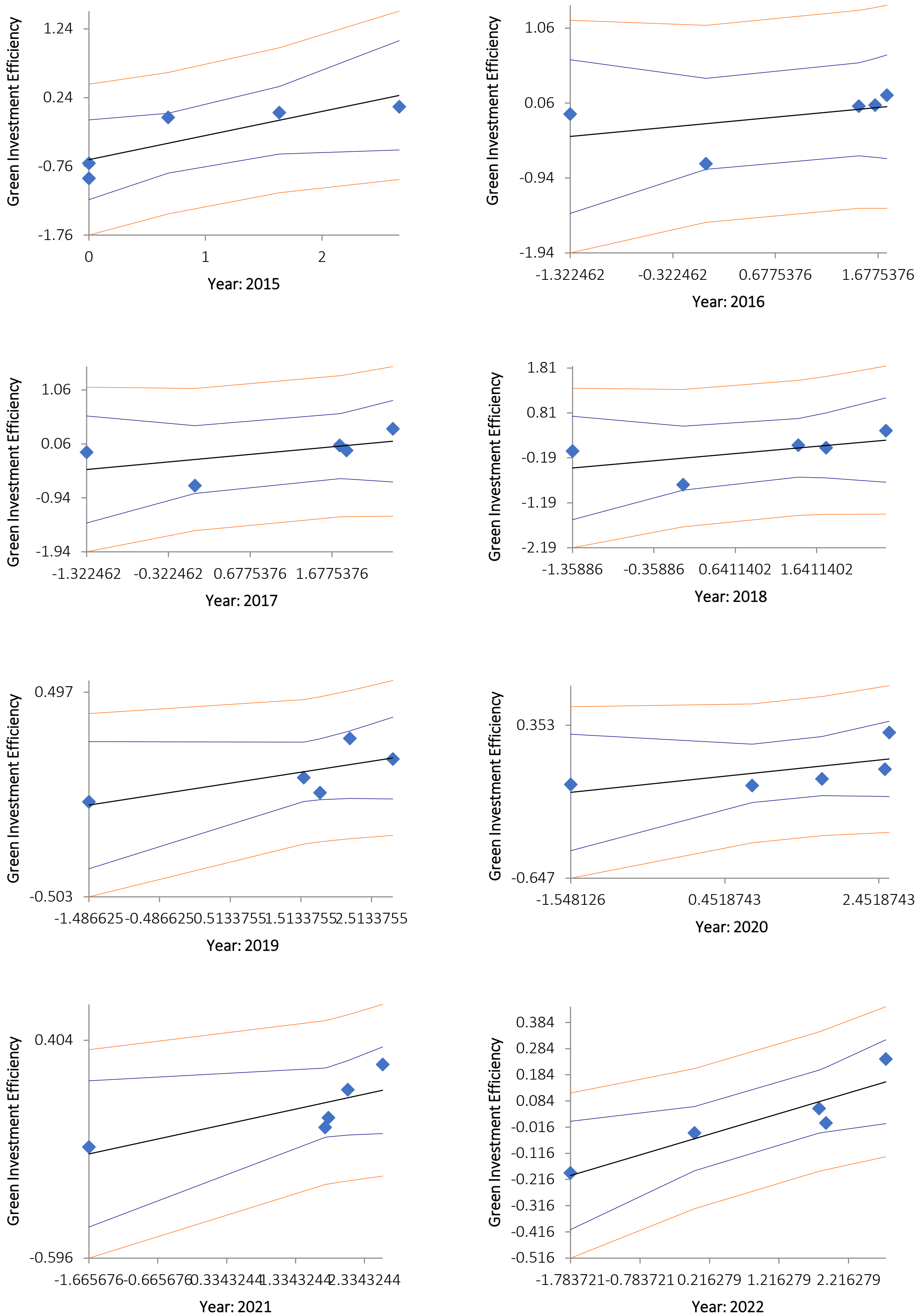

Figure 1. Energy firms

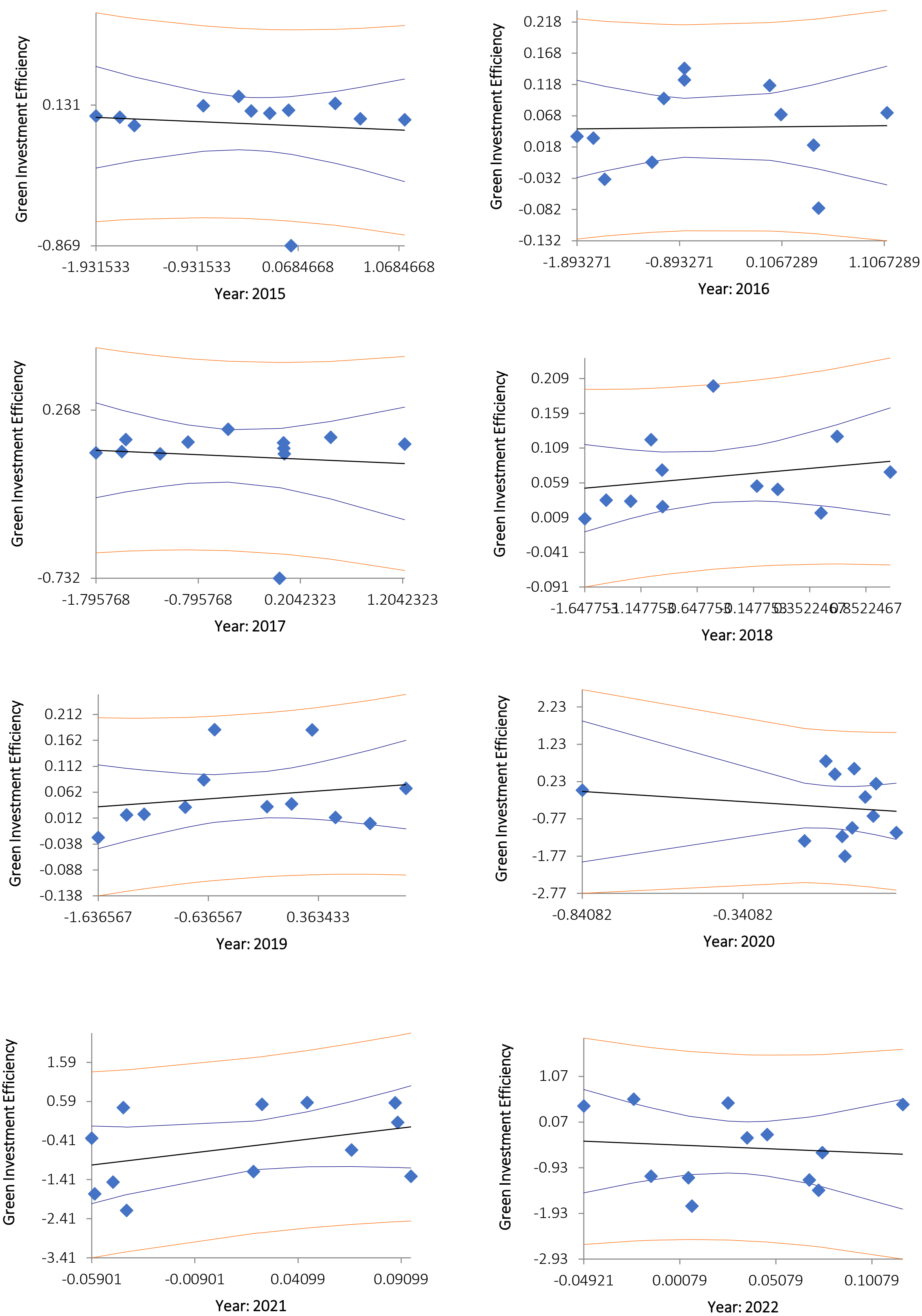

Figure 2. Mining firms

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Figure 3. Summary of over-investment and under-investment of energy and mining firms

3.1.4. Inferential analysis

In this subsection, the impact of investment opportunities on green investment was examined. Two additional variables – political connection and greenhouse gas emissions were considered together with other variables in the Richardson residual measurements model (Model 1). The study employed the Generalized Least Square (GLS) Regression as a robust estimate for Model 2. Fixed and Random effects are static techniques for panel models; both were estimated and the Hausman test was performed to determine which technique to choose. The results in Table 4 suggested that the null hypothesis, the Random-effects model, was appropriate and cannot be rejected with a p-value of 0.5272, however, GLS was estimated to address the possible issue of heteroscedasticity and serial autocorrelation; the regression results are shown in Table 5.

Table 4 revealed that investment opportunity had a positive impact on green investment and con-

Table 3. Hausman test

Variables	(b)	(B)	(b–B)	sqrt(diag(V_b–V_B))
	fe	Re	Difference	Std. err.
IOP	.209286	.3507072	–.1414212	.0562215
Lev	2.319605	2.60957	–.2899642	.1903636
Cash	–.8562682	–.5118719	3443963	.
Size	–.2746622	–1.184814	.9101514	.3368416
OpRn	.4476955	.6305257	–.1828302	.0838965
GAGEM	.0805371	–.0511789	.131716	.0969454

Note: chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 5.13 Prob > chi2 = 0.5272.

Table 4. Impact of investment opportunity on green investment

Variables	Fixed Effects	Random Effects	GLS
IOP	.209	.351**	.228***
	(.168)	(.159)	(.067)
Lev	2.32***	2.61***	1.77***
	(.444)	(.401)	(.237)
Cash	–.856	–.512	–.527*
	(.707)	(.71)	(.306)
Size	–.275	–1.185***	–1.282***
	(.377)	(.17)	(.096)
OpRn	.448	.631**	.284**
	(.274)	(.261)	(.123)
PC		–.417	–.205
		(.746)	(.188)
GHGEM	.081	–.051	–.09***
	(.137)	(.097)	(.032)
_cons	.326	7.629***	8.926***
	(2.755)	(1.284)	(.726)
Observations	101	101	101
Pseudo R^2	.4059	.8094	N/A
Year Dummies	Yes	Yes	Yes

Note: Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$.

firmed hypothesis 2. It had a coefficient value of 0.228 and was significant at a 1% level. This means that a unit change in investment opportunity will result in a 0.228 unit increase in green investment. This finding is consistent with other previous studies (Chen et al., 2011; Liu et al., 2022) in general, investment opportunities motivate general investment and confirm the hypothesis that investment opportunities affect green investment positively. These characteristics were also reflected in green investment, where leverage and operating return were positively correlated with a green investment with coefficients of 1.77 and 0.284 and significant at 1% and 5% respectively. Variables, such as Cash, Size, and Chgem, however, were negatively related to green investment with coefficients of –0.527, –1.282, and –0.09, respectively, at different significant levels. This means that a unit change in cash, size, and Chgem will lead to a decrease in green investment. Political connection (PC) had a negative effect on green investment but was not statistically significant, implying that variations in political connections do not affect green investment.

4. DISCUSSION

From the empirical results, the investment in ecology by energy and mining firms showed a dichotomy of behavior in terms of environmental sustainability. There is no consistent commitment to addressing ecological issues. The investment pattern reflects both overinvestment and underinvestment, but both companies have been underinvesting recently despite the global and national government's war readiness to combat environmental challenges. This finding is contrary to what Liu et al. (2022) found in China's energy sector. The study reported that environmentally friendly investments in the energy sector represent overinvestment, which means that the level of green investment was more than what was thought to be required. Furthermore, the external variable – pollical connections – reported a negative effect on green investment. This is contrary to the study by Liu et al. (2022) that reported a positive relationship between political connections and green investment. The reason for this may be a lack of proper oversight on the part of the government to ensure resources channeled to the state-owned enterprises are utilized as directed. Regarding pollutant emissions, it was expected to be positively correlated with green investment, however, according to Liu et al. (2022), the relationship between pollutant emissions and green investment is not one of direct causation, but rather one of intricate transmission that takes years to show any results. It suggested a minimum 20-year sample

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period to be able to achieve a positive and statistically significant correlation between pollutant emissions and green investment.

5. LIMITATIONS OF THE STUDY

The proportionate efficiency, which depicts the comparative level and evolution of green investment efficiency of energy and mining firms in the sample, was reflected in the green investment efficiency estimated using the Richardson residual measurement model. The model does not, however, give the efficiency's exact size; the sample size could be increased to overcome this issue. The study had a small size of 17 firms, which is against the accepted notion that a high sample size of at least 20 years is more representative of the ideal efficiency of green investments (Liu et al., 2022; Zahan & Chuanmin, 2021). Larger data samples, hence, could be employed for further studies.

CONCLUSION AND POLICY IMPLICATIONS

The study investigates green investments in energy and mining firms in South Africa to determine the efficiency level in terms of overinvestment and underinvestment. A general Richardson residual measurement model and an enhanced Richardson residual measurement model are used to achieve this. The enhanced Richardson residual measurement model incorporated two control variables – political connections and emissions of polluting substances. This enabled the internal and external characteristics of green investments to be captured. The study considered 17 firms (5 energy and 12 mining) because of the significant effect of their operations on the environment and data availability from 2015 to 2022 for the empirical analysis. The energy firms included Eskom, a state-owned entity. For each of these firms, the efficiency of green investments is evaluated, and factors influencing green investment are examined.

The empirical analysis produced insightful findings. During the sample period, the actual green investment was below what was thought to be required for South Africa's energy and mining firms. For instance, in energy firms, there was underinvestment from 2015 to 2018, although, there was some level of optimization at some point. From 2019 to 2021, there were improvements in the green investment levels which even showed overinvestment, however, the level dropped in the year 2022. This shows that inefficient green investment tends to be consistent, despite national and global calls for deliberate commitment to green investment, as a corporate social responsibility. The same can be said about the mining industries that show great inefficiency (underinvestment) from 2020 to 2022. The study contributes to the literature by conducting the first micro-level assessment of the efficiency of investment in a sustainable environment in South African energy and mining firms, building on earlier studies on the topic.

These empirical findings and analysis point to practical enhancements that may have to be implemented in terms of managerial and policy implementations to maximize the impact of green investments in the South African energy and mining industries. Firstly, since the government is planning to spend up to R7.9 billion on green investment and R400 billion on alternative sources of energy, there should be adequate oversight to ensure that underinvestment should be optimized especially in government-owned entities. Secondly, there should be fundamental improvements made to environmental policy, targeting green investment efficiency in both energy and mining industries; also, emphasis should be placed on the strict implementation of these policies.

AUTHOR CONTRIBUTIONS

Conceptualization: Oloyede Obagbuwa.
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APPENDIX A

Table A1. Variable descriptions

Variables	Abbreviation	Description	Sources
Green Investment	GIV	Log (pollution control costs/rehabilitation costs) total assets	Annual Financial/ Integrated Annual Report
Investment Opportunity	IOP	Net Profit/Shareholders' Equity	Annual Financial /Integrated Annual Report
Leverage	Lev	Total Liability/Sum of liability and equity	Annual Financial /Integrated Annual Report
Cash Flow	Cash	(Cash and Cash Equivalents + short-term Investment/Total Assets	Annual Financial /Integrated Annual Report
Firm Size	Size	Log (Total Assets)	Annual Financial /Integrated Annual Report
Operating Returns	OpRn	EBIT/(Opening total assets + Closing total assets)/2)	Annual Financial /Integrated Annual Report
Political Connection	PC	Dummy variable: 1 for State-Owned Enterprise, 0 if otherwise	Eskom Website
Pollution Emissions	PEM	Log (Tonne of Emissions tCO2e- Scope 1 + 2 + 3)	Annual Financial /Integrated Annual Report