THE EFFECTS OF RENEWABLE ENERGY INTEGRATION ON PROFITABILITY & EMPLOYMENT- A CASE OF SOUTH AFRICAN MINES

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By

ORATILE SIKOE

2399815

Supervised by Prof. Dambala Kutela

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ABSTRACT

The mining industry has been seen as one of the most energy-intensive industries in the world. That is also responsible for being a source of critical raw materials for other sectors in a country, such as manufacturing, construction, transportation, and energy sectors. In the past years we have observed an increase in mining companies adopting renewable energy in order to introduce cleaner energy sources into their mining operations. However, the economic effects of renewable energy source adoption are understudied in South Africa. This research is set out to examine and understand the effects of renewable energy integration into the mining industry on profitability and employment, with the use of the Autoregressive Distributed Lag Stationarity (ARDL) model. Our results revealed that there is a positive long-run relationship between renewable energy integration, employment, and mining profitability in the South African mining industry, including in the short-run. More specifically, the results show that the adoption of renewable energy sources bolsters both profitability and employment in the mining industry of South Africa such that a unit integration of renewable energy will most likely result in a respective percent increase in employment and mining profitability. Our research is the first of its kind in providing this evidence compared to related literature which is not industry specific. Overall, our findings underscore the importance of the transition by industries to renewable energy to simultaneously promote economic growth and ameliorate environmental quality in the context of developing countries where extractive industries pervade.

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1. INTRODUCTION

The mining industry can be seen as one of the most energy-intensive industries in the world. It is also responsible for being a source of critical raw materials for other sectors in a country, such as manufacturing, construction, transportation, and energy sectors (Igogo *et al.,* 2021). It is imperative for countries to have a reliable and adequate supply of raw materials to enable them to meet their socio-economic development goals (Kittipongvises and Dubsok, 2017). Several developed countries have benefited greatly from the mining industry and mineral investments, recently there have also been developing countries experiencing mineral-led economic growth as most developing countries have a higher reliance on the primary and secondary sectors.

The cost of electricity and other energy sources such as diesel and heavy oils for mines have increased substantially over the past years (Votteler and Brent, 2017). As a result, South African mine's business performance has been adversely affected by the constantly increasing energy costs. Energy costs are observed as some of the most significant expenses in mining operations and are on average about 15% to 40% of their total operational cost (Igogo *et al.,* 2021). With about 57% of the energy consumed coming from fossil fuels, of which 33% is from oil products, 13% from coal, and 11% from natural gas, this shows that mining is a highly dirty industry (Igogo *et al.,* 2021). This is also due to the fact that most mines are located in remote areas and must rely on diesel, heavy oils, and coal to some extent. While the mining industry provides developing nations with considerable opportunities for their development, there is an imminent need to reduce the negative effects of mining activities on the environment. The minerals extracted through the mining process are deeply intertwined with the global economy and are expected to maintain their crucial significance in the future (Kammen *et al.,* 2024). Consequently, it is important to tackle the environmental repercussions of mining operations, particularly as efforts to reduce greenhouse gas emissions and mitigate the impacts of global warming intensify (Kittipongvises and Dubsok, 2017).

In the past years we have observed an increase in mining companies adopting renewable energy sources and integrating cleaner energy sources into their operations, therefore there is a need to study how this renewable energy integration has an impact on mining companies.

1.2. PROBLEM STATEMENT

The mining and mineral industry is necessary for countries to have an adequate & reliable supply of minerals to meet their socio-economic development (Artiach *et al.*, 2011). Though important, the environmental impacts from mining are hugely significant. In addition, the overall performance of the mining industry in South Africa is negatively affected by constantly rising electricity and fuel costs (Neingo & Tholana, 2016). Therefore, there is a need now more than ever for the mining industry to adopt renewable energy sources into their energy mix. With recent amendments to the registration threshold for self-generation of electricity facilities from 1mw to 100mw, this could potentially help to allow mining firms to be able to generate their electricity.

The aim of this research is to examine the effects of integrating renewable energy into the South African mining industry on their profitability, and employment. To examine whether integrating renewable energy into South African mines will produce the same positive effects as some countries in the world, on their profitability and employment. The research aims to fill the knowledge gap and provide mining firms with the information they would require to be able to decide on whether to pursue integrating renewable energy into their energy mix and hopefully inspire more research to be done into renewable energy adoption in other industries and how governments and energy suppliers can foster these adoptions.

Microeconomic production theory examines how firms decide the quantity of raw materials to be utilized and the quantity of products to be produced and sold. They were examining the amount of output to be produced from a given set of inputs, and factors of production such as labour and capital (Igogo, *et al.*,2021). As per the Cobb-Douglas production function, the theory informs us that as better factors of production such as renewable energy are utilized in production better outputs can be expected and increased profitability of the firm. Similarly, as better human capital is employed in the production of the firm profits can be seen to increase, however surrounding renewable energy controversy this would mean more skilled employers would be required which leaves the question of what about the low-skilled individuals such as the general works that drive diesel bowsers in mines. This research aims to examine what the effects of renewable energy integration in mining firms may be in the sense of the above-mentioned factors of production.

1.2. RESEARCH OBJECTIVES

The focus of the research is to study the microeconomic effects of renewable energy integration profitability and employment of the South African mining industry. For the research, the main objective is to test how renewable energy and profitability relate to each other, along with renewable energy and employment in the South African mining industry. Additionally, the secondary objectives of the research are as follows; to examine how the integration of renewable energy into the mining industry can influence profitability and employment be it positive or negative. To examine the possibility of a long-run or short-run relationship among the mentioned variables. As well as to potentially influence and provide policy recommendations to foster the integration of renewables in mines.

1.3. RESEARCH QUESTIONS AND HYPOTHESIS OF THE STUDY

The study aims to answer the below research questions:

Will the integration of renewable energies have an impact on the mining industry’s profitability through investments in renewable energy infrastructure and systems, energy and electricity cost savings, and increased investor confidence?

Will the integration of renewable energies in the mining industry impact employment in the mining industry through the increased creation of jobs due to the construction of renewable energy systems or job losses as the mining industry moves away from dirty energy towards the cleaner kind?

1.4. HYPOTHESIS OF THE STUDY

H_0: There is no significant relationship between renewable energy integration and mining profitability (GDP) in South Africa

H_1: There is a significant relationship between renewable energy integration and mining profitability (GDP) in South Africa

H_0: There is no significant relationship between renewable energy integration and mining employment in South Africa

H_1: There is a significant relationship between renewable energy integration and mining employment in South Africa

1.5. SIGNIFICANCE OF THE STUDY

Recent increasing global carbon emissions from using fossil fuels are a great concern as a result of their negative impacts on the environment (Ziervogel, *et al.,* 2014). Climate change is one of the world's current pressing issues. Observed rapid climate change has a vast range of probable health, ecological, and physical impacts, such as extreme weather conditions and events, thus high dependence on non-renewable energy such as crude oil and coal of which the South African mining industry makes use of form part of the global carbon emissions (Ziervogel, *et al.,* 2014). The mining industry can be seen as one of the most energy-intensive industries in the world therefore, there is a need to introduce more renewable energy sources in their operations (Ziervogel, *et al.*, 2014).

One of the objectives of the research is to examine whether renewable energy integration in the South African mining industry will have an impact on the industry's profitability and employment. As a result, the study will seek to determine whether increasing the rate of integration of renewable energy in the mining industry can potentially provide solutions to the mining cut and save on energy costs improving their profitability. And to potentially increase employment in the industry, or alternatively maintain and avoid job cuts as a result of decreased energy costs and reliable energy supply. This may provide direction to policymakers to assist them in making well-informed policy decisions regarding the emerging renewable energy sector in the country.

The renewable energy sector has only recently gained much interest as it is relatively new in the field of economics, therefore more studies can be done to develop and increase awareness. Environmental issues such as global warming, which stem from increasing carbon emissions from industries such as the mining industry, give the study the perspective of what ought to be done to combat such a global crisis. As global warming and the use of non-renewable energies are of great concern currently, conducting research on renewable energies is crucial (Ziervogel, *et al.*, 2014). The findings of this research are important and relevant to contribute to the established body of existing knowledge in the context of the renewable energy sector and the mining industry.

The empirical literature will provide gaps on which the study will aim to contribute, therefore it is enabling policymakers to make policy decisions based on the new knowledge and information that has come into light.

1.6. CONTRIBUTION OF THE STUDY

The research outcomes will show that there are opportunities for the integration of renewable energies in the South African mining industry, and these renewable energy resources should be an area of focus for mining houses and policymakers. The results will enable policymakers to make industrious policies in the context of the South African mining industry. The research seeks to assess and identify any issues regarding the integration of renewable energies in the mining industry, and the actions that can be taken to resolve these issues.

The outcomes of the research should assist the Department of Mineral Resource and Energy, as well as the Minerals Council of South Africa and policymakers to not only understand but to consider the importance of integrating renewable energy in the mining energy systems. Additionally, to aggressively promote the development of renewable energy projects in mining. The research will cast a light on the potential short-term and long-term effects of renewable energy on the employment and the profitability of the mining industry, assisting policymakers in making well-informed decisions to mitigate any challenges renewable energy integration in the mining industry may pose to employment and profitability.

1.7. OUTLINE OF THE STUDY

The study will be organised as follows: Chapter one will introduce the topic to be investigated, the research objectives, the hypothesis of the study, as well as how the study will contribute to various policymakers and mining agents. The second chapter of the study will unpack the theories behind the renewable energies and mining industry as well as the studies done pertaining to the topic at hand. Chapter three entails the research design incorporated, which will explain all the techniques. Chapter four will unpack the results and analysis of the study, and lastly, the chapter will present conclusions along with policy recommendations.

2. LITERATURE REVIEW

There is a gap in the literature available that this study aims to fill with present studies that have looked at similar factors. The challenge in the availability of literature does however pose opportunities to look at previous studies that have investigated the opportunities that mining companies can explore with renewable energy integration.

2.1 THEORETICAL BACKGROUND

Controversy surrounding renewable energy as a job creator or job killer is taking place amid the transition from fossil fuel energy and renewable energy (Moyo *et al.,* 2017). Many authors believe that renewable energy development as an emerging energy creates new jobs through the increase of investors (Zhao and Luo, 2017). This corresponds to the work of Votteler and Brent (n.d) in South Africa, where they see that renewable energy integration as hybrid systems have job creation potential contrary to the findings of Zhao and Luo (2017) where they find no evidence of renewable energy generation as a job creator. However, they do find that employment can in turn encourage the development of renewable energy, this could be in the sense that when more people are getting employed there may be an increased need for renewable energy generation as more people may afford it or require more energy for usage, and governments may be forced to look other forms such as renewable energy as an energy source. To date, renewable energy like the ones used for energy generation through wind and solar power is more affordable than the conventional technologies and energies presently used in mines, as the commonly utilised energies have much higher prices (Lazard, 2000). The use of renewable energy in mines has the ability to offer a great opportunity to reduce the energy costs and carbon emissions of mines (Ziervogel, *et al.,* 2014). Making the mining industry less concerned about the fluctuations in fuel prices. Renewable energy provides a great economic opportunity where mines can also earn additional revenue and increase their profits by selling surplus electricity generated by renewable technology (Mahdi et al., 2023).

Applying the Autoregressive Distributed Lag (ARDL) and Johansen cointegration technique, (Lin and Maubarak, 2014) analysed the relationship between renewable energy consumption, GDP, carbon dioxide emissions, and labour. The presented results indicated that there is a bi-directional causality between renewable energy consumption and economic growth and that labour impacts renewable energy consumption in the short run (Zhao and Luo, 2017). Still, there exists no evidence of causality between carbon emissions and renewable energy consumption (Zhao and

Luo, 2017). Of which the study by Sebri and Ben-Salha (2014) employing a similar method revealed results that correspond to the work of Lin and Maubarak, however, the bi-directional causality between renewable energy consumption and economic growth may be contrary to beliefs that as the economy grows more renewable energy will be consumed, essentially implying that economic growth may not cause renewable energy consumption in some cases such as those of countries that rely on dirty energy.

In the context of energy economics, there are numerous research papers about the causality between economic growth measured with respect to Gross Domestic Product (GDP); a proxy for profitability in the context of this research, energy consumption, and other related variables C02 emissions in both developing and developed nations.

2.1.1 GROWTH HYPOTHESIS

Energy consumption plays a vital role in driving economic growth. Especially for an economy that is heavily reliant on energy, this theory suggests that higher energy consumption correlates with increased real GDP. Consequently, a decrease in energy consumption limits economic growth.

2.1.2 CONSERVATION HYPOTHESIS

This hypothesis contends that the consumption of energy is determined by economic growth and not vice versa; hence an increase in real GDP accelerates energy consumption. On the contrary, this hypothesis relates to energy conservation policies that are aimed to minimise energy consumption and waste, and therefore may not have a detrimental impact on real GDP. Thus, if these policies could be enforced with little or no detrimental impacts on economic growth. In this sense, a unidirectional causal relationship that runs from economic growth to energy consumption insinuates that a country is not entirely energy-dependent for its economic growth.

2.1.3 FEEDBACK HYPOTHESIS

Where real GDP and energy consumption are interdependent, with bi-directional causality between them. This hypothesis also demonstrates that an energy policy aimed at improving energy usage efficiency will not have a harmful effect on economic growth.

2.1.4 NEUTRALITY HYPOTHESIS

This hypothesis does not establish a causality between economic growth and energy consumption. In other words, energy consumption is not intricately linked with GDP, which might mean that energy expansion or conservation policies have no impact on economic growth and therefore have no impact on energy consumption.

2.2. EMPIRICAL BACKGROUND

According to Igogo *et al.*, (2021), mining companies have to rely on diesel, coal, and dirty energy sources due to the remoteness of their locations. The authors do believe that in principle, mines could use renewable energy, energy recovery, and carbon capture to replace, supplement, and mitigate the environmental and economic impacts of using fossil fuels (Igogo *et al.*,2021). The mining industry is susceptible to supply and demand shocks which in turn affect metal and energy source prices as seen with the Russian-Ukraine war (Igogo *et al.*,2021). Due to the price shocks experienced the cost of production and revenue of mines is affected. With the electricity use by mines trend slowly coming to an end as energy prices increase and mines face a carbon tax, mines have been exploring renewable energy sources with self-generation options of up to 100 MW without having to comply with inconvenient licensing requirements (tralacBlog, 2021).

Votteler and Brent (2017) examined the potential of renewable electricity sources for mining operations in South Africa, where they found results that electricity from Eskom and a renewable source particularly solar and onshore wind possessed the greatest potential for South African mines. With A diesel hybrid version being the lowest-performing source. An onshore wind hybrid version had similar results as the solar PV hybrid, however, the wind hybrid slightly has a lower job creation potential than solar PV.

Recent works of literature regarding renewable energy showed that labour, technological progress, capital, and economic growth as the basic elements for renewable energy development.

Zhao and Luo (2017) examined the development of renewable energy in China by studying the driving forces of the quality of the environment, regulations, and the employment of renewable energy generation. The authors adopted renewable energy as a metric for the quality of the environment and evaluated the relationship between income and renewable energy using Environmental Kuznets Curve (EKC) theories (Zhao & Luo, 2017). The observed results revealed a quadratic relationship between renewable energy and income however, they failed to provide evidence that renewable energy generation is a job creator in China when the lagged unemployment rate is included as an explanatory variable (Zhao & Luo, 2017). When the authors considered the employment population, the results indicate that employment can contribute to the development of renewable energy (Zhao & Luo, 2017). Contrary to Votteler and Brent (n.d), the authors fail to provide an energy-specific examination to specify which exact renewable energy source failed to show evidence of job creation, while Votteler and Brent specified that solar PV had higher job creation potential than wind.

Choi and Song (n.d), presented a wind and PV power systems review used in operating mines around the world, the considered energy systems were found not to meet 100% of the energy demands of mining sites. However, they present significant energy cost savings and energy backup for mines when storage is available.

Pao and Fu (2013) looked at the relationship between real GDP and four types of energy consumption: total primary energy consumption (TEC), total renewable energy consumption (TREC), non-hydroelectric renewable energy consumption (NHREC), and non-renewable energy consumption (NREC) (Romero, *et al., 2020*). They utilised the annual data during the period of 1980 to 2010 and they used the cointegration test which indicated the long-run equilibrium in Brazil's labour force, real GDP, and the types of energy consumption. The authors pointed out that NHREC and TREC influence real GP positively, whereas NREC and TEC impacts are insignificant. VEC models indicated a unidirectional relationship from NHREC to economic growth, a bidirectional relationship between TREC and Real GDP, and a unidirectional relationship from economic growth to TEC and NREC in the long run, without feedback (Omri, 2014). The authors recommend that Brazil should expand renewable energy, which will not only stimulate economic growth but also enhance its leadership role in order to compete with developed countries, given the fact that Brazil is an independent energy economy.

Dreger et al. (2011) examined the long-run causality between real GDP and renewable energy consumption, including energy prices for 25 OECD countries for the period 1981- 2007 by using annual data. Cointegration between the variables indicates that international developments dominate the long-run causality between real GDP and energy consumption. Moreover, the results propose that energy consumption is price inelastic. Causality tests revealed a bi-directional causal relationship between energy consumption and economic growth (Omri, 2014). The authors are of the view that policymakers should consider the international impact on energy demand when developing efficient energy policies.

Bhattacharya et al., (2015) examined the impact of renewable energy consumption on economic growth in 38 countries. Panel data for the period 1991 to 2012 was used by the authors, they utilized ordinary least squares (OLS) to evaluate long-run elasticities. GDP was used as the dependent variable and LB, GFCF, and REC were used as independent variables. Their findings reveal that there is a positive and significant long-run relationship between renewable energy consumption and economic growth.

Zaman et al. (2015) carried out a study to determine whether the consumption of renewable energy adds to economic growth, they incorporated labour and capital as potential determinants of production function in the case of Pakistan. The research made use of the auto-regressive distributed lag (ARDL) model as well as the rolling window approach (RWA) for cointegration. The study utilized quarterly data for the period 1972Q1 until 2011Q4. The analysis was applied through the vector error correction model (VECM) Granger causality and innovative accounting techniques. The results of the study are cointegrated and show long-run causality among the variables. Moreover, renewable energy consumption (REC), capital (K), and labour (L) boost economic growth. The causality analysis reveals that there is a feedback effect between renewable energy consumption and economic growth.

Saad and Taleb (2017) investigated the causal relationship between economic growth (GDP) and renewable energy consumption (REC) in 18 European countries. They utilised annual data for the period 1990 to 2014 by applying the panel vector error correction model (VECM). Furthermore, the Granger causality test was applied to determine the linkage between renewable energy consumption (REC) and economic growth (GDP). Their results reveal unidirectional causality that runs from economic growth (GDP) to renewable energy consumption (REC) in the short run. Although, there is bidirectional causality between REC and GDP in the long run.

Fang (2011) examined the relationship between GDP, renewable energy consumption and its share, labour, and capital, and the per capita research and development expenditure using the Cobb-Douglas production function. The author found that renewable energy consumption has a positive and significant impact on real GDP and GDP per capita, GDP which can be used as a proxy for the profitability of industries in an economy. Similarly, Inglesi-Loz (2016) employed the Cobb-Douglas function to examine the impact of renewable energy consumption, employment, and research and development expenditure on economic welfare using panel data techniques. The results displayed that there was a positive and statistically significant influence between the variables. Indicating that in the above authors' case in which they found similar results, as renewable energy consumption increases GDP can also be expected to increase and potentially as well have positive impacts on employment. This contradicts the widely held belief that renewable energy is a job killer, especially in countries that are highly dependent on dirty energy generated from coal.

3. RESEARCH METHODOLOGY AND DESIGN

The proposed objectives that were developed in the study proposal will be analysed using multiple regression techniques and annual time series data and analysis techniques, specifically the autoregressive distributed lag (ARDL) approach. A cointegration test is utilised to analyse the long-run equilibrium relationship among variables. The data will be quantitative secondary data obtained from the financial statements of mines in South Africa over a 12-year period.

The advantages of the ARDL approach include the fact that it does not need any unique order of integration of the variables. It can be utilised whether the variables are integrated of order zero I(0) or of order one I(1). Another advantage of this approach is that the short-run and long-run coefficients can be estimated simultaneously and lastly, the ARDL is more suited for smaller samples compared to methods such as the Engle-Granger test.

3.1 DATA SOURCES

The data will be obtained using secondary quantitative data from the different annual statements of the mines. The measurements of the proposed study will observe and record the secondary quantitative observations using STATA. This level of measurement will be numeric as data will not possess any ordinal or nominal properties.

3.2 DATA DESCRIPTION

The proposed dependent variables are profitability and employment. While the independent variable is renewable energy consumption. Control variables will include labour force and gross fixed capital formation.

(a) **Labour Force (LF):** Consists of individuals from the age of 15 that fall into the economically active population of the International Labour Organization: these are all the individuals who provide labour that will produce goods and services during a specified duration. This involves both the unemployed and the working (StatsSA, 2020). This data is sourced from the World Bank indicators database. It is an important control variable when using GDP as a proxy for profitability in the mining sector because it represents investment in physical assets like machinery and infrastructure, which are critical to the sector's long-term growth and productive capacity. This helps distinguish the effects of capital expansion, such as new mines or technological upgrades, from profitability fluctuations. It is an important is a key input in production, because it directly influence output and profitability.

(b) **Renewable Energy Consumption (REC):** Electricity consumption produced from numerous renewable energy sources in the energy mix from South African Mines. This data is sourced from the World Bank indicators database. REC is an important control variable for GDP in the mining sector helps assess its impact on reducing operational costs, improving profitability through sustainability, and attracting investment by meeting environmental standards.

(c) **Gross Fixed Capital Formation (GFCF):** Consists of producer’s investments over a period. This is used as a proxy for investment in renewable energy projects in the mining industry. The data is sourced from the SARB statistical query. It is an important control variable when using GDP as a proxy for profitability in the mining sector because it represents investment in physical assets like machinery and infrastructure, which are critical to the sector's long-term growth and productive capacity. This helps distinguish the effects of capital expansion, such as new mines or technological upgrades, from profitability fluctuations.

(d) **Employment (EMPL):** This is defined as a consensus between an employer and an employee that the employee will provide specific services. In this instance, the contribution of mining towards GDP in South Africa is used as a proxy for employment. The data is sourced from the SARB statistical query.

(e) Profitability (PROF): This is the measured difference between the revenue received from services provided or goods sold by a firm, and the total costs incurred by the firm.

3.3 MODEL SPECIFICATION

The ARDL approach would be carried out to examine the short-run and long-run relationship. The ARDL bounds test with error correction terms will be formulated as proposed for (1) Profitability and (2) Employment:

$$LnEMP_t = Ln\beta_1 CTX_{t-1} + Ln\beta_2 CPF_{t-1} + Ln\beta_3 EXPRE_{t-1} + Ln\beta_4 GDP_{t-1} + Ln\beta_5 LB_{t-1} + Ln\beta_6 EC_{t-1} + \varepsilon_t \; .... (1)$$

$$LnPROF_t = Ln\beta_1 CTX_{t-1} + Ln\beta_2 CPF_{t-1} + Ln\beta_3 EXPRE_{t-1} + Ln\beta_4 GDP_{t-1} + Ln\beta_5 LB_{t-1} + Ln\beta_6 EC_{t-1} + \varepsilon_t \; .... (2)$$

Where ECt−1 represents the lagged error correction term obtained from the long-run cointegration function. When the t-statistic on the EC is significant it would show the presence of a long-run relationship, while when it has significant variables in first differences it indicates evidence of short-run relationships. To verify the goodness of fit of the proposed model, diagnostic tests for serial correlation, function form, normality, and heteroscedasticity will be performed.

3.4 RESEARCH TECHNIQUES

3.4.1 STATIONARITY TESTS

Stationarity is an essential feature of giving the variables employed in the model statistical credibility. Stationary testing is important to ensure the validity of the results. This means that the results of statistical research can be interpreted in a meaningful way. Unit root test is used to test the stationarity of the variables which are non-stationary and can lead to giving the wrong estimation. In plain terms, the Yt time series is stationary if these conditions are met:

- E(Yt) = constant for all t;
- Var(Yt) = constant for all t; and
- Cov (Yt, Yt+k) = constant for all t and all k _= 0, or if its mean, variance, and covariances remain the same over time (Asteriou & Hall, 2011).

3.4.2 AUGMENTED DICKEY-FULLER (ADF) TEST

Dickey and Fuller (1979, 1981) developed a non-stationary test model. The main idea of their analysis was to test for non-stationary if it is equal to checking the presence of a root unit. The test model is shown below:

$\Delta Y t = \alpha + \gamma yt\text{-}1 + \lambda t + \Sigma api{=}1i\Delta yt\text{-}i + \varepsilon t$………………………. (4)

$\Delta Y t = \alpha + \gamma yt\text{-}1 + \Sigma api{=}1i\Delta yt\text{-}i + \varepsilon t$……………………………. (5)

In this shown time series regression, the letter "t" represents the trend variable and, εt presents the white noise error term. Therefore, in equation 5, the alternative hypothesis of a unit root that occurs in the autoregressive interpretation of a time series is measured as α = 0, and it is evaluated against the alternative hypothesis of a stationary process, for instance, α ≠0

3.4.4 JOHANSEN COINTEGRATION TEST

The Johansen Cointegration test is performed following Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests of unit root. As stated by Komaruman (2011), the Johansen Cointegration procedure is applied to check for cointegration in the vector process. Autoregressive Lag Length is required in the Johansen cointegration procedure. According to Bum (2009), there are mainly two methods for cointegration test, which are Johansen and Juselius, Engle and Granger. However, in this study, Johansen cointegration is preferred as Bum (2012) suggested that Engle and Granger as some drawbacks such as subjective normalisation of parameters and finding it hard to approximate enough cointegration vectors.

The presence of cointegration is detected when the null hypothesis reveals that there is no cointegration and can be rejected at none. The decision is based on the basis that the critical value is less than the trace-statistic value, thus in such case, the null hypothesis is rejected. Furthermore, if the prob value is less than the level of significance of significance (0.05), the null hypothesis is rejected. At most one, there is the presence of one cointegration equation as shown by the null hypothesis. The rejection and acceptance of the null hypothesis is concluded on the comparison between the critical value and trace statistic value. There is cointegration when the critical value is greater than the trace statistic value and the null hypothesis cannot be rejected.

3.4.5 AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) MODEL

The research will employ the Autoregressive Distributed Lag (ARDL) approach in order to determine the long-run relationship between the impacts of energy consumption on economic growth in South Africa for the period of 1990 - 2017. Odhiambo (2009) is of the view that this approach makes it attainable to estimate both the short-term and long-term coefficients of the single equation cointegration process. The coefficients of the method are unregulated and, as such, the short-term dynamics are not determined by the long-term equilibrium relationship. As such another motivation for this research to pursue the ARDL model is that it has the best small sample properties, as opposed to both the Engel and Granger (1987) procedures and Johansen (1991, 1995) maximum probability reduced rank.

ARDL model is considered to be flexible, as a result, it can be utilised irrespective of variables with different orders of integration, whereas the Johansen technique requires that the variables should be integrated of the same order. In addition, the ARDL approach is strong enough to overcome the residual serial correlation and the issue of endogenous regressors at the same time, as a result, this offers the ARDL an advantage over other co-integration approaches. Inder (1993) contends that the ARDL method is more accurate and dependable in small samples than in the Johansen technique.

The ARDL technique provides precise tests for the identification of a unique cointegration vector, however, just like any other single equation cointegration technique, it also suffers from a weakness that can only be valid when there is a unique cointegration vector. However, Muchapondwa and Pimhidzai (2011) are of the view that there is no certainty that a unique cointegration vector will always be there. Peseran et al. (2001) introduced the model of Autoregressive distributed lag (ARDL) to integrate I (1) and I (0) variables in the same model. Peseran et al. (2001) maintain the view that, before estimating the model at hand, the regressand variable should be non-stationary in order for the model to perform correctly. Peseran et al. (2001) and Beloumi (2014) contend that variables employed in the model ought to be incorporated in order I (2) under normal or structural conditions. The ARDL cointegration model can be specified as follows:

$$GDPt = \beta 0 + \Sigma\, ni{=}0\beta 11\Delta GFCFt\text{-}1 + \Sigma\, ni{=}0\beta 12\Delta LFt\text{-}1 + \Sigma\, ni{=}0\beta 13\Delta RECt\text{-}1$$
$$+\ \lambda 11GFCFt\text{-}1\ + \lambda 12LFt\text{-}1 +\ \lambda 14RECt\text{-}1\ +\ \mu t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$\beta 0$ represents the constant term, $\beta 11 – \beta 14$ and $\lambda 11 – \lambda 14$ represents the regression coefficients in the model and μt represents the error term of white noise.

3.6.4 ERROR CORRECTION MODEL (ECM)

The ECM model is a time series regression model employed to test the cointegration relationship between two or more variables in the model. The ECM has the advantage of including short-run and long-run information to correct the disequilibrium of the model in the previous period. The ECM coefficient is referred to as the ECT, it has to be negative and statistically significant to accept evidence of a long-run relationship between the dependent variable and explanatory variables.

The error correction model (ECM) can be expressed as follows:

$$GDPt = \beta0 + \Sigma\ ni{=}0\beta11\Delta GFCFt\text{-}1 + \Sigma\ ni{=}0\beta12\Delta LFt\text{-}1 + \Sigma\ ni{=}0\beta13\Delta RECt\text{-}1$$

$$+ \pi5\ ECMt\text{-}1 + \mu t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (9)$$

$\beta0$ represents the constant term, $\beta11 - \beta14$ and $\lambda11 - \lambda14$ represent the regression coefficients in the model, ECMt-1 represents the error correction and μt represents the error term of white noise.

3.4.5.1 Requirements for The Application of Autoregressive Distributed Lag Model (Ardl) Approach to Cointegration Testing

Regardless of if the estimated parameters are of I(0) or I(1) or a combination of both, the ARDL technique may be utilised. This assists in preventing pre-testing issues related with a conventional co-integration analysis which involves the classification of variables in I(0) and I(1) (Nkoro and Uko, 2016). As a result, this ensures that the bound co-integration testing process does not need a pre-testing of the variables used in the unit root model and is stable because there is a single long-term relationship between the underlying variables. If the F-statistic value in the Wald test reveals that a single long-run causality exists and sample data is small, the ARDL error correction presentation is becoming relatively more effective. If the F-statistic value in the Wald test reveals that there are multiple long-run causal relations, therefore, the ARDL technique cannot be used. Consequently, the Johansen and Juselius (1990) technique can be utilised. If the F-statistics or Maximal eigenvalue reveals that there is a single long-run causality, the ARDL technique can be used instead of Johansen and Juselius technique.

3.4.5.2 Steps of ARDL Cointegration Approach

The following steps determine whether the aforementioned requirements regarding the ARDL approach are met:

Step 1: Estimation of the presence of the long-run relationship of parameters. In the first step, the presence of a long-term relationship among the variables under examination is evaluated by the computation of the Bound F-statistic, in order to determine a long-term relationship between the variables. Therefore, this bound F-statistic is performed on each of the variables since they are known to be endogenous variables whereas others are considered to be exogenous variables.

Step 2: Choosing the suitable lag length for the ARDL Model

Nkoro and Uko (2016) maintains the view that, to select the correct model of the long-term underlying equation, it is important to calculate the appropriate lag length(k) by applying proper model order selection criteria, like; AIC (Akaike Information Criterion), SBC (Schwarz Bayesian criterion) or HQC (Hannan-Quinn criterion).

Step 3: Reparameterization the ARDL Model into ECM (Error Correction Model)

If there is a case of spurious results, the data should be different in order to achieve stationarity in the parameters. However, the regression equation tends to give us short-run causal relations among variables. As a result, it does not provide information regarding the long-run behaviour of the variables in the model. Thus, the concept of ECM is imperative, as it reveals both long-run and short-run information.

3.4.6. Advantages of Utilising The ARDL Approach (Nkoro And Uko, 2016)

Besides the fact that this model can also be used to assess non-stationary parameters, it also integrates lag structures and therefore can easily be expanded to include panel data. Endogeneity in the model is not a concern since it is free from residual correlation and the parameter estimates are a single equation. The ECM can be constructed from the ARDL model through the use of a simple linear transformation that combines short-term changes with long-term balance without losing long-term information. The ARDL model can differentiate between regressor and regressand variables in the midst of a single long-term relationship and can classify co-integrating vectors in the presence of multiple cointegrating vectors.

Disadvantages of utilising the ARDL approach (Nkoro and Uko, 2016)

There may be difficulties in successfully determining the correct correlation between variables in the data comprising the root unit, as problems of spurious correlation could arise. If there is a stochastic (random) trend in the data, the ARDL model will estimate the trend instead of modelling the actual dynamics.

4. RESULTS AND DISCUSSIONS

4.1. DIAGNOSTIC TESTS

To establish the successful performance of the regression model numerous diagnostic tests, have to be performed.

4.1.1. NORMALITY TEST

It is assumed that the residuals are normally distributed with a zero mean and as well as a constant variance which is necessary to test the residuals. Asteriou and Hall (2011) proposed that the violation of this assumption will result in an inferential statistic of a regression model not being valid to study it. The Jarque-Bera (JB) test of normality quantifies the kurtosis and skewness measures of the OLS residuals. The p-value of the test needs to be greater than 0.05 percent level of significance.

4.1.2 HETEROSCEDASTICITY TEST

A situation that occurs where the variance of the model is not constant and violates the CLRM assumption, whereas homoscedasticity occurs when there is an equal spread of variance which can lead us to accept the null hypothesis. In econometrics, it is used to measure the spread of the variance. Asteriou and Hall (2011) emphasised that heteroscedasticity is likely to occur in cross-sectional data, however, it does not imply that time series data cannot experience heteroscedasticity. It can be detected by using a two-ways approach, firstly the informal way of graphs, and secondly by using appropriate tests to come to the conclusions of the goodness of fit of the model. The white heteroscedasticity test is an LM test that does not depend on normality assumptions, and it can propose a particular choice for explanation in a regression.

4.1.3 SERIAL CORRELATION TEST

To avoid the residuals being corrected, the presence of serial correlation should not be detected. The DW test will be utilised to determine the presence of serial correlation among variables. Certain assumptions need to be met in order to validate the test such as, a constant term needs to be included in the regression model, the formula should not contain a lagged dependent, and the serial correlation is only assumed to be only of the first order. The DW test's drawbacks are corrected by the LM test developed by (Breusch & Godfrey, 1978) to accommodate the different errors left out of the DW test.

4.1.4 RAMSEY TEST

This test is performed to check if the regression functionality is normal. Therefore, the p-value of the test should be greater than 0.05 percent level of significance.

4.1.5 CUSUM AND CUSUMSQ TEST

CUSUM and CUSUMsq tests will be used to test the accuracy of the variables using the significance level of 5%. The blue line should not cross the two red lines using a 5 percent level of significance.

4.1.6 JARQUE-BERA

The Jarque-Bera test will be used to test for the underlying distribution of the data, and to test if the data follows normal distribution by calculating the skewness and kurtosis of the dataset, which are measures of the shape of the distribution.

As highlighted in the introduction the econometric techniques and tools are to be used to fulfil the objectives of the study. The procedure and methods are relevant and appropriate to conduct and analyse the results fully in chapter four. This chapter has highlighted the research methodology this study is going to follow which is ARDL methodology and cointegration test which is Johansen and Juselius.

4.2. DIAGNOSTIC TESTING RESULTS

Model 1: Employment

Test	Breusch Godfrey Serial Correlation	Bresusch Pagan	Ramsey Reset	Jarque-Bera
Null Hypothesis	No Serial Correlation	No Heteroskedasticity	No Misspecification	Residuals are normally distributed
F-statistic	0.4470	0.1495	0.8378	2.6875
Probability value	0.3499	0.1534	0.8378	0.2609

Conclusion	Fail to reject HO	Fail to reject HO	Fail to reject HO	Fail to reject HO

Model 2: Profitability

Test	Breusch Godfrey Serial Correlation	Bresusch Pagan	Ramsey Reset	Jarque-Bera
Null Hypothesis	No Serial Correlation	No Heteroskedasticity	No Misspecification	Residuals are normally distributed
F-statistic	0.7738	0.0666	0.7523	1.1403
Probability value	0.7226	0.9920	0.6352	0.5654
Conclusion	Fail to reject HO	Fail to reject HO	Fail to reject HO	Fail to reject HO

Author's own computation

Diagnostic tests are conducted to assess the validity of the model. It has been validated that the short-run model error terms are free from serial correlation, and heteroskedasticity, there is no misspecification in the model and residuals are normally distributed. Also, DW statistics value is greater than that of R-squared, which validates that the short-run models are not spurious.

The long-run variable's stability was evaluated using the CUSUM (cumulative sum of recursive residuals). The results are shown in Figures 4.1 and 4.2. The findings did not dismiss the null hypothesis at a 5% level of significance since the test plot was within the crucial limits. It can therefore be realized that our chosen ARDL model is stable.

Figure 4.1: Model 1 (Profitability) CUSUM Test

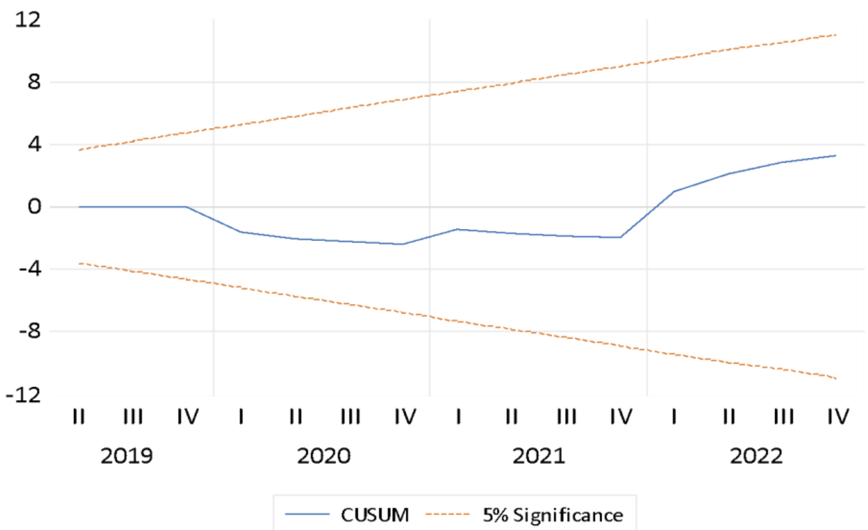
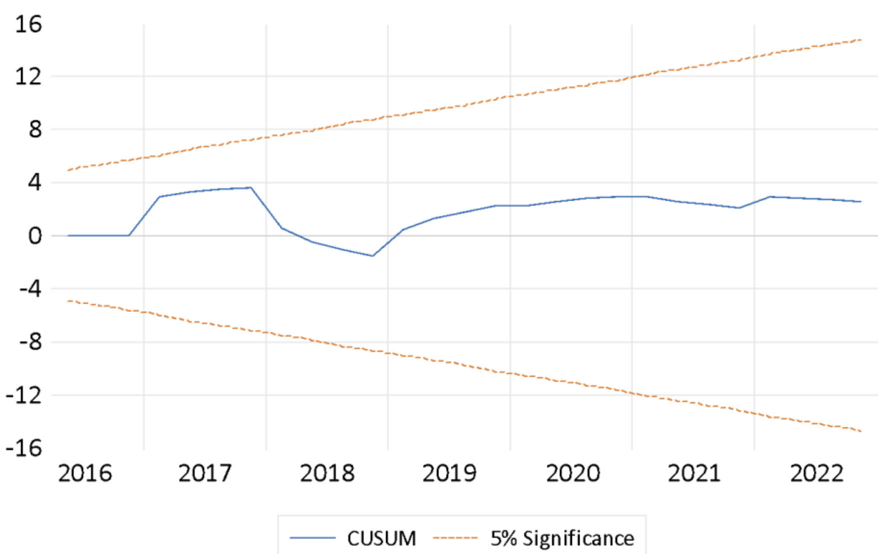


Figure 4.2: Model 2 (Employment) CUSUM Test



Author's own computation

The study investigated the impact of renewable energy integration on mining profitability and employment in South Africa using the ARDL model for the period of 2010 to 2022 by using annual time-series data. This chapter started with displaying descriptive statistics that highlighted the nature of data. ADF was employed to determine whether the variables are stationary. The results of the stationarity tests revealed that variables are not integrated of the same order, hence I (0) and I (1), as a result, the ARDL estimation model was applicable.

Performing bounding tests to cointegration to detect the presence of long-run relationship, the f-statistic was greater than the upper-critical bound, which revealed that series are cointegrated. The results of the ARDL model showed a positive and significant relationship between renewable energy consumption, mining profitability, and employment both in the short-run and long-run. Stability and diagnostic tests have been performed and have usually demonstrated that the model is robust and that the predicted parameters for short-term and long-term parameters are stable.

4.3. MODEL RESULTS AND DISCUSSION

This chapter presents all the testing models used to analyse the impact of renewable energy integration on profitability and employment in the South African mining industry for the period 2011-2020. The interpretation and analysis of the results are mainly on renewable energy integration, profitability, and employment. Table 4.1 depicts the descriptive statistics of the variables employed in the study.

Table 4.1: Common Sample of Descriptive Statistics

	LPROF	LBF	REC	LGDP	LGCF	EMPL
Mean	12.53378	16.93612	8.530000	11.26460	11.34706	100.2231
Median	12.45372	16.95623	8.070000	11.27705	11.42762	98.10000
Maximum	13.08830	17.00636	9.820000	11.29217	11.65872	109.2000
Minimum	12.16444	16.81079	7.640000	11.19035	10.99247	94.80000
Std. Dev	0.282309	0.059299	0.803453	0.029330	0.190368	5.066174
Skewness	0.861819	-0.677738	0.524273	-1.335208	-0.136341	0.533941
Kurtosis	2.626519	2.27227	1.664798	3.787074	1.994409	1.733968
Jarque-Bera	6.739240	5.128431	6.244796	16.79298	2.352067	5.943615
Probability	0.034403	0.076980	0.044051	0.000226	0.308500	0.051211
Observations	52	52	52	52	52	52

Author's Own Computation

Wenger (2012), states that if the skewness coefficients fall around -0.5 and +0.5, a small residual skewness is evident. The sign of the coefficient indicates the direction that the skewness has. If the sign of the coefficient is negative it means the distribution is skewed to the left, then if the coefficient is positive, it means the distribution is skewed to the right.

In Table 4.1, the variables LBF, LGDP, and LGCF have a negative coefficient of -0.677738, -1.335208, and -0.136341 respectively which implies that the distribution is marginally skewed to the left, and variables LPROF, REC, and EMPL have positive coefficients of 0.861819, 0.524273 and 0.533941respectively indicating that the distribution is skewed to the right.

The probability shows that variables LPROF, REC, LGDP, and EMPL are statistically significant, with a probability of 0.034403, 0.044051, and 0.000226, respectively. While LBF 0.076980 and LGCF 0.308500 are statistically insignificant.

4.3. EMPIRICAL TESTS RESULTS

4.3.1. UNIT ROOT TEST RESULTS

The findings of the unit root test can be presented either informally or formally. In this study, the results of the unit root test are presented formally. ADF unit root test is employed to test whether variables are stationary or not. Table 4.2 below provides the results of ADF test.

Table 4.2: ADF Unit Root Test Results

Variable	Model	Level		First Difference	
		T-statistic	P-value	T-statistic	P-value
REC (I)	Intercept	-1.13699	0.6551	-2.913236	0.0816
	Trend and Intercept	-1.357274	0.8070	-3.889690	0.0647
	None	0.056201	0.6776	-3.128341	0.0059
LGDP	Intercept	-2.93337	0.0759	-3.090811	0.0636
	Trend and Intercept	-2.340015	0.3805	-3.22370	0.1429

	None	-0.878929	0.3108	-3.256713	0.0047
LBF	Intercept	-5.462209	0.0027	-3.893390	0.0237
	Trend and Intercept	-4.623734	0.0277	-4.253664	0.0499
	None	-0.557975	0.4500	-4.201796	0.0011
EMPL	Intercept	-2.240634	0.9994	-1.035994	0.6893
	Trend and Intercept	-0.508287	0.9575	-4.102267	0.0591
	None	2.029456	0.9804	-0.242389	0.5705
LPROF	Intercept	-3.380121	0.0422	-2.783566	0.0982
	Trend and Intercept	-2.242584	0.4221	-2.723945	0.2546
	None	-0.726993	0.3762	-2.912105	0.0088
LGCF	Intercept	-2.943632	0.0748	-0.033294	0.9261
	Trend and Intercept	0.020133	0.9851	-4.904385	0.0199
	None	-1.420943	0.1365	-1.154438	0.2055

Author's Own Computation

Table 4.2 shows the Level and First difference results of the ADF-Fisher Chi-Square Test. The unit root test results are integrated of order 0 and 1. The null hypothesis of the ADF Test is that there is a unit root present. Using the p-value approach of hypothesis testing at a 5% level of significance, the rejection rule states that the null hypothesis should be rejected when the p-value is strictly less than 0.05. The conclusion would be that the observed variable is stationary.

After studying the results of the ADF-Fisher Chi-Square Test, all the variables EMPL, REC, and LGDP are non-stationary at Level form except LGCF and LPROF which are stationary at Trend, and Intercept, respectively. At first difference, all the variables are stationary. Therefore, this implies that the variables are integrated of order (I).

4.3.2. JOHANSEN COINTEGRATION TEST RESULTS

As confirmed by the ADF test results, all the variables in the model are shown to be integrated in order I (0) and I (1), thus this makes the Johansen Cointegration Test to be applicable to the model. Table 4.3. and Table 4.4 provides results for Cointegration (Trace) and Cointegration (Max-eigen), respectively.

Table 4.3: Johansen Cointegration (Trace Statistic: Model 1 Employment)

Hypothesized No of CE (s)	**Trace Statistic**	**0.05 Critical Value**	**Probability Value**
None*	241.2294	69.81889	0.0000
At most 1*	93.64561	47.85613	0.0000
At most 2 *	40.30987	29.79707	0.0022
At most 3	11.03033	15.49471	0.2096
At most 4	1.915059	3.841465	0.1664

Table 4.4: Johansen Cointegration (Max-Eigen Value: Model 1 Employment)

Hypothesized No of CE (s)	**Max-Eigen Statistic**	**0.05 Critical Value**	**Probability Value**
None*	147.5838	33.87687	0.0000
At most 1*	53.33575	27.58434	0.0000

At most 2*	29.27954	21.13162	0.0029
At most 3	9.115270	14.26460	0.2767
At most 4	1.915059	3.841465	0.1664

Table 4.5: Johansen Cointegration (Trace Statistic: Model 2 Profitability)

Hypothesized No of CE (s)	Trace Statistic	0.05 Critical Value	Probability Value
None*	243.0610	69.81889	0.0000
At most 1*	61.72673	47.85613	0.0000
At most 2	26.41015	29.79707	0.1169
At most 3	7.327108	15.49471	0.5399
At most 4	0.076379	3.841465	0.7823

Table 4.6: Johansen Cointegration (Max-Eigen Value: Model 2 Profitability)

Hypothesized No of CE (s)	Max-Eigen Statistic	0.05 Critical Value	Probability Value
None*	181.3342	33.87687	0.0000
At most 1*	35.31658	27.58434	0.0042
At most 2*	19.08304	21.13162	0.0944
At most 3	7.250729	14.26460	0.4599
At most 4	0.076379	3.841465	0.7823

4.4. DETERMINING THE LAG LENGTH CRITERIA

One of the most crucial aspects of the ARDL is to determine the lag length that the study is going to employ. ARDL model regression entails time series data regression that uses lagged values of regress and variable as regressor variable. The selection of the lag length criterion is significant as it prevents the incorrect rejection or approval of the expected results. Moreover, the length of the lag also impacts the ability to dismiss the null hypothesis.

Thus, the approach to information criteria is used in this analysis as a way of choosing a lag order. Table 4.7 shows how many lags, which is 3 lags that the model will use according to AIC, FPE, HQI, and LR.

Table 4.7: Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	98.78179	NA	2.78e-10	-7.815149	-7.569721	-7.750037
1	205.9312	160.7241*	3.12e-13	-14.66093	-13.18837	-14.27026
2	240.5055	37.45550	1.92e-13	-15.45879	-12.75909	-14.74256
3	288.6072	32.06776	7.72e-14*	-17.38393	-13.45708*	-16.34214*

4.5. BOUND TESTING APPROACH FOR COINTEGRATION

Cointegration tests can assist in assessing whether the variables have a long-term relationship. In the case where there is a presence of cointegration, this would imply that the variables share a similar pattern of behaviour with respect to their long-term variability. One of the key benefits of the cointegration method is the potential to integrate the long-term and short-term relationship between variables within an all-inclusive framework. In this analysis, the ARDL bound test approach to cointegration is the most suitable if there is a high possibility of a separate order of integration between variables (Pesaran et al., 2001).

Table 4.8: Bound Test Results (Model 1)

T statistic	Value	K
F Statistic	10.83634***	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Table 4.9: Bound Test Results (Model 2)

T statistic	**Value**	**K**
F Statistic	9.852574***	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Author's own computation

Notes: l0 Bound = 2.2   I1 Bound = 4.37

The value of the test statistic (10.83634 and 9.852574) is found to be greater than that of I1 Bound compiled values thus we reject the null hypothesis of no long-run relationship.

***, **, * represents significance at 1%, 5% and 10%, respectively.

4.7. AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) RESULTS FOR LONG RUN RELATIONSHIP

Table 4.10: Long Run Relationship Coefficients ARDL (Model 1 Employment)

Variable	Coefficient	T-Statistic	P-Value
LGCF	4.0167	2.0738	0.0440
LGDP	19.1711	1.8854	0.0660
LLF	-10.9908	-1.8780	0.0670
REC	0.8233	2.8095	0.0074
C	-23.8779	-0.1923	0.8483

Table 4.11: Long Run Relationship Coefficients ARDL (Model 2 Profitability)

Variable	Coefficient	T-Statistic	P-Value
LGCF	0.1910	2.5481	0.0146
LGDP	-0.6276	-1.8440	0.0722
LLF	1.9229	4.2734	0.0024
REC	0.1351	4.5355	0.0000
C	1.1387	0.20488	0.8386

4.8. ECM RESULTS (SHORT RUN)

Table 4.12: ECM Form Results (Model 1 Employment)

Variable	Coefficient	T-Statistic	P-Value
D(LGCF)	0.1910	2.8712	0.0064
D(LLF)	1.9229	5.0705	0.0000
D(REC)	0.1351	5.4823	0.0000
ECM-1	-0.1796	-3.3667	0.0016
R-Squared	0.5128		

DW Statistic	2.0580

Table 4.13: ECM Form (Model 2 Profitability)

Variable	Coefficient	T-statistic	P-value
D(REC)	0.1848	4.2563	0.0001
ECM-1	-0.3152	-2.2869	0.0152
R-squared	0.7215		
DW Statistic	3.0563		

Author's own computation

ECM represented as:

$$\Delta LEMPL = B_0 + \Delta LREC_{t-1} + \Delta LGCF_{t-1} + \Delta LLB_{t-1} + ECT_{t-1}$$

The error correction term is referred to as the speed of adjustment of the equilibrium towards a long-run relationship which is represented by Employment (EMPL) and Mining Profitability (PROF). ECM is used to adjust the model to last year's disequilibrium and to correct the model.

4.9. DISCUSSIONS

Table 4.2 shows the Level and First difference results of the ADF-Fisher Chi-Square Test. All the variables EMPL, REC, and LGDP are non-stationary at Level form except LGCF and LPROF which are stationary at Trend, and Intercept, respectively. EMPL with the following coefficients at level, Intercept 0.9994, Trend 0.9575 respectively, and at first difference Intercept 0.6893, Trend 0.0591, respectively. LPROF at first difference, all the variables are stationary. Therefore, this implies that the variables are integrated of order (I).

The Johansen cointegration test results shown in tables 4.3, 4.4, 4.5, and 4.6, respectively, show the presence of cointegration among all the variables being investigated. The value of Max-Eigen and trace statistic shows three cointegration equations for both trace and Max-Eigen at Model (1) and two cointegration equations for trace and three cointegration equations for Max-Eigen, respectively. Thus, such a null hypothesis is rejected on the basis that the trace-stat is greater than the critical value. Moreover, the prob-value is less than the level of significance (0.05). At most 3 for Model (1) and Model (3), the trace-stat is smaller than the critical value and the prob-value is greater than 0.05, thus the null hypothesis of one cointegration equation is rejected. Furthermore, the Max-Eigen value for both models does yield the same outcome which indicates three cointegration equations, which means that the null hypothesis is rejected.

At most 3 and 4 for both Models, both Max-Eigen and trace statistic values are less than the critical value, which indicates that there is a long-run relationship between renewable energy consumption, employment, GDP per capita, mining profitability, labour force, and gross fixed capital formation. Thus, this result supports the results found by Anyikwa et al. (2017), that there is a long-run relationship between renewable energy consumption and economic growth in South Africa. Also supports the findings of Zaman et al. (2015) who assessed whether energy consumption adds to economic growth or not. The author found that energy consumption has a significant impact on economic growth in Pakistan.

Tables 4.8 and 4.9 show that the value of the F-statistic (10.83634 and 9.852574) is greater than that of the upper bound at a 1 percent level of significance. Thus, this indicates that there is an existence of cointegration between energy consumption, employment, and mining profitability in South Africa. In simple terms, there is a long-run relationship between renewable energy consumption, employment, and mining profitability in South Africa, which supports the results of Khobai and Le Roux (2017) provided in Chapter 2 in the empirical review section. Thus, these results support the objective of the study being “whether there is a long, long run between employment, mining profitability and renewable energy consumption in South Africa.” Also, these results are consistent with those of Dreger et al. (2011) who examined the long-run causality between real GDP and renewable energy consumption, indicating that there is cointegration among variables. The author contends that renewable energy consumption causes economic growth to increase in 25 OECD countries.

Pao and Fu (2013) results are consistent with the findings of this study which reveals that there is a cointegration between renewable and non-renewable energy consumption and economic growth in both the short and long run.

Tables 4.10 and 4.11 present long-run results of ARDL for both models. These results reveal that gross capital formation (LGCF) has a positive and statistically significant relationship toward both employment and mining profitability in the long-run. Implies that 1 increase in gross capital formation (LGCF) will result in a 4.0167 and 0.1910 percent increase in employment (EMPL) and mining profitability (LPROF) respectively and, these results are consistent with the findings of Bhattacharya et al., (2016) highlighted in chapter two.

Critically, this relationship fosters a virtuous cycle of growth. As employment rises, more individuals earn income, leading to increased demand for goods and services, which stimulates further investment. This cycle can also reduce poverty levels and improve social stability, as higher employment rates contribute to a more equitable distribution of wealth. The consistency of these results with prior findings, such as those by Bhattacharya et al. (2016), reinforces the validity of the relationship, suggesting that policies aimed at boosting gross capital formation could have far-reaching benefits. However, it is essential to consider potential diminishing returns or external factors that might influence these dynamics, ensuring that growth remains sustainable and inclusive over the long term.

A positive relationship between the Labour force and economic growth, as highlighted by Zaman et al. (2015), is crucial for fostering a robust economy. The findings indicate that an increase in the Labour force can significantly enhance mining profitability, which is a vital sector in many economies, especially in resource-rich countries like South Africa. This dynamic suggests that as more individuals enter the Labour market, productivity and efficiency in industries can rise, leading to greater output and profitability. Such growth can stimulate investments, create jobs, and increase overall economic activity, contributing to a virtuous cycle of development and prosperity.

Conversely, the negative and statistically insignificant relationship between the Labour force and employment in model 1 raises concerns, particularly in the context of South Africa's high unemployment rates. This discrepancy may stem from structural issues within the economy, such as skills mismatches or inadequate job creation relative to the growing Labour supply. If the Labour force expands without corresponding increases in employment opportunities, it can lead to social unrest and economic instability. Therefore, while a growing Labour force is beneficial, it must be matched with effective Labour market policies that promote job creation and skill development to ensure that the potential benefits of increased Labour participation translate into tangible economic growth and improved living standards.

Gross Domestic Product (LGDP) in the model is found to be positive and statistically insignificant towards employment, implying that a 1 percent increase in LGDP will lead to 19.1711 units increase on employment in South Africa, however, in model 2 it is found to be negative and statistically insignificant towards mining profitability, implying that 1 percent increase in LGDP will to 0.6271 percent decrease in mining profitability in the long run in South Africa. These results are in alignment with the study of Bethuel et al., (2014) who found out that GDP exhibits an asymmetric relationship towards employment.

A positive relationship between Gross Domestic Product (GDP) and employment can enhance economic growth by creating more job opportunities, leading to increased consumer spending and demand. This cycle contributes to overall economic resilience, reduces unemployment, and improves productivity. Conversely, the negative relationship between GDP and mining profitability indicates that while economic growth may benefit employment, it can also challenge specific sectors like mining through increased costs and regulatory pressures. Policymakers need to balance promoting GDP growth with supporting key industries to ensure inclusive and sustainable economic progress.

Renewable energy consumption is found to be positive and statistically significant towards employment and mining profitability in South Africa in the long run. Implying that a 1 percent increase in renewable energy consumption (REC) will lead to 0.8233 and 0.1351 percent increase in employment and mining profitability, respectively. These results resonate with the study of Saad and Taleb (2018), who found that renewable energy integration is positive and statistically significant in the long run toward economic growth.

The positive relationship between renewable energy consumption (REC) and employment, as well as mining profitability in South Africa, demonstrates the economic benefits of transitioning to renewable sources. An increase in REC can create jobs and enhance energy security, contributing to economic stability and reduced unemployment. Additionally, integrating renewable energy in the mining sector can lead to cost savings and improved efficiency, making the industry more competitive. This shift not only addresses environmental concerns but also positions South Africa for sustainable long-term growth, as highlighted by Saad and Taleb's (2018) findings on the positive impacts of renewable energy on economic development.

Based on the results shown in Tables 4.12 and 4.13, the estimated ECMt-1 coefficient is -0.17 and -0.31. Since the ECM value should be negative and significant, therefore this suggests that the findings confirm the presence of a long-run relationship among variables. The findings show that the divergence from the long-run growth direction because of a certain disturbance is adjusted by 17 % and 31% per year, respectively.

The short-run results show that gross capital formation (LGCF) exhibits a positive and statistically insignificant relationship towards mining profitability (PROF). The Labour force (LLF) shows a positive and statistically significant relationship towards mining profitability (PROF). Furthermore, renewable energy consumption (REC) shows a positive and significant relationship with mining profitability (PROF). ECM has an R-squared of 51% and 72% respectively, which shows that the model is significantly having a goodness of fit that can be utilised to explain the dependent variables being EMPL and PROF.

5. ROBUSTNESS OF THE STUDY

Assessing the robustness of the study requires several key considerations, of which include ensuring that our ARDL model has been correctly specified using the AIC. Diagnostic tests have been conducted to ensure that the model assumption is not violated and to establish the successful performance of the regression model. These included the normality test, which assumed that the residuals are normally distributed with mean zero. The heteroskedasticity test, and serial correlation test to avoid the residuals being correlated. Ramsey test, to check if the regression functionality is normal and the CUSUM and CUSUMSQ test to examine the accuracy of the variables. Jarque-bera tests to check for the underlying distribution of the data and if it follows a normal distribution. From the diagnostic tests, it has been confirmed that there is no misspecification in the model, the residuals are normally distributed, and the short-run model error components are devoid of serial correlation and heteroskedasticity. Furthermore, the DW statistics value is higher than the R-squared value, confirming the validity of the short-run models.

We assessed the stability of the long-run variable using the Cumulative Sum of Recursive Residues, or CUSUM. Figures 4.1 and 4.2 display the findings. Given that the test plot was contained within the critical ranges, the results did not reject the null hypothesis at a 5% level of significance. Thus, it may be concluded that the ARDL model we have selected is stable.

Assessing the external validity of the study in order to understand if the results are specific to the South African mining industry or if they can be generalised to other sectors or regions. From that we can assess that our study results are only specific to the South African mining industry and cannot be generalised for other regions, however, in terms of other sectors it leaves room for it to be studied. Overall, our study results also align with existing literature and economic theory, by showing that the adoption of renewable energy sources reinforce both profitability and employment in the mining industry of South Africa such that a unit integration of renewable energy will most likely result in a respective percent increase in employment and mining profitability.

6. LIMITATION OF THE STUDY

The study focused on examining the effects of renewable energy integration on profitability and employment in the South African mining industry. The study was limited to a period of 12 years, from 2010. Indicating that the study did not use a large sample. Because there were only four independent variables included in the model to account for their effects on GDP, the dependent variable, the model may be imprecise and erroneous due to the exclusion of several significant factors. There is a chance for more research to be done because of the limitations the study found. A larger sample size can be used by applying the studied years' period. Since a larger sample size yields more reliable results, this would guarantee a more desired statistical conclusion.

7. CONCLUSION

The main results from the empirical study revealed a special relationship that continues in the long run with the application of the Bound Testing method. The Bound Testing results revealed that there is a long-run relationship between renewable energy integration, employment, and mining profitability in the South African mining industry, similar results were revealed in the short run as well. The diagnostic and stability tests performed revealed a robust and stable model supporting the choice of the ARDL model.

The study aimed to assess the impact of renewable energy integration on the profitability and employment of the mining industry for the period 2010 to 2022. The study’s hypotheses state that renewable energy integration has a significant relationship and impact on profitability and employment in the South African mining industry. To attain the objective, various analyses were done. Together with the assessment of empirical and theoretical studies supporting the study. In the study, several theories such as the neutral hypothesis, growth hypothesis, feedback hypothesis, and conservation hypothesis were considered. These theories have given rise to several foundations and conclusions. Nevertheless, the fundamental premise among all of them was that policymakers should use renewable energy consumption as a mechanism in the mining industry to foster increased profitability and employment, specifically in the long run.

Using annual time-series data from the period 2010 to 2012, the frequency of the data ensured a sufficient number of observations. The ARDL approach provides explicit tests for the detection of a unique cointegration vector; it does however suffer from a flaw that is only applicable where there is a unique cointegration vector. More specifically, the results show that the adoption of renewable energy sources bolsters both profitability and employment in the mining industry of South Africa such that a unit integration of renewable energy will most likely result in a respective percent increase in employment and mining profitability. Our research is the first of its kind in providing this evidence compared to related literature which is not industry specific. Overall, our findings underscore the importance of the transition to renewable energy to simultaneously promote economic growth and ameliorate environmental quality in the context of developing countries where extractive industries pervade.

8. POLICY RECOMMENDATIONS

The findings presented in this study have several policy implications. Based on the empirical findings, the study recommends the following:

The long-run relationship between renewable energy integration, profitability, and employment in the South African mining industry was revealed to be significant and positive. Following the growth hypothesis which holds that energy consumption plays a significant role in increased profitability and employment. The result in the short run also shows a positive and significant relationship between renewable energy integration, employment, and profitability. Therefore, this calls for an increase in investments for renewable energy sources in the South African mining industry, as this will boost the country's economic growth in the long run. In order to promote investment in renewable energy technologies, obstacles such as high taxes and costs such as the carbon tax need to be decreased, in order to foster the increase in the production, integration, and ultimately the consumption of renewable energy. Tax cost reduction also affords higher profit gains in the short-run than in the long-run.

9. REFERENCE LIST

Artiach, T.L., Nelson, D and Walker, J. (2011). The determinants of corporate sustainability performance. Account. Finance. 50, pp31–51.

Belke, A., Dobnik, F. and Dreger, C., 2011. Energy consumption and economic growth: New insights into the cointegration relationship. Energy Economics, 33(5), pp.782-789.

Bhattacharya, M., Paramati, S.R., Ozturk, I. and Bhattacharya, S., 2016. The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. Applied Energy, 162, pp.733-741.

Fang, Y. (2011). Economic welfare impacts from renewable energy consumption: the China experience. Renew Sustain Energy Rev.15:5120–8.

Igogo, T., Awuah-Offei, K., Newman, A., Lowder, T., & Engel-Cox, J. (2021). Integrating renewable energy into mining operations: Opportunities, challenges, and enabling approaches. Applied Energy, 300, 117375.

Inglesi-Lotz, R. (2016). The impact of renewable energy consumption to economic growth: a panel data application. Energy Econ.53:58–63.

Kammen, DM., Kapadia, K and Fripp, M. (2004). Putting renewables to work: how many jobs can the energy industry generate? A report of the renewable and appropriate energy Labouratory. Berkeley, CA: University of California.

Khobai, H. and Le Roux, P., 2017. The relationship between energy consumption, economic growth, and carbon dioxide emission: The case of South Africa. International Journal of Energy Economics and Policy, 7(3), pp.102-109.

Klinger, S. and Weber, E., 2020. GDP-employment decoupling in Germany. Structural Change and Economic Dynamics, 52, pp.82-98.

Kittipongvises, Suthirat. (2017). Assessment of Environmental Impacts of Limestone Quarrying Operations in Thailand. Environmental and Climate Technologies. 20. 10.1515/rtuect-2017-0011.

Lazard (2000). ‘Levelized Cost of Energy and Levelized Cost of Storage.

Lin, B and Moubarak, M.(2014). Renewable energy consumption – Economic growth nexus for

China. Renew Sustain Energy Rev.40:111–7.

Moyo, C., Dingela, S., Kolisi, N., Khobai, H. and Anyikwa, I., 2017. Renewable energy consumption and unemployment in South Africa.

Neingo, P. N., & Tholana, T. (2016). Trends in productivity in the South African gold mining industry. Journal of the Southern African Institute of Mining and Metallurgy, 116(3), 283-290.

Nkoro, E. and Uko, A.K., 2016. Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. Journal of Statistical and Econometric Methods, 5(4), pp.63-91.

Omri, A. (2014). An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. Renewable and Sustainable Energy Reviews, 38, 951-959.

Pao, H.T. and Fu, H.C., 2013. Renewable energy, non-renewable energy, and economic growth in Brazil. Renewable and Sustainable Energy Reviews, 25, pp.381-392.

Pesaran, M.H., Shin, Y. and Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), pp.289-326.

Romero, A., Millar, D., Carvalho, M., & Abrahão, R. (2020). 100% renewable fueled mine. Energy, 205, 117964.

Saad, W. and Taleb, A., 2018. The causal relationship between renewable energy consumption and economic growth: evidence from Europe. *Clean Technologies and Environmental Policy*, *20*, pp.127-136.

StatsSA (2020). Statistics South Africa. [Online] Available: Statistics South Africa | Improving Lives Through Data Ecosystems (statssa.gov.za) (Accessed 30 November 2023).

Sebri M, Ben-Salha O. On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. Renew Sustain Energy Rev 2014;39:14–23.

TralacBlog, (2021). *Ramaphosa raises self-generation cap – a promising step in the right direction, but more is needed.* [Online] Available: https://www.tralac.org/blog/article/15253-ramaphosa-raises-self-generation-cap-a-promising-step-in-the-right-direction-but-more-is-needed.html [Accessed 15/10/2022]

Votteler, RG and Brent, G (2017). A mining perspective on the potential of renewable electricity sources for operations in South Africa: Part 2 - A multi-criteria decision assessment, *Journal of the Southern African Institute of Mining and Metallurgy*, 117(3):299-312.

Zaman, A.U., (2015). A comprehensive review of the development of zero waste management: lessons learned and guidelines. *Journal of Cleaner Production*, *91*, pp.12-25.

Zhao, X. & Luo, D. (2017). "Driving force of rising renewable energy in China: Environment, regulation and employment", *Renewable and Sustainable Energy Reviews,* vol. 68, pp. 48-56.

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., ... & Warburton, M. (2014). Climate change impacts and adaptation in South Africa. Wiley Interdisciplinary Reviews: Climate Change, 5(5), 605-620.