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The Impact of Renewable Energy on Job Growth in South Africa

by

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ABSTRACT

The threat of climate change and the consequent need for renewable energy development is an issue of growing importance across the world. While the environmental benefits of renewable energy are commonly documented and accepted, the economic impact of renewables on job growth is less commonly agreed upon. For South Africa in particular, the nature of this impact is crucial to understand since the country suffers from both unsustainable carbon emissions and unemployment rates. This study investigates the impact of renewable energy consumption on total employment in South Africa over the period 1970-2021. The autoregressive distributed lag model was employed to test the long-run and short-run impacts of renewable energy consumption on employment in a multivariate framework including other determinants of labour demand. Our findings indicate that renewable energy consumption does not have any significant statistical impact on total employment. Additionally, our findings indicate the importance of economic growth, human capital levels, foreign direct investment, energy consumption and international trade in determining job growth. Therefore, the study advocates for further research into the determinants of labour demand in South Africa, and the active creation of a positive relationship between renewable energy and job growth given the current low carbon energy transition that is taking place in South Africa.

1 INTRODUCTION

Climate change is a global issue of increasing importance, with many countries aiming to urgently “green” their economies particularly through transitioning towards a low-carbon energy system. A key feature of this is the promotion of renewable energy.

Renewable energy development is often promised to provide countries not only with low-carbon energy but with job growth as well. However, the latter of these two claims is widely disputed and often ends up dependent on the country in focus and its other socio-economic characteristics.

Energy generation/consumption in general may be a significant potential driver of employment levels through its relationship with economic growth and development, which has a consequent impact on employment levels (the nature of these relationships depends on the country in focus). Particularly regarding developing countries, energy is a major driver of industrialization, and high levels of energy consumption is an indication of a country's economic development (Chang and Fang, 2022).

Conceptually, when focusing on renewable energy and job growth/loss, there are four different ways that employment levels may be impacted by a rapid transition to renewable energy sources: Job creation, job replacement, job losses, and job "greening" (Nasirov, Girard, Pena, Salazar and Simon, 2021).

South Africa in particular finds itself in dire need of renewable energy development as Africa's largest producer of pollutant emissions. The country's over-reliance on coal energy has led to a "dirty economy" that produces disproportionate amounts of carbon emissions. (Menyah and Wolde-Rufael, 2010).

However, South Africa also suffers from very high levels of unemployment. By the end of 2021, the country's narrowly defined unemployment rate reached 35.3%, while its expanded unemployment rate reached 46.2%. (PWC, 2022)

Therefore, the question of whether renewable energy development creates or destroys jobs is crucial for the country's socioeconomic and energy policies, since it cannot afford to

sacrifice jobs to promote renewable energy but also cannot continue with its current levels of unsustainable pollutant emissions.

This paper thus investigates the potential impact of renewable energy development on job growth in South Africa over the period 1970-2021. The ARDL Bounds test approach to cointegration is employed to estimate the short and long-run impact of renewable energy consumption on total employment in a multivariate framework including other determinants of labour demand.

It is important to note from the outset that any relationship found between renewables and job growth does not exist in nature but is actually man-made. Thus, they can be changed through public and private action so that sustainable job growth is possible.

This paper provides a thorough analysis on a very specific relationship in South Africa, making a unique contribution to the literature on the topic.

This paper contributes to the current literature by focusing on the impact of renewable energy on job growth in South Africa. Current studies focusing on this relationship in South Africa are scarce, often making use of limited datasets or alternative statistical analysis methods which leave their findings open to increased limitations. This paper's use of updated datasets and time series analysis, specifically that of an ARDL model, should provide more reliable findings than many previous studies on the country.

Furthermore, previous studies done on the determinants of employment in South Africa do not often take energy consumption/production into account, while those that do almost certainly do not differentiate between renewable and non-renewable energy. Similarly, previous studies done on the relationship between energy production/consumption and employment/economic growth in South Africa most-probably do not investigate the other determinants of employment very thoroughly. This paper's multivariate framework consists of carefully selected determinants of labour demand (based on theoretical and empirical literature) which provides a good measurement of South Africa's socio-economic environment, such that the impact of other macroeconomic variables on job growth can be reliably estimated.

Section 2 provides a brief background on South Africa's unemployment, emissions, and energy environment. Section 3 provides the paper's literature review. Section 4 provides the paper's theoretical framework. Section 5 sets out the data and econometric model. Section 6 provides and discusses our empirical results. Section 7 provides conclusions and recommendations.

2 A BRIEF BACKGROUND ON SOUTH AFRICA'S UNEMPLOYMENT, EMISSION AND ENERGY

2.1.1 Employment

South Africa has one of the highest unemployment rates in the world. By the end of 2021, the country's narrowly defined unemployment rate reached 35.3%, while its expanded unemployment rate reached 46.2%. Both the narrow and expanded unemployment rates have continued to increase since 2015, while the country's total employment has continued to decline since 2018. Even with economic growth potentially creating 2 million jobs by 2030, considering current macroeconomic trends, the narrowly defined unemployment rate can be expected to increase to 39.3% by 2030. Under this scenario, South Africa will likely maintain the highest total and youth unemployment rates in the world (PwC, 2022).

South Africa must identify areas that will have large impacts on GDP and job growth and where big change is possible without necessarily needing big financial commitments. Ensuring the correct skills base to address the needs of the labour market is key in this regard, as there has been and currently is a mismatch between the expected financial conditions and the ability of the economy to deliver on these expectations (PwC, 2022).

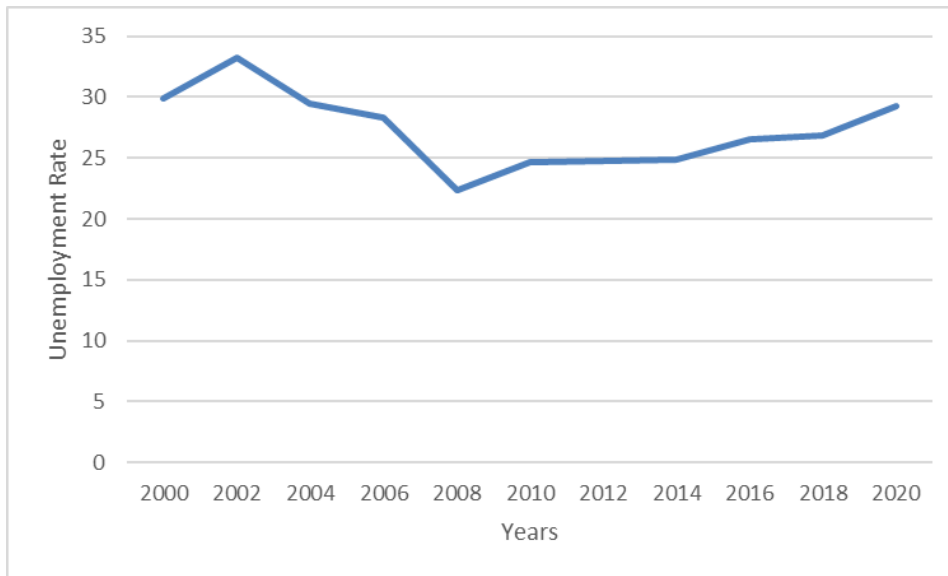


Figure 1: South Africa Unemployment Rate 2001-2021

Source: World Bank Databank

2.1.2 Energy and Pollution

South Africa is also faced with a policy dilemma regarding its pollution levels and general environmental impact. Its economy is heavily dependent on its energy sector, which itself is heavily dependent on coal. This has led to the country's over-reliance on coal, creating a "dirty" economy that produces very high levels of CO₂ emissions relative to its size and output. (Menyah and Wolde-Rufael, 2010). South Africa is ranked 25th in the world in terms of population (Worldometer, 2022), 32nd in the world in terms of GDP (Worldometer, 2022), but 15th in the world in terms of CO₂ emissions (Worldometer, 2022).

There is also little to dispute regarding the country's dependence on fossil fuels for energy and its connection to its pollution levels. In 2015, South Africa produced 457.7 million tonnes of CO₂ equivalent, of which 233.5 (51%) million tonnes was emitted by the "power and heat" sector. This is directly linked to the energy sector's reliance on coal and other fossil fuels since almost 70% of South Africa's primary energy consumption in 2015 came from coal while over 20% was from oil (Mcsweeney and Timperley, 2022).

This sort of economy, against the background of worldwide climate change and the need for reduced greenhouse gas emissions, is unsustainable. On numerous occasions, South Africa and its leaders have pledged to fight climate change by reducing its pollution emissions, such as the submission of its "climate pledge" for the Paris climate talks in 2015 whereby

emissions were “pledged” to peak between 2020 and 2025, falling from thereon (Mcsweeney and Timperley, 2022)

However, not only was South Africa’s climate pledge rated as “highly insufficient” by the independent scientific analysis *Climate Action Tracker* but its efforts in reducing its emissions have often been viewed as insufficient. This is due to several factors, such as “overriding priorities” like poverty and inequality, a lack of political follow-through, and major energy sector challenges where the national power supplier *Eskom* has been haunted by financial problems and governance concerns (Mcsweeney and Timperley, 2022).

2.1.3 Holistic View of the South African Energy Sector

In 2022, coal is still the primary source of energy in South Africa especially in electricity generation, making up 80% of the total system load. Renewable energy (i.e., wind, solar PV and CSP) made of 7.3% of the total energy mix (CSIR, 2023). The country’s primary electricity provider is Eskom, a state-owned-entity. Eskom provides more than 80% of South Africa’s electricity through various types of power stations, including coal-fired (the primary source of energy generation), hydroelectric, nuclear, pumped storage, wind, and diesel (Eskom, 2023).

However, the power utility claims to be moving away from being the sole supplier of electricity in South Africa, rather focusing on “being an enabler of electricity generation” (Eskom, 2023). It also aims to transition towards “being a cleaner and more sustainable company” through their “Just Energy Transition (JET) programme”, with the goal of achieving zero emissions by 2050 with an increase in sustainable jobs (Eskom, 2023).

These transition goals appear to be supported by government, with Minerals and Energy Minister Gwede Mantashe announcing (in 2021) eight independent power suppliers expected to supplement the country’s electricity supply from August 2022 through power generated by solar energy, wind, liquified natural gas and battery storage (Khumalo, 2021).

The need for supplementary electricity generation is largely due to Eskom’s capacity issues, which has led to sever power-outages in South Africa over the past decade. In 2022, the

country experience 3,751 hours of power-outages, while 2023 is expected to easily exceed these levels (Omarjee, 2023).

Energy regulation in South Africa is carried out by The National Energy Regulator of South Africa (NERSA). NERSA is a regulatory authority which oversees the country's "energy industry in accordance with government laws and policies, standards and international best practices in support of sustainable development". It aims to support the development and sustainability of energy industries, while also ensuring the affordability of and accessibility to their products. The entity falls under the Department of Mineral Resources and Energy (Government, 2023).

2.1.4 Renewable Energy in South Africa

A necessary course of action which has consistently been acknowledged by South Africa and its leaders is the adoption of renewable energy sources (RES). Through lessening its dependence on coal and other fossil fuels for energy and moving towards RES, the country can reduce its carbon emissions and other pollution while simultaneously securing sustainable energy sources to support its economic growth.

Numerous national policies have been planned and implemented to increase the mix of energy sources for South Africa, with a focus on increasing the share of energy from renewable energy sources. In 2011, the country's Department of Energy released the *Integrated Resource Plan (IRP) 2010-2030* which was meant to be continuously revised to meet the country's changing energy supply and demand needs. However, due to a lack of follow-through in periodical revision, this plan was not effective. In 2018, the country's Minister of Energy published a draft IRP which updated the energy forecast from the current period to the year 2030. Both the IRP2010 and IRP2019 contain capacity allocations for electricity generated from renewable technologies (CDH, 2022).

However, even with ineffective public policies, South Africa's share of primary energy and electricity production from renewable sources has shown very significant growth since 2013. We can see this in figure 2 below.

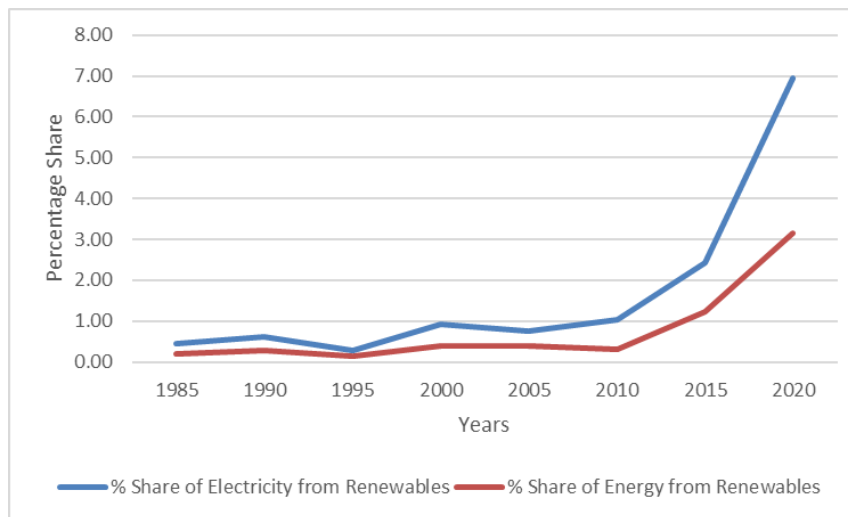


Figure 2: Share of primary electricity and energy from renewables

Source: OurWorldinData

The costs of renewable energy have also significantly fallen during the past decade, with new renewable technology now being “considerably cheaper” than fossil fuel alternatives. The most notable of these sources are solar and wind power, with their respective costs falling 80% and 60% respectively in just four years. Solar and wind power form the majority of South Africa’s renewable energy supply plan, while hydroelectricity plays a relatively small role in the electricity system (Mcsweeney and Timperley, 2022).

South Africa must continue to work on increasing its share of energy from renewable sources. The International Renewable Energy Agency (IRENA) estimates that, by 2050, 90% of the world’s electricity can and should come from renewables. And while this goal may be too ambitious for a coal-dependent country like South Africa, the scientific studies and evidence are clear that the world must reduce its emissions by almost half by 2030, working towards reaching net-zero emissions by 2050, so that the worst impacts of climate change can be avoided (UN, 2022).

3 LITERATURE REVIEW

It is unsustainable for South Africa to continue its reliance on fossil fuels for energy. However, it is also clear that the country must also address its issue of unemployment. Therefore, national policies should aim to simultaneously tackle both without sacrificing one for the other and understanding the relationship between renewables and employment is thus, a necessary step to take.

3.1.1 Determinants of Employment

Modelling Labour Demand in South Africa

We agree with Bashier and Wahban (2013) in their investigation of the impact of macroeconomic variables on labour employment in Jordan using time series analysis. They concluded that “the demand for labour is most likely treated as any other demand model in both theoretical and empirical economic literature where labour demand is considered as the dependent variable and a set of other variables that influence labour demand as the independent variables”. With this thinking, South Africa’s employment levels are determined by demand for labour in the country, which should be treated as a dependent variable in our estimations. Therefore, we must determine which variables to include as our independent variables which drive labour demand in South Africa.

As previously discussed, a country’s socio-economic environment can influence the impact of renewable energy on job growth (determining its nature and significance). Therefore, this focus on other macroeconomic variables and their potential impact on employment levels in South Africa are crucial to account for the country’s specific socio-economic environment.

Hodge (2009) argues that changes in South Africa’s unemployment are the result of changes in both the demand and the supply side of the economy and therefore concludes that the main reason for the persistently high and rising rates of unemployment in South Africa was/is the very large increases in the labour force rather than deficient growth or poor employment performance of the economy. The key to lowering unemployment is thus through increasing both economic growth rates as well as the labour absorption rate so that “jobless growth” is avoided. Therefore, the country’s economic growth levels and total labour force growth may be direct drivers of labour demand.

The impact of South Africa’s economic growth on its employment levels is strongly supported in numerous studies. T. L.A. Leshoro (2013) focused solely on the relationship between the two variables in South Africa, examining the direction of causality between employment and economic growth. The empirical result showed that economic growth does lead to increased levels of employment. This finding is especially important in our theoretical

framework, as it allows for the argument that (renewable) energy consumption/production can influence job growth through its influence on economic growth (which is discussed further in the following sub-section).

Muzindutsi and Maepa (2014) argue that “the main determinant of employment (in South Africa) is human capital, which is the value that a given individual can add to productive capacity”. In this case, human capital includes any education, training, experience, and other individual characteristics which would influence a person’s productivity. The idea is that improved human capital and increased production would interact in such a way that the benefited economic sectors would create opportunity for job growth.

However, this would imply that shocks to a country’s output may not directly lead to an increase or decrease in employment levels, since the level of worker productivity and its relationship with economic growth would need to be taken into account. Arguments have been made that the rapid growth of productivity (such as in manufacturing) has reduced employment by leading to producers reducing jobs and switching to capital-intensive production. Therefore, combined with output, worker productivity may be a direct determinant of the country’s employment levels.

In most literature, Foreign Direct Investment (FDI) is often accepted and promoted as a driver of sustainable economic growth in countries via its positive spillover effects such as job creation, transfer of skills and technology, increasing competition and enhancing human capital in the host country. Several studies concluded that FDI promotes economic development of the host country, thus creating employment opportunities for economically active citizens. Particularly regarding developing economies, such as South Africa, numerous arguments have been made for the importance of FDI to economic growth and job growth (Tshepo, 2014).

Tshepo (2014) estimates the impact of FDI on economic growth and employment in South Africa from 1990 to 2013. Their cointegration tests found there to be a long-run relationship between the variables, with their Granger Causality test results finding that the direction of causality runs from FDI to both economic growth and employment. Therefore, their study

supports the hypothesis that FDI has a positive impact on GDP growth and employment in South Africa.

Domestic investment, or gross fixed capital formation (GFCF), has often been recognized in theory as an essential component to facilitate a country's economic growth and employment. Empirical literature has generally established a robust positive relationship between investment and economic growth. However, there are limited empirical studies estimating the impact of investment on job creation (Meyer, Sanusi, 2019).

Meyer and Sanusi (2019) estimates the relationship and direction of causality between investment and economic growth and between investment and employment in South Africa. Their results found evidence of a long-run relationship between the variables and suggested evidence in favour of bi-directional causality between employment and economic growth. However, while growth was found to drive investment, the opposite was not. Investment was not found to have a significant impact on growth or employment in South Africa.

International trade is typically regarded as a source of economic growth and development and job growth for countries. In recent decades, it has significantly increased across the world, thanks in large part to advances in transportation and digital technologies, and progressive market openings through trade agreements. Often, this process has helped create jobs in both developed and developing economies (OECD, 2022).

Chinembiri (2010) investigated the extent to which South Africa's imports, exports, wages, and output impacted its employment levels across the primary, secondary, and tertiary sectors from 1970-2008. Thus, they modelled the effects of trade on employment in South Africa in a Labour Demand framework. Their analysis revealed that the derived labour demand in the primary and secondary sector industries was impacted negatively by increased imports. They also found insufficient statistical evidence to suggest that derived labour demand for any of the sectors was increased by exports. Therefore, whether through just imports and/or exports or through liberalization, trade openness most likely has a direct influence on employment in South Africa (Chinembiri, 2010).

The Phillips curve is an economic concept stating that inflation and unemployment have a stable and inverse relationship. Proponents of the concept argue that there is always a trade-off between inflation and the unemployment rate, and so a higher inflation rate will most certainly be associated with a lower unemployment rate. However, there are also those who believe that low and stable inflation is a precondition for sustainable long-term economic growth and thus employment creation, and that inflation targeting has had important benefits for the countries that have adopted it. Both views have merit, particularly regarding South Africa with its monetary policy and high unemployment levels (Vermeulen, 2015).

Vermeulen (2015) investigates the effect of inflation on employment in South Africa via the effects of inflation on output, exploring both long and short-run effects of this relationship. They find that the output positively impacts the level of employment in the long run. Additionally, their causality tests indicate clear causality running from output to employment, lending further empirical support to the hypothesis that output drives employment and thus that factors which support or harm economic growth would have a similar influence on employment. However, they did not find evidence of a relationship between the level of inflation and employment growth. An inflation shock was shown to have a positive effect on employment growth in the short run but was not found to be statistically significant. Therefore, inflation and price levels may not be a direct driver of employment in South Africa.

South Africa is a developing economy with high levels of unemployment. Because of this, many studies have been conducted to determine the country-specific determinants of labour demand, and thus the determinants of employment. From the literature reviewed in this paper, there appear to be several variables that are reliably found to be drivers of labour demand in the country, and thus are necessary inclusions in any model of South African employment levels. These variables are:

- Some measure of economic growth, such as GDP.
- Some measure of international trade, such as trade openness.
- Some measure of human capital in South Africa, such as worker productivity.
- Some measure of international investment, such as foreign direct investment.

Energy and Growth

Considering the relationship under investigation is that between renewable energy and employment levels, it is worthwhile to consider energy consumption/production as a whole and its importance to employment levels through its impact on economic growth. Especially considering the low share of South Africa's energy supply made up by renewable energy, it may prove necessary to include other measures of energy consumption/production to fully account for the impact of energy on employment.

In the modern world, energy is crucial for a country's socio-economic development. Energy generation and consumption is consistently found to drive a variety of economic functions. It is often considered an important input in modern growth models. A reliable, abundant, sufficient, and sustainable energy supply is essential for long-term viability and economic prosperity of any country, irrespective of its level of economic growth. Particularly regarding developing countries, energy is the major driver of industrialization, and high levels of energy consumption is an indication of a country's economic development (Chang and Fang, 2022).

Regarding South Africa, but also similarly for almost all countries across the world, energy generation and consumption may be a significant potential driver of employment levels through its relationship with economic growth and development. However, it is necessary for governments and stakeholders to understand the dynamic interaction between energy and growth specific to their country for them to construct and implement effective and robust energy and environmental policies. Of particular interest to policy makers is the direction of causality between energy and growth (i.e., does one cause the other?).

Energy-growth literature has produced four well-established relationships between the two variables based on causality flows. The first involves the energy-led growth hypothesis which asserts that economic growth is premised on increased energy consumption (i.e., energy causes growth). The second consists of the conservative hypothesis in which economic activities are said to drive higher energy consumption (i.e., growth causes energy). The third is represented by what is known as feedback causality where causality is observed to be running from both sides (i.e., growth and energy cause each other). Finally,

the fourth strand centres on the neutrality hypothesis where there is no causality in either direction from economic growth or energy consumption (Bekun, Emir, and Sarkodie, 2018).

Fortunately, the relationship between energy consumption and economic growth in South Africa has been quite thoroughly researched, with focus on the energy-led growth hypothesis. We draw from Kumar, Stauvermann, Loganathan, and Kumar (2015), Lin and Wesseh Jr. (2014), and Bekun, Emir, and Sarkodie (2018) who all investigated the relationship between energy consumption and economic growth in South Africa.

Kumar, Stauvermann, Loganathan, and Kumar (2015) examine the energy elasticity with other critical factors which influence growth (trade openness and financial development), reviewing the causality effects between the variables. Their causality results find unidirectional causality from energy consumption to output.

Lin and Wesseh Jr. (2014) "reassess the existing evidence of causal interdependence between energy consumption and economic growth in South Africa". They find evidence of long-run unidirectional Granger causality running from energy consumption to economic growth and feedback between employment and economic growth in the short run. They reinforce their Granger causality tests with the long-run estimates which indicate that energy consumption is positively correlated with economic growth in the long run. They conclude that the country is highly energy-dependent and that energy conservation policies will negatively impact economic growth in South Africa. They state their results have serious environmental implications, suggesting that energy use in South Africa would have a long-run effect of raising the country's CO₂ emission levels, and that the government should develop a balanced energy structure with a higher share of renewable energy.

Bekun, Emir, and Sarkodie (2018) investigate the long run and causality interaction between energy consumption and growth in South Africa while accounting for capital, labour, and the dynamics of carbon dioxide emissions. They find support for a long-run equilibrium relationship among the variables. Their causality test results indicate one-way causality from energy use to economic growth. Additionally, they found an inverted U-shaped pattern between energy use and economic growth in the long run, suggesting that there is less

intensification of energy consumption at a higher level of economic development, suggesting a decline in energy intensity as the country develops.

It appears to be an obvious conclusion that South Africa's economy is energy-dependent to the point that energy consumption directly causes economic growth. Therefore, we can assume that the country's energy consumption may have a direct impact on its employment levels through its economic growth, providing us with theoretical reasoning for this paper's analysis. A possible limitation of this paper's findings could be that a relationship observed between renewable energy and growth may not reflect in a relationship between renewable energy and employment. Even if this is the case, it would in itself prove to be an important finding.

This paper's econometric framework of employment determinants must include sufficient measures of South Africa's energy consumption. While some measure of renewable energy use was to be included from the outset as the focus of our analysis, energy use from non-renewable sources will be included to provide an overall representation of energy consumption.

3.1.2 Renewable Energy and Employment

Measuring the Impact of Renewables

Increasing renewable energy generation helps to reduce a country's air pollution, mitigate climate change, and increase its energy security. However, the claims of its positive effects on employment are ambiguous as it has both a direct and indirect effect on labour. Therefore, the overall effect on employment depends on the direction and strength of these two effects. If they are both in the same direction and it is positive to employment, irrespective of the strength of each, the overall effect will be positive. However, if the effects (direct and indirect) are in different directions, the overall effect will be driven by the effect with the largest magnitude.

The potential positive impact of renewables on employment is largely through the generation of "green jobs/green employment". Green jobs represent a keystone of transitioning to a low-carbon "green" economy because they are jobs that "contribute substantially to

preserving or restoring environmental quality”. Even though the concept of green jobs remains broad and without a fixed definition, they are jobs that contribute towards maintaining or restoring environmental quality and avoiding future damage to the earth's ecosystems. Therefore, employment created through the generation and maintenance of renewable energy sources would qualify as green jobs (Meyer and Sommer, 2014).

Studies generally show that renewable energy is more labour-intensive than conventional energy. This has often been used as a point for promoting renewable energy in developing countries where there are high levels of unemployment (such as South Africa). However, promoting renewable energy technologies may reduce productivity and increase costs if the existing production system is not well streamlined to adopt renewable energy technologies, meaning that the higher labour intensity of renewable energy technologies should not automatically be considered beneficial to countries (Nasirov, Girard, Pena, Salazar and Simon, 2021).

In the short run, the gross effect on employment of increasing investments into renewable energy sources is generally positive. However, in the long run, this may be diminished or even offset by negative impacts, such as green energy investments crowding out investments into other potentially more productive energy sectors, and through increased energy costs for households and firms (Jaraitė, Karimu and Kažukauskas, 2017).

This highlights the importance of distinguishing between the gross and net employment effects of renewable energy, as well as distinguishing between direct employment effects and indirect or induced employment effects. Studies on the impact of renewable energy on employment can often lead to overly optimistic results since they may just take the gross effect of renewables into account. Gross effects include only the impact on employment in the specific energy sector (such as the green jobs created) which does not capture the economy-wide employment effects. Therefore, this will be positive while net effects would include both positive and negative impacts, showing the overall impact on employment (Meyer and Sommer, 2014; Lambert and Silva, 2012).

Conceptually, when discussing nationwide employment and energy, there are four different ways that employment might be impacted by a rapid transition to renewable energy sources (Nasirov, Girard, Pena, Salazar and Simon, 2021):

1. Job creation. The expansion of new technology in the economy could generate new products, services, and infrastructure. This can create new jobs across sectors of the economy but may require new skills to be developed.
2. Job replacement. Some existing jobs in conventional energy sectors will be replaced by jobs in the renewable energy sectors. This can be rapid or gradual depending on the growth of the renewable energy industry, with respective consequences for job profiles and skill requirements.
3. Job losses. The withdrawal of conventional energy activities could lead to substantial job losses, without direct replacement. This may have an impact on indirect and induced employment as well.
4. Job “greening”. Many existing jobs will adapt to new job profiles in the renewable energy sector. Experience shows that rapid renewable energy growth can lead to skill gaps and labour shortages, such as for qualified engineers and appropriately trained technicians with specific knowledge of renewable energy technologies. Emerging countries often lack such skills.

Obviously, evaluating the link between renewable energy and employment is not simple. Input-Output models, CGE models, and analytic assessment models are among the methodologies most used to examine the impact of renewable energy deployment on job creation. However, all three approaches fail to capture important structural changes that come from the introduction of emerging technologies into a country’s energy mix (Nasirov, Girard, Pena, Salazar and Simon, 2021).

Previous Studies on the Impact of Renewables

There have been advances in time-series and panel-data econometric techniques in recent decades, as well as the availability of long data series. This has allowed researchers to make use of these econometric approaches and datasets to investigate the relationship between renewables and economic growth/employment in different countries/regions (Jaraité et al., 2017)

Similarly, in recent decades a significant number of studies have been done that studied the causal associations between renewable energy and economic growth. However, the causal relationship between renewable energy and employment has been less researched.

C. Chang and M. Fang (2022) investigated the impact of renewable energy consumption on the economic growth of the BRICS and N-11 economies from 1995 to 2019. They aimed to fill the gap in the literature by focusing on the BRICS and N-11 countries as these two groups comprise of most rapidly developing economies and are expected to experience rapid economic expansion. While it was disappointing that South Africa was not included in the BRICS country group, the study's results are relevant for this paper as many of the BRIC and N-11 countries are aiming for improved economic growth rates and thus need improved energy-growth policies.

They found renewable to be a significant long-run driver of economic growth and thus established that the renewable energy-growth hypothesis exists in BRICS countries. In contrast, for N-11 countries, renewable energy was found to have a negative relationship with economic growth. Their results also revealed a unidirectional relationship from renewable energy to economic growth in BRICS economies, and from economic growth to renewable energy in N-11 economies.

Therefore, we can expect there to exist a potential relationship between renewable energy and economic growth, similar to that of conventional energy and growth, and it would be through this relationship that renewable energy may impact employment rates. However, the nature of the impact (whether positive or negative) may be country specific.

Meyer and Sommer (2014) investigate employment effects from renewable energy deployment by evaluating 23 selected impact studies from peer-reviewed journals. They find that most investigated scenarios show positive net employment effects, but given the heterogeneity of assumptions, the results of the different studies are not very comparable. Thus, they tentatively conclude that the increased introduction of renewable energy into the energy mix of different countries shows positive net effects of employment creation, but state that further studies focusing on developing countries are required to validate or debunk these conclusions on a global scale.

Their analyses also show that the way in which renewables are subsidized or financially supported plays a major role in determining the resulting employment effects. Additionally, employment effects are influenced by the technological lead of the region (i.e., their global competitiveness). This supports that the link between renewables and employment is therefore not straightforward but rather dependent on numerous other country characteristics and model assumptions. Therefore, there is perhaps little guidance that can be offered by previous studies which focus on other countries dissimilar to South Africa.

Khobai, Kolisi, Moyo, Anyikwa and Dingela (2020) examined the relationship between renewable energy consumption and unemployment in South Africa over the period 1990-2014. They make use of an autoregressive distributed lag model to test the long-run and short-run impacts of renewable energy consumption on unemployment. Included in their analysis were Gross Fixed Capital Formation as a percentage of GDP, Government Expenditure as a percentage of GDP, and Credit to the private sector as a percentage of GDP. Their results indicate that renewable energy consumption has a negative and significant effect on unemployment in the long run, but that the variables have an insignificant relationship in the short run.

The findings of Khobai et al. (2020) are very relevant to this paper, as their study made use of time-series econometric techniques to analyse the impact of renewables on unemployment, specifically focusing on South Africa and taking the country's other characteristics into account through the inclusion of other variables. Therefore, their results provide us with the best indication of the impact renewables has on employment in South Africa, which is expected to be positive.

Turning our attention to other countries in the world, Jaraité et al., (2017) summarise results from 16 empirical studies that use time-series and panel-data econometric techniques to analyse relationships between renewable energy and economic growth. Most relevant studies find support for the feedback hypothesis implying that there is bidirectional causality between renewable energy and economic growth (i.e., both variables influence each other). Some of the studies included total employment as a factor of economic activity. Most of

these studies found no support for causality between renewable energy and employment, while the remaining studies found that renewable energy contributes to employment.

The study by Jaraitė et al., (2017) investigates the long-run effects of renewable energy support policies on economic growth and employment in 15 European Union member states (the most homogenous in terms of renewable energy policies) from 1990 to 2012 using panel-data time-series econometric techniques. Generally, their results provide evidence to support that renewable energy policies promote growth and employment in the short run, especially in the case of wind capacity, but do not support that these policies promote economic growth in the long run.

Therefore, the studies done on the impact of a country's renewable energy development/consumption on its levels of employment generally reveal positive findings, but this is heavily dependent on numerous other factors. We can conclude that, while there is promise of a positive impact of renewables on employment in South Africa, a country-specific investigation which takes South Africa's characteristics into account is required to further strengthen this theory. Therefore, the findings of Khobai et al. (2020) provides us with the most reliable results from which to base our investigation.

4 THEORETICAL FRAMEWORK

The theoretical underpinning of our empirical analysis stems from demand theory with a focus on labour demand and its potential determinants in South Africa.

South Africa faces both the issues of high unemployment levels and unsustainable levels of pollution due to its reliance on fossil fuel energy. Therefore, estimating whether there exists a relationship between the two and of what nature such relationship is (whether positive or negative), can be vital for the country's energy policies going forward.

It has also been consistently shown by previous literature that the link between a country's renewables and economic growth (and thus employment levels) is dependent on numerous other country characteristics. Therefore, we investigate the impact of renewable energy on South Africa's employment levels in a multivariate framework including the following other

determinants of labour demand: economic growth, labour productivity, trade openness, and foreign direct investment.

An additional inclusion in our framework will be measures of South Africa's energy environment. As said before, the literature clearly shows South Africa's economy to be energy-dependent to the point that energy consumption directly causes economic growth and therefore may have a direct impact on employment levels. Thus, this paper's econometric framework will include fossil fuel consumption in tandem with renewable energy consumption to provide a more complete measure of South Africa's energy consumption.

As reflected in the literature review, we expect economic growth, trade openness, and foreign direct investment to have positive impacts on job growth. Labour productivity is expected to be significant, but the nature of its impact on job growth may be positive or negative. The primary focus of this study is on the possible impact of renewable energy consumption on job growth, which we expect to have a positive impact when combined with fossil fuel consumption.

The nature of the potential relationship between renewable energy and employment is complex. Time series analysis appears to be the most reliable approach to unravel such an analysis since it enables us to estimate the overall impact on the country's net employment levels from renewable energy development rather than just focusing on gross employment as previous studies have done. As is the case in R. B. Swain, A. Karimu, E. Gråd (2022), even though the paper's analysis will not explicitly distinguish between the direct and indirect effects of renewable energy and the other determinant variables on employment, a net employment effect will be determined, suggesting that both these effects are captured in the model's estimations.

The ARDL model approach would be best suited to investigate any cointegrating relationships and estimate the potential relationship due to its ability to handle cointegration (IHSEViews, 2017). The benefits of the ARDL model approach are discussed further in section 5.2.

This paper's analysis will contribute to the literature through focusing on the potential direct impact of renewable energy development on job creation, particularly in South Africa where

such research may be lacking given its importance and relevance to the country. Furthermore, including additional variables as measures of the country's human capital levels and energy environment, and making use of updated time-series datasets should separate this paper and its findings from any previous ones of similar nature.

5 EMPIRICAL FRAMEWORK

5.1 DATA

The focus of our study is on the impact of renewable energy on employment. Due to the link between renewables and non-renewables (i.e., to capture overall energy consumption), we must also explicitly control for non-renewable consumption in addition to the identified key drivers of labour demand.

Data for the study is sourced from various databases that cover the period 1970-2021. The time frame is given by data availability across the variables in the study to avoid dealing with missing data and their likely implication on the model estimation. These variables are presented below with their associated sources.

Total Employment is included as a measure of South Africa's employment levels. It is sourced from *The Conference Board Total Economy Database* (as done by Menyah and Wolde-Rufael (2010)).

Primary energy consumption from renewables (TWh) is included as a measure of renewable energy in South Africa. Data for these variables is sourced from *Our World in Data, South Africa: Energy Country Profile*.

Fossil fuel consumption (TWh) is included as a measure of non-renewable energy consumption in South Africa and is sourced from *Our World in Data, South Africa: Energy Country Profile*.

GDP per capita growth (annual %) is included as a measure of economic growth. Data was sourced from *The Worldbank Databank*. We have chosen to use *GDP per capita growth*

(annual %) as opposed to total GDP or GDP growth since we expect it to be a better measure of inclusive growth which would have a stronger relationship with employment.

Trade (% of GDP) is included as a measure of South Africa's trade openness. *Labour productivity per person employed in 2020 international dollars (converted using purchasing power parities)* is included as a potential measure of worker productivity. *Foreign direct investment (net inflows (BoP, current US\$))* is included as a potential measure of foreign investment. Data for these variables was sourced from *The Worldbank Databank*, except for Labour productivity which was sourced from *The Conference Board Total Economy Database*.

A major advantage of our empirical study is the number of years available for our time series analysis. Our empirical study will make use of 51 observations of data. Jaraité et al. (2015) state that most of the empirical studies on the topic from those they reviewed analysed only 20-30 years of data. Therefore, simply through having a larger sample size available for our empirical analysis, our estimates should provide a somewhat more reliable estimate of the impact of renewables on employment in South Africa.

5.1.1 Summary Statistics

Summary statistics for the logarithmic form of the variables are presented in table 1 below. The standard deviations of the variables all indicate low levels of volatility apart from the log of Renewable Energy Consumption (1.103). According to the Jarque-Bera test statistics, the log of Total Employment, Labour Productivity, and Trade Openness are normally distributed (at least at a 5% level of significance).

Table 1: Summary Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Jarque-Bera
L(Total Employment)	16.220	16.290	16.610	15.810	0.269	4.657*
L(Renewable Energy Consumption)	1.455	1.506	3.475	-2.674	1.103	30.118***
L(GDP per capita growth)	2.288	2.381	2.659	0.869	0.314	127.480***
L(Labour Productivity)	10.620	10.620	10.810	10.420	0.118	3.118

L(Fossil Fuel Consumption)	6.875	6.988	7.260	6.044	0.362	6.499**
L(Trade Openness)	3.903	3.920	4.189	3.575	0.140	2.099
L(FDI)	23.180	23.090	23.710	22.980	0.203	10.575***

, **, * refer to statistical significance at a 10%, 5%, and 1% level respectively.*

5.2 ECONOMETRIC MODEL

This paper's econometric approach will mirror that of Khobai et al. (2020) which made use of an autoregressive distributed lag model to test the long-run and short-run impacts of renewable energy consumption on unemployment in South Africa. Importantly, their analysis included other drivers of labour demand to capture country-specific characteristics.

This study examines the impact of renewable energy development on employment in South Africa. The autoregressive distributed lag model (ARDL) approach to cointegration is adopted to test the long-run and short-run impacts of renewable energy consumption on total employment in a multivariate framework to account for other country-specific characteristics.

To investigate the relationship between different variables, various studies have made use of cointegration models. However, unlike other cointegration models, the ARDL model approach has a few major advantages:

1. The model is useful when estimating non-stationary data because it provides consistent short-run dynamic and long-run relationship regardless of if the model's variables are stationary (integrated of order zero, $I(0)$), integrated of order one ($I(1)$), or a mixture of the two (as long as no variables are integrated of order 2 or more) (L. Yang, S. B. Danwana, F. Y. Issahaku, 2022);
2. The model's estimations are applicable even for a small sample size (as is often the case regarding renewable energy consumption/production); and
3. If some of the independent variables are endogenous (i.e., if there exists a multicollinearity problem), this model approach should provide unbiased estimates of short-run and long-run models, and a valid T-statistics (N. Y. Nuru, H. Y. Gereziher, 2022)

Considering the large number of variables included in the analysis framework, the advantages of the ARDL model approach should aid in ensuring reliable estimations of the potential impact of renewable energy on employment in South Africa.

The implementation of the ARDL-bounds test approach involves two steps. In the first step, the ARDL model is estimated using ordinary least squares (OLS) to determine the existence of a long-run relationship between total employment and our independent variables. If a long-run relationship is identified among our variables, the second step involves the estimation of the long-run and short-run model coefficients.

Thus, we will look to estimate the following error correction representation of the ARDL model (equation 1), short-run model (equation 2, also known as the error correction model (ECM) form), and long-run model (equation 3):

$$\begin{aligned} \text{Log}(E_t) = & c + \sum_{i=1}^j \alpha_1 \text{Log}(E_{t-j}) + \sum_{i=0}^j \alpha_2 \text{Log}(RE_{t-j}) + \sum_{i=0}^j \alpha_3 \text{Log}(GDP_{t-j}) + \\ & \sum_{i=0}^j \alpha_4 \text{Log}(LP_{t-j}) + \sum_{i=0}^j \alpha_5 \text{Log}(FF_{t-j}) + \sum_{i=0}^j \alpha_6 \text{Log}(T_{t-j}) + \sum_{i=0}^j \alpha_7 \text{Log}(FDI_{t-j}) + \\ & \beta_1 \text{Log}(RE_{t-1}) + \beta_2 \text{Log}(GDP_{t-1}) + \beta_3 \text{Log}(LP_{t-1}) + \beta_4 \text{Log}(FF_{t-1}) + \beta_5 \text{Log}(T_{t-1}) + \\ & \beta_6 \text{Log}(FDI_{t-1}) + \varepsilon_t \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Log}(E_t) = & c + \beta_1 \text{Log}(E_{t-1}) + \beta_2 \text{Log}(RE_{t-1}) + \beta_3 \text{Log}(GDP_{t-1}) + \beta_4 \text{Log}(LP_{t-1}) + \\ & \beta_5 \text{Log}(FF_{t-1}) + \beta_6 \text{Log}(T_{t-1}) + \beta_7 \text{Log}(FDI_{t-1}) + \text{ect} \end{aligned} \quad (2)$$

$$\begin{aligned} \text{Log}(E_t) = & \beta_1 \text{Log}(RE_t) + \beta_2 \text{Log}(GDP_t) + \beta_3 \text{Log}(LP_t) + \beta_4 \text{Log}(FF_t) + \beta_5 \text{Log}(T_t) + \\ & \beta_6 \text{Log}(FDI_t) \end{aligned} \quad (3)$$

Where E is South Africa's total employment levels, RE is renewable energy consumption, FF is fossil fuel energy consumption, GDP is GDP per capita growth, LP is labour productivity, T is trade openness and FDI is foreign direct investment. Variable selection was guided by the reviewed literature and the labour demand theoretical underpinnings for this study. The logarithmic form of all variables will be used in this paper's analysis for easy interpretation of the results and to reduce potential outlier effects in the model estimates.

Model 1 will allow us to establish if there is a cointegrating relationship between the variables, model 2 will provide us with any short run impacts on the dependent variable, while model 3 will provide long run impacts on the dependent variable.

The optimal number of lags for the variables in our ARDL model (model 1) is selected using the AIC information criteria, but the HQ and SC criteria will also be used for support.

The ARDL bounds test approach has several advantages over the other cointegration tests. Firstly, the test can be conducted with variables of varying orders of integration unlike tests such as the Johansen cointegration test. Secondly, the ARDL approach is robust in cases of small sample sizes. Lastly, the technique utilised a reduced form equation compared to the system approach adopted by other techniques such as the Johansen test. (Khobai, Kolisi, Moyo, Anyikwa and Dingela, 2020)

6 EMPIRICAL RESULTS AND DISCUSSIONS

6.1.1 Unit root tests

Although the ARDL method is applicable irrespective of whether the underlying regressors are integrated of order 0 or 1 (i.e., are stationary or not) we still conduct unit root tests to ensure that there is no series integrated of order 2 or higher. Common unit root testing methods are the Augmented Dickey and Fuller (ADF) test, Phillips and Perron (PP) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The ADF test assumes that the sequence may contain autoregression process, and the PP test assumes that the data contains moving average process. For data of small size, ADF testing may lack efficiency, while the KPSS test is more convenient (Zhao and Luo, 2017).

Because of their differing underlying assumptions, and different strengths and weaknesses, there exists complementarity within these three testing methods, so all three will be used in this study. When a variable was found to be non-stationary, the same unit root tests were applied to its first difference to test whether it is integrated of order 2 or more.

Where the tests results differed, the most common finding was accepted and used. When the results of the three tests differed significantly, visual plots of the time series and their ACF and PACF functions were consulted for support.

The unit root results for testing at the levels of the variables and first difference of the variables are reported in Tables 2 and 3, respectively.

The results showed mixed integration of $I(0)$ and $I(1)$ variables. The results find that renewable energy consumption “passed” each of the unit root test at level, whereas each of the other variables become stationary after first difference as shown in Table 2. While there were mixed results across the unit root tests regarding the stationarity of some series (GDP per capita, FDI, and trade openness), nearly all of the test results found the series to be integrated of $I(1)$ or less (meaning that no series were integrated of order 2 or higher). Therefore, we can continue with our model estimations without issue.

Table 2: Unit Root Tests Results (Levels)

Variable (Levels)	ADF with Intercept Only	ADF with Intercept and Trend	PP	KPSS	Stationarity
L(Total Employment)	-1.25	-0.75	-1.054	1.337***	Non-Stationary (4/4 test results)
L(Renewable Energy Consumption)	-3.19**	-4.11***	-4.795***	0.847***	Stationary (3/4 test results)
L(GDP per capita growth)	-2.77	-2.61	-2.874	0.127	Non-Stationary (3/4 test results)
L(Labour Productivity)	-1.25	-1.55	-1.597	0.664**	Non-Stationary (4/4 test results)

L(Fossil Fuel Consumption)	-3.39**	-0.6	-0.668	1.252***	Non-Stationary (3/4 test results)
L(Trade Openness)	-2.23	-2.22	-2.109	0.249	Non-Stationary (3/4 test results)
L(FDI)	-2.17	-3.96**	-5.293***	1.075***	Non-Stationary (mixed results – visual plot and ACF/PACF functions consulted)

*** Null hypothesis rejected at a 1% level

** Null hypothesis rejected at a 5% level

Table 3: Unit Root Tests Results (First Difference)

Variable (First Difference)	ADF with Intercept Only	ADF with Intercept and Trend	PP	KPSS	Order of Integration
L(Total Employment)	-2.12**	-2.65	-4.729***	0.203	I(1)
L(Renewable Energy Consumption)	-6.73***	-6.60***	-7.928***	0.147	I(0)
L(GDP per capita growth)	-5.48***	-5.47***	-6.679***	0.209	I(1)

L(Labour Productivity)	-3.38**	-3.34	-4.800***	0.13	I(1)
L(Fossil Fuel Consumption)	-3.72***	-5.21***	-7.511***	0.819***	I(1)
L(Trade Openness)	-5.17***	-5.11***	-6.415***	0.075	I(1)
L(FDI)	-6.98***	-6.90***	-13.634***	0.075	I(1)

*** Null hypothesis rejected at a 1% level

** Null hypothesis rejected at a 5% level

6.1.2 Lag Length Selection

A necessary step of the ARDL approach is to choose the appropriate lag length before applying the ARDL bounds test. The choice of lag length should be exercised with care, as inappropriate lag length selection can lead to biased results which cannot be used for policy analysis. To select lag lengths for our model, we use the Akaike Information Criteria (AIC) since it gives robust results compared to other criteria. However, the SC and HQ criteria were also consulted to support our choice.

Our model's AIC results for the top 20 possible models are shown below:

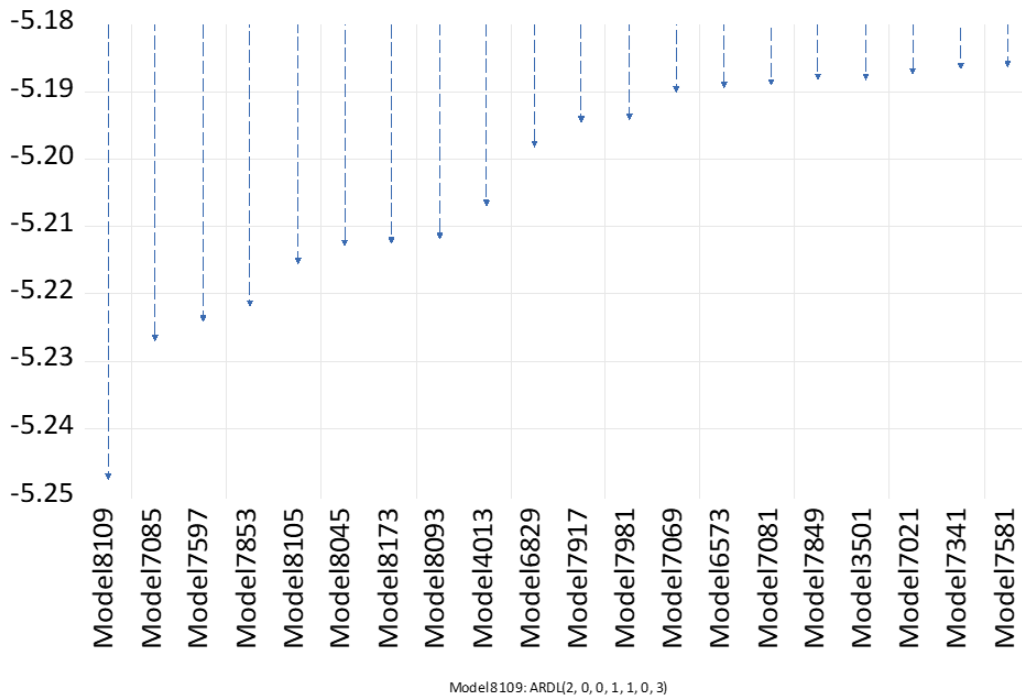


Figure 3: AIC Lag Length Selection (top 20 models)

Our results indicate that *total employment* should be included up to lag length 2, *primary energy consumption from renewables (TWh)*, *GDP per capita growth (annual %)*, and *trade (% of GDP)* should be included without any lags, *fossil fuel consumption* and *labour productivity* up to lag length 1, and *Foreign direct investment, net inflows (BoP, current US\$)* up to lag length 3. The SC and HQ criteria provided similar indications as the AIC. Therefore, we will continue with these lag lengths in our estimations.

6.2 MODEL ESTIMATIONS

The data is thus estimated using the model equations (1), (2), and (3) as presented in section 5.2 (*Econometric Model*) to address the objectives of this paper, with the addition of the Lag Length Selections given in section 6.1.2 (*Lag Length Selection*).

As shown in Table 3, using the F-Bounds test approach to cointegration, a long-term cointegrating relationship was found to exist among the variables of our ARDL model. Thus, we continue with the short-run and long-run estimations.

Table 4: F-Bounds Test: Null Hypothesis of No Cointegration

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.482903	10%	1.99	2.94
k	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

In our short-run estimation results, we see that the error correction term is statistically significant and has a coefficient estimate of -0.015 indicating a slow return from disequilibrium as shown in Table 4.

Table 5: Short and Long-run Model Estimations

Short-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Intercept	0.435	0.026	16.515	0.000***
D(Log(Total Employment))	0.016	0.041	0.385	0.700

D(Log(Renewable Energy Consumption))	0.000	0.001	-0.109	0.914
D(Log(GDP per capita growth))	0.066	0.003	21.364	0.000***
D(Log(Labour Productivity))	-0.847	0.032	-26.776	0.000***
D(Log(Fossil Fuel Consumption))	-0.003	0.021	-0.147	0.883
D(Log(Trade Openness))	0.030	0.011	2.711	0.007***
D(Log(FDI))	-0.017	0.005	-3.767	0.000***
ECT	-0.015	0.001	-15.948	0.000***

Long-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Log(Renewable Energy Consumption)	-0.052	0.052	-1.000	0.317
Log(GDP per capita growth)	4.518	0.693	6.519	0.000***
Log(Labour Productivity)	1.541	0.349	4.418	0.000***
Log(Fossil Fuel Consumption)	0.485	0.150	3.231	0.001***
Log(Trade Openness)	-0.226	0.293	-0.769	0.442
Log(FDI)	-1.725	0.586	-2.942	0.003***

*, **, *** refer to statistical significance at a 10%, 5%, and 1% level respectively.

The log of *GDP per capita growth*, *labour productivity*, *trade openness*, and *FDI* are statistically significant at a 5% level, with respective coefficient estimates of 0.066 (positive but small), -0.847 (negative and relatively large), 0.030 (positive but small), and -0.017 (negative but small).

In our long-run estimation results, we see that the log of *GDP per capita growth*, *labour productivity*, *fossil fuel consumption*, and *FDI*, are statistically significant at a 5% level at least, with respective coefficient estimates of 4.518 (positive and very large), 1.541 (positive and large), 0.485 (positive and somewhat large), and -0.226 (negative and somewhat large).

The log of *Renewable energy consumption* was not found to be significant at any level in the short or long run. Its coefficient estimates were negative but very small in both models.

6.2.1 Model diagnostics

Diagnostic tests were run to ensure the reliability of the model, and their results are shown in the Table 5. The Jarque-Bera test statistic indicates that the data is normally distributed. The Box-Ljung test statistic indicates that the residuals are independently distributed (i.e., the model does not show significant lack of fit). The Breusch-Pagan-Godfrey test statistic

indicates that homoscedasticity is present (the residuals are distributed with equal variance). The Ramsey RESET test statistic indicates that the estimated model is free from specification errors. Furthermore, the CUSUM test graph (reported in figure 4) indicates model/parameter stability. However, the CUSUM squared test graph (reported in figure 5) finds some evidence of instability in the variance of the regression error.

Table 6: Diagnostic Test Results

Diagnostic Tests	Test Statistic	P value
Jarque-Bera Normality test	0.073	0.964
Box-Ljung test	12.695	0.2412
Breusch-Pagan-Godfrey Heteroscedasticity test	0.763	0.691
Ramsey RESET Specification Test	0.694	0.411

Figure 4: CUSUM Test

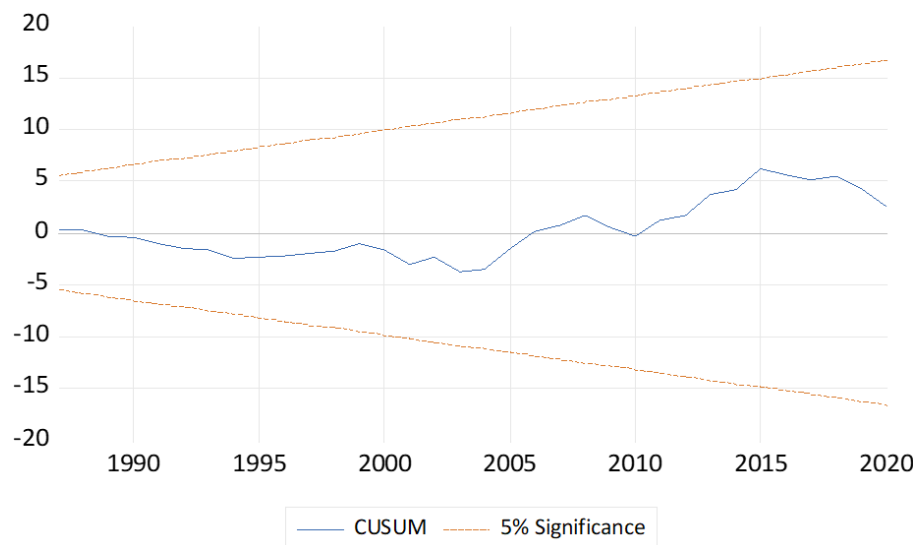
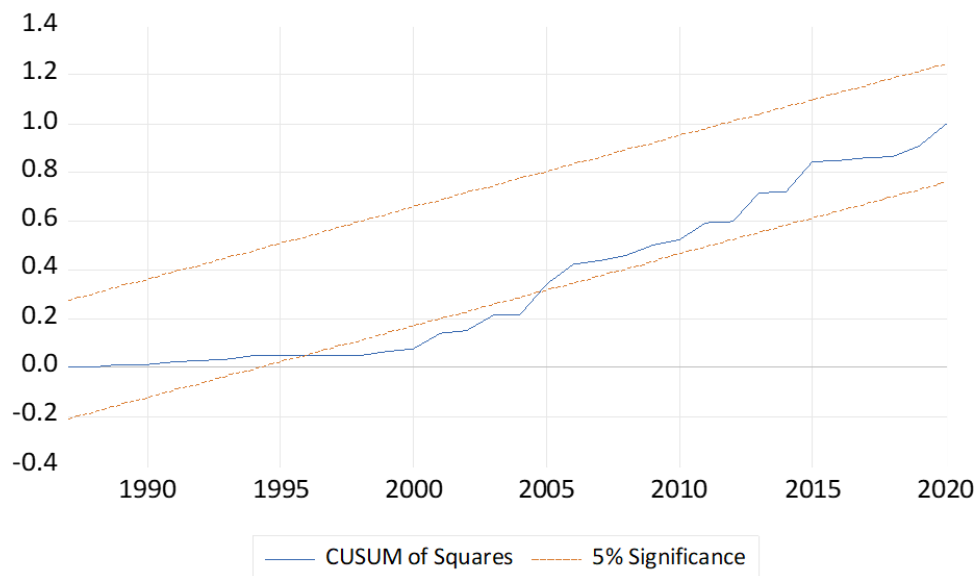


Figure 5: CUSUM Squared Test



A potential issue found with the model is that of multicollinearity (high correlation among the independent variables). This would make it difficult to determine the individual effect of each independent variable on the dependent variable, potentially undermining the model's estimations. To address this, a correlation matrix among the independent variables was calculated (provided in the appendix). Worryingly high correlation (greater than 0.6) was found between *Fossil fuel consumption* and two other variables. To ensure reliability of our model estimates, the model was re-estimated without this variable.

The existence of a long-term relationship between the variables was not rejected at a 5% level. Additionally, in our short run model, the error correction term was still found to be statistically significant and between 0 and -1, allowing us to continue with the interpretations of our estimations (provided in the appendix).

In the short and long run, renewable energy consumption was not found to have a statistically significant impact on employment levels.

In the short run, GDP per capita growth and trade openness were found to have a statistically significant but small positive impact on employment levels, while foreign direct investment and labour productivity were found to have statistically significant and large negative impacts on employment levels.

In the long run, GDP per capita growth and labour productivity were both found to have a statistically significant positive impact on employment levels.

While these estimations differ from those of the original model, they do not in any way contradict them. Long-run cointegration is still found among the variables, while renewable energy is not found to have a significant impact on employment levels. Economic growth is still found to be a driver of job growth, while labour productivity is found to have a negative influence in the short run and a positive influence in the long run.

6.3 DISCUSSIONS

6.3.1 Renewable Energy

In all our estimations, the primary focus of our investigation was on the impact of renewable energy on job growth in South Africa, and the log of *Renewable energy consumption* was not found to be significant at any level in the short or long run. Its coefficient estimates were near-0 in the short run and negative but very small in the long run.

At first interpretation, these findings may seem disappointing especially considering the findings of previous research indicating the potential of renewable energy to promote job growth. However, while that may not be the case in South Africa, it is relieving to find that renewable energy consumption does not have any significant negative impact on employment levels. Therefore, our findings indicate that renewable energy does not promote or deter job growth in South Africa- there is no significant impact from renewables on employment.

These findings are also important as they suggest that the widely-found relationship between South Africa's energy consumption and economic growth do not reflect in a relationship between energy consumption and employment levels.

Our findings differ somewhat from those of Khobai et al. (2020) which indicated that renewable energy consumption has a negative and significant effect on unemployment in South Africa in the long run. However, this initial inconsistency between our studies' results is explained or even offset by the following points:

- Both studies found an insignificant relationship between the variables in the short run, supporting each other's results.
- Khobai et al. (2020) made use of a dataset spanning 1990-2014, while this study made use of a dataset spanning 1970-2021. The difference of around 25 observations between the datasets may have led to differing estimation results.

However, we would expect our estimation results to be more reliable in this regard (having used a larger dataset).

- Khobai et al. (2020) estimated the impact of renewables on unemployment in a multivariate framework including Gross fixed capital formation, Government expenditure, and Credit to the private sector. Not only did our model use total employment instead of unemployment to measure any potential impact on job growth, but the variables included in our framework differ completely from those of Khobai et al. (2020). As before, we expect our variable choices to be more appropriate and provide more reliable results, especially considering the literature reviewed on determinants of labour demand in South Africa.

Therefore, while they may be unexpected or disappointing based on other studies done on the topic, this paper's findings of no significant impact from renewables on job growth in South Africa should be considered reliable.

6.3.2 Determinants of labour demand- Comparisons with previous research

Short Run

In our short-run estimates, the log of *GDP per capita growth*, *labour productivity*, *trade openness*, and *FDI* were found to be significant in determining labour demand. Our findings suggest that economic growth has a small but positive impact on employment which is as expected and is consistent with previous research.

Labour productivity was found to have a large negative impact on employment, which is somewhat expected even if disappointing. This supports the study of Muzindutsi and Maepa (2014) which discussed arguments that rapid growth of productivity may reduce employment by leading to producers reducing jobs and switching to capital-intensive production. The relationship between human capital and economic growth in South Africa must thus be re-evaluated and re-structured such that they simultaneously promote job growth.

Trade openness was found to have a small but positive impact on employment, which is consistent with typical international trade theory views (OECD, 2022). This finding is also somewhat supportive of the studies of Meyer and Sanusi (2019) and Chinembiri (2010) which found exports and imports to have significant impact on South Africa's employment

levels (respectively). Even though our finding of trade having a positive impact on employment may differ somewhat from that of Chinembri (2010), this can simply be explained by dataset size and the choice of other variables included in the multivariate framework.

FDI was found to have a small negative impact on employment which was somewhat surprising and not consistent with the findings of Tsheop (2014) which supported the hypothesis of FDI having a positive impact on GDP growth and employment in South Africa. However, our findings support each other in the sense that both studies found significant impact from FDI to employment in South Africa, and the differences between our estimated nature of this impact can again be explained by dataset size and the choice of other variables included in the multivariate framework.

Long Run

Our long-run model's estimations provided similar results to our short-run model. The log of *GDP per capita growth*, *labour productivity*, and *FDI* were again found to be significant in determining labour demand. Contrasting with the short-run estimations was that *trade openness* was not found to be significant while *fossil fuel consumption* was found to be significant. Our findings suggest that economic growth has a very large positive impact on employment, which again is as expected and is consistent with previous research. Therefore, both short and long-run estimates support the theory of economic growth promoting job growth.

Contrasting to the short-run, labour productivity was found to have a large positive impact on employment, but this is still somewhat expected. Both model findings are supported by the research and discussions of Muzindutsi and Maepa (2014) which argue that “the main determinant of employment (in South Africa) is human capital”. Our findings suggest that, given enough time, the theory holds that improved human capital and increased production interact in such a way that job creation is supported.

Like in the short-run, FDI was found to have a negative (but now larger) impact on employment. As before, this is somewhat surprising and not consistent with the findings of Tsheop (2014). However, our findings still support the significance of FDI to employment in South Africa, and the differences between our estimated nature of this impact can still be

explained by dataset size and the choice of other variables included in the multivariate framework.

Fossil fuel consumption was found to have a positive and somewhat large impact on employment levels in the long run. This was expected and is consistent with the findings of Kumar et al. (2015), Lin and Wesseh Jr. (2014), and Bekun et al. (2018) who all found evidence of a positive relationship between energy consumption and economic growth in South Africa. However, this finding is noteworthy since it supports the theory that there may exist a direct relationship between energy consumption and employment levels in South Africa, whereby energy consumption promotes job creation.

7 SENSITIVITY ANALYSIS

7.1 RENEWABLE ENERGY GENERATION

It can be argued that most of the job creation that would result from renewable energy would be dependent on renewable energy production where skilled and unskilled labour is employed to generate the technology that is deployed for energy production. Although consumption may drive production which in turn drives job creation, this may be an indirect effect. This may be the reason why there was no impact found from renewable energy on employment in the context of South Africa.

A robustness check was run using a measure of renewable energy production rather than consumption. This was done through replacing the *Renewable energy consumption* variable with *Renewable energy generation* (drawn from the same data source) (series plotted in the appendix). The stationary checks for this variable found it to be stationary (as was the case for *renewable energy consumption*), which allows us to continue with our estimations as before. The model estimations are provided in the appendix.

Encouragingly, the sensitivity analysis estimations largely mirror those of the original model, providing even more positive results where it does differ.

In the short run, the log of *GDP per capita growth*, *labour productivity*, *trade openness*, and *FDI* are all still statistically significant at a 5% level, with respective coefficient estimates of

0.065 (positive but small), -0.844 (negative and relatively large), 0.030 (positive but small), and -0.014 (negative but small).

The log of *Renewable energy generation* is statistically significant at a 10% level and has a fairly large positive impact on employment levels (with a coefficient of 0.448).

In our long-run estimation results, we see that the log of *GDP per capita growth*, *labour productivity*, *fossil fuel consumption*, and *FDI*, are statistically significant at a 5% level at least, with respective coefficient estimates of 3.1491 (positive and very large), 0.911 (positive and large), 0.453 (positive and somewhat large), and -0.982 (negative and somewhat large).

These estimations support the findings of the paper's model, but also suggest that while renewable energy consumption may not have a significant relationship with employment levels, renewable energy production may have a significant and positive impact on employment levels through the generation of jobs to produce renewable energy technology.

7.2 ACCOUNTING FOR A POTENTIAL STRUCTURAL BREAK

It can be argued that, given the long nature of the time period considered, the paper's analysis would benefit from accounting for the potential effect of structural change. This may be shown in the CUSUM squared test which shows that there may be a problem of structural break in the data. To account for this, the model was run with a dummy variable created to account for a potential structural break from 1996 to 2004. The model estimations are provided in the appendix.

Encouragingly, the sensitivity analysis estimations largely mirror those of the original model. *Trade openness* is no longer statistically significant in the short run, while the *log of GDP per capita growth*, *labour productivity*, and *FDI* are all still statistically significant at a 1% level, with respective coefficient estimates of 0.065 (positive but small), -0.832 (negative and relatively large), and -0.019 (negative but small). The dummy variable is significant at a 10% level and has a small but negative impact on employment.

Labour productivity is no longer statistically significant in the long run, while the log of *GDP per capita growth*, *fossil fuel consumption*, and *FDI*, are still statistically significant at a 1% level, with respective coefficient estimates of 3.333 (positive and very large), 0.790 (positive and large), -1.253 (negative and somewhat large). The dummy variable is significant at a 5% level and has a fairly large negative impact on employment.

Apart from the insignificance of trade in the short run and labour productivity in the long run, our model produces similar results as previously even when accounting for a potential structural break.

These estimations support those of the original model, further supporting the reliability of our findings.

8 CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 Initial Remarks

All research into a topic of this nature must firstly acknowledge that regardless of the nature of the relationship found between renewable energy sources and employment/economic growth, we must not discourage renewable energy development. Positive economic impacts from transitioning towards a low-carbon economy, such as boosting employment, are just additional arguments for climate mitigation policies. They must be considered co-benefits of environmental policies and not its primary justification. (I. Meyer, M. W. Sommer, 2014) (R. J. Lambert , P. P. Silva, 2012).

It is also important to remember and understand that any relationship(s) between renewable energy and job creation do not occur naturally – they are products of the socio-economic environment and thus can be systematically changed. Regardless of this paper's findings, South Africa must work towards building and supporting a fundamentally positive relationship between environmental sustainability and job growth.

8.1.2 Our findings

Further econometric analysis on the relationship between renewable energy and employment in South Africa is necessary to have reliable results upon which to base future

socio-economic energy policies. However, our analysis yielded noteworthy findings which should contribute to the relevant literature, paving the way for future research.

We set out to investigate any potential impact of renewable energy on job growth in South Africa. Additionally, we also aimed to estimate the impacts of other labour demand determinants on employment in South Africa using updated datasets and time series analysis. Our analysis made use of renewable energy consumption and total employment levels in a multivariate framework including GDP per capita growth, labour productivity, fossil fuel consumption, trade openness, and foreign direct investment.

The ARDL Bounds test approach to cointegration was used, with the results indicating that there exists a long-run relationship between the model's variables. Thus, the short and long-run models were estimated.

In both the short and long run, renewable energy consumption was not indicated to have any significant impact on total employment levels in South Africa. While somewhat unexciting, this finding is not unexpected and still supports the development of renewable energy in South Africa since no negative significant impact from renewables on job growth was found.

However, in our sensitivity analysis, a positive and somewhat statistically significant impact was found from renewable energy generation on employment levels at least in the short run. These may suggest that while renewable energy consumption may not have a significant relationship with employment levels, renewable energy production may have a significant and positive impact on employment levels through the generation of jobs to produce renewable energy technology.

Regarding the other determinants of labour demand, our estimation results yielded arguably much more interesting findings.

In both the short and long run, GDP per capita growth had significant and positive impact on employment levels, further supporting the theory that economic growth causes job growth.

In both the short and long run, labour productivity was found to have a large significant impact on employment levels. However, this impact was estimated to be negative in the short run and positive in the long run. This finding supports that the impact of a country's human capital levels on its job growth varies depending on its relationship with other socio-economic variables. Our findings thus indicate that increasing human capital levels in South Africa may negatively influence job growth in the short term (most likely through employers switching from labour to capital-intensive production), but that higher levels of productivity will eventually lead to increases in job growth in the long term (most likely through increased economic prosperity for businesses and the country).

In both the short and long run, FDI was found to have a significant but negative impact on employment levels. This finding was somewhat surprising as the theory expects FDI to promote a country's job growth. However, our estimations still support the significance of FDI on employment in South Africa, and simply show the need for further research into the nature of the impact of FDI on job growth when taking other macroeconomic variables into account.

In the short run, trade openness was found to have a small but significant positive impact on employment. This finding supports the general macroeconomic theory that states trade to be a driver of a country's economic and job growth. Particularly for a developing country like South Africa, this is a promising finding which supports trade liberalization as a driver of employment.

In the long run, fossil fuel consumption was found to have a positive and somewhat large impact on employment levels. While this finding was somewhat expected given the significance of the country's dependence on its coal resources (South Africa accounted for about 67 percent of Africa's proven coal reserves as at the end of 2020 based on British Petroleum, 2022 estimates), especial in electricity generation, creating a number of jobs in the coal mining sector.

8.1.3 Limitations

As discussed in sections 6.2.1 and 7, limitations of this model may include potential multicollinearity among the independent variables, incorrect variable selection (making use

of renewable energy consumption rather than generation), and a possible structural break in the dataset. However, in each case, once these potential limitations were accounted for and the model re-estimated, the results did not contradict our findings (further supporting them to a large degree).

8.1.4 Take-aways from this study

The results of this study's estimations show interesting findings for the determinants of labour demand in South Africa. In particular, the significance impacts of labour productivity and fossil fuel consumption on employment levels strongly advocate for their inclusion in future models of this nature, and the potential negative impact of FDI on employment advocates for future research on its relationship with job growth.

However, the primary focus of this study was on the potential impact of renewable energy on job growth in South Africa, and our findings indicate that there is no such significant impact present (specifically between renewable energy consumption and employment levels). However, a potential positive relationship may exist between renewable energy generation/production and job growth. This offers great promise for climate change mitigation and reduced unemployment to be simultaneously pursued by South Africa.

8.2 RECOMMENDATIONS: INVESTING IN GREEN JOBS AND A GREEN ECONOMY

The transition of a country towards a low-carbon energy system and overall green economy requires “strong government initiative, a stable political framework for investments and private engagement”. (I. Meyer, M. W. Sommer, 2014)

There is considerable potential for growth in renewables and renewable employment, and overall growth in the green economy and green jobs in South Africa. However, the relevant markets must be supported by stable and sensibly designed investment strategies, such as long-term supporting schemes (e.g., feed-in tariffs) and a global approach towards climate protection (e.g., carbon taxes, caps, and trade systems). (I. Meyer, M. W. Sommer, 2014)

Public and private policies must promote and support the importance of resource-saving technologies like renewable energy and recycling. Investment into low-carbon technologies

should have a stronger emphasis on improving resource productivity and not simply on marginally reducing pollutant emissions to appear “greener”. (I. Meyer, M. W. Sommer, 2014)

Specifically, with South Africa's high unemployment levels in mind, efforts must be made to identify the growing demands for jobs in renewable energy markets. Following this, the right skills should be identified and targeted to create a smoother transition to renewable energies and to ensure that the benefits of new opportunities are spread broadly throughout society. Shortages of labour with the needed skills in different value-chain stages of renewable energy development (particularly technical and engineering skills for construction, operation, and maintenance) have already been identified in many countries before. (S. Nasirov, A Girard, C. Pena, F. Salazar, F. Simon, 2021)

Therefore, a comprehensive mapping of information on human capital competence is necessary to identify the skills and knowledge available in the renewable job market. To meet the growing labour demands of renewable energy markets, the South African government, with support from the private sector, should establish appropriate policies in a long-term strategy to coordinate the relevant skills training. To this end, competence capacity-building and educational programs need to be clearly aligned with projected investments into renewables. (S. Nasirov, A Girard, C. Pena, F. Salazar, F. Simon, 2021)

Finally, whatever policies are developed promoting a transition to a low-carbon economy with green job growth, they should be continuously monitored and evaluated, and updated according to the evolution of the energy sector, particularly considering the diminishing fossil fuel reserves across the world. It is crucial that South Africa’s public sector and private sector collaborate to generate robust policies and mechanisms that create a positive relationship between renewables and job growth.

9 REFERENCES

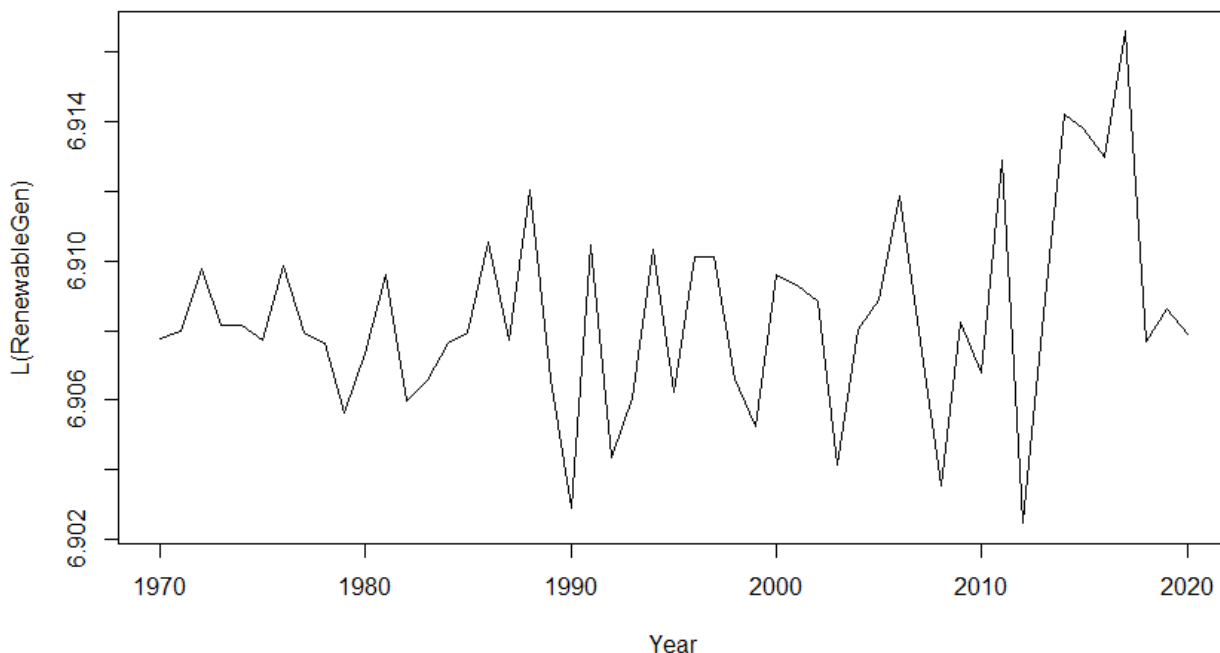
- A.A. BASHIER, A.N. WAHBAN. (2013). *The Determinants of Employment in Jordan: A Time Series Analysis*. International Review of Management and Business Research.
- B. Lin, P. Wesseh Jr. (2014). *Energy consumption and economic growth in South Africa reexamined: A nonparametric testing approach*. Renewable and sustainable energy reviews.
- British Petroleum (2022). *Statistical Review of World Energy*
- C. Chang, M. Fang. (2022). *Renewable energy-led growth hypothesis: New insights from BRICS and N-11 countries*. Renewable Energy.
- Chinembiri, E. K. (2010). *An Empirical Assessment of the Impact of Trade Liberalization on Employment in South Africa*. TPS.
- D Meyer, K Sanusi. (2019). *A CAUSALITY ANALYSIS OF THE RELATIONSHIPS BETWEEN GROSS FIXED CAPITAL FORMATION, ECONOMIC GROWTH AND EMPLOYMENT IN SOUTH AFRICA*. Sciendo.
- F. Bekun, F. Emir, S. Sarkodie. (2018). *Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa*. Science of the Total Environment.
- H. Khobai, N. Kolisi, C. Moyo, I. Anyikwa, S. Dingela. (2020). *Renewable Energy Consumption and Unemployment in South Africa*. *International Journal of Energy Economics and Policy*.
- H. Ritchie, M. Roser. (2022, 06 01). *South Africa: Energy Country Profile*. Retrieved from Our World In Data: <https://ourworldindata.org/energy/country/south-africa>
- Hodge, D. (2009). *GROWTH, EMPLOYMENT AND UNEMPLOYMENT IN SOUTH AFRICA*. South African Journal of Economics.
- I. Meyer, M. W. Sommer. (2014). *Employment Effects of Renewable Energy Supply – A Meta Analysis*. Austrian Institute of Economic Research – WIFO.
- J. Jaraitė, A. Karimu, A. Kažukauskas, P. Kažukauskas. (2015). *Renewable Energy Policy, Economic Growth and Employment in EU Countries: Gain without Pain?* Centre for Environmental and Resource Economics.
- K. Menyah, Y. Wolde-Rufael. (2010). *Energy consumption, pollutant emissions and economic growth in South Africa*. Energy Economics.
- P.F. Muzindutsi, M.M. Maepa. (2014). *Manufacturing Production and Non-Agricultural Employment rate in South Africa: Time Series Analysis*. Journal of Economics and Behavioral Studies.
- PwC, S. (2022). *South Africa Economic Outlook The next inflation challenge: salary and wage increases*. PwC.
- R Mcsweeney, J Timperley. (2022, 05 23). *The Carbon Brief Profile: South Africa*. Retrieved from Carbon Brief: <https://www.carbonbrief.org/the-carbon-brief-profile-south-africa/>
- R. J. Lambert , P. P. Silva. (2012). *The challenges of determining the employment effects of renewable energy*. Renewable and Sustainable Energy Reviews.
- R. Kumar, P. Stauvermann, N. Loganathan, D. Kumar. (2015). *Exploring the role of energy, trade and financial development Exploring the role of energy, trade and financial development*. Renewable and sustainable energy reviews.
- S. Nasirov, A Girard, C. Pena, F. Salazar, F. Simon. (2021). *Expansion of renewable energy in Chile: Analysis of the effects on employment*. Energy.

- TheConferenceBoard. (2021, August 01). *Total Economy Database*. Retrieved from The Conference Board: <https://www.conference-board.org/data/economydatabase/total-economy-database-productivity>
- Tshepo, M. (2014). *The Impact of Foreign Direct Investment on Economic Growth and Employment in South Africa: A Time Series Analysis*. Mediterranean Journal of Social Sciences.
- UN. (2022, 05 25). *Climate Action* . Retrieved from United Nations: <https://www.un.org/en/climatechange/raising-ambition/renewable-energy>
- Vermeulen, C. (2015). *Inflation, growth and employment in South Africa: Trends and trade-offs*. ERSA.
- Worldometer. (2022, 05 23). *CO2 Emissions by country*. Retrieved from <https://www.worldometers.info/co2-emissions/co2-emissions-by-country/>
- Worldometer. (2022, 05 23). *Countries in the world by population (2022)*. Retrieved from <https://www.worldometers.info/world-population/population-by-country/>
- Worldometer. (2022, 05 23). *GDP by country*. Retrieved from <https://www.worldometers.info/gdp/gdp-by-country/>
- X. Zhao, D. Luo. (2017). *Driving force of rising renewable energy in China: Environment, regulation and employment*. Renewable and sustainable energy reviews.
- Zach. (2022, 07 02). *Statology*. Retrieved from What is a good R-Squared value?: <https://www.statology.org/good-r-squared-value/>

9.1 APPENDIX

9.1.1 Renewable Energy Generation

Figure: Log(Renewable energy generation)



Using the ADF test (-4.73), renewable energy generation was found to be stationary at a 1% level.

Model Estimations

The data is thus estimated using the model equations (1), (2), and (3) as presented in section 5.2 (*Econometric Model*) to address the objectives of this paper, with the addition of the Lag Length Selections given in section 6.1.2 (*Lag Length Selection*). In this model, we make use of Renewable Energy Generation as opposed to Renewable Energy Consumption.

Using the F-Bounds test approach to cointegration, a long-term cointegrating relationship was found to exist among the variables of our ARDL model. Thus, we continue with the short-run and long-run estimations.

In our short-run estimation results, we see that the error correction term is statistically significant and has a coefficient estimate of -0.022 indicating a slow return from disequilibrium.

Table: Short and Long-run Model Estimations (using renewable energy generation)

Short-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Intercept	-1.03256	0.061779	-16.714	2.00E-16***

D(Log(Total Employment))	0.022268	0.039709	0.561	0.57494
D(Log(Renewable Energy Generation))	0.447605	0.185405	2.414	0.01577*
D(Log(GDP per capita growth))	0.065429	0.002962	22.091	2.00E-16***
D(Log(Labour Productivity))	-0.84414	0.030193	-27.958	2.00E-16***
D(Log(Fossil Fuel Consumption))	0.001471	0.019591	0.075	0.94015
D(Log(Trade Openness))	0.028847	0.0107	2.696	0.00702**
D(Log(FDI))	-0.01404	0.004347	-3.229	0.00124**
ECT	-0.02192	0.001292	16.967	2.00E-16***

Long-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Log(Renewable Energy Generation)	9.87	10.1013	0.977	0.328517
Log(GDP per capita growth)	3.149	0.3445	9.142	2.00E-16***
Log(Labour Productivity)	0.911	0.2415	3.77	0.000163***
Log(Fossil Fuel Consumption)	0.453	0.1121	4.04	5.35E-05***
Log(Trade Openness)	-0.297	0.2065	-1.44	0.149944
Log(FDI)	-0.982	0.3104	-3.164	0.001554**

, **, *** refer to statistical significance at a 10%, 5%, and 1% level respectively.

In the short run, the log of *GDP per capita growth*, *labour productivity*, *trade openness*, and *FDI* are all still statistically significant at a 5% level, with respective coefficient estimates of 0.065 (positive but small), -0.844 (negative and relatively large), 0.030 (positive but small), and -0.014 (negative but small). The log of *Renewable energy generation* is statistically significant at a 10% level and has a fairly large positive impact on employment levels (with a coefficient of 0.448).

In our long-run estimation results, we see that the log of *GDP per capita growth*, *labour productivity*, *fossil fuel consumption*, and *FDI*, are statistically significant at a 5% level at least, with respective coefficient estimates of 3.1491 (positive and very large), 0.911 (positive and large), 0.453 (positive and somewhat large), and -0.982 (negative and somewhat large).

9.1.2 Accounting For Potential Structural Break

A dummy variable was created to account for a potential structural break from 1996 to 2004.

Table: Short and Long-run Model Estimations (with dummy variable)

Short-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Intercept	0.670788	0.040765	16.455	2.00E-16***

D(Log(Total Employment))	-0.00986	0.040253	-0.245	0.80646
D(Log(Renewable Energy Consumption))	0.000293	0.001079	0.271	0.78615
D(Log(GDP per capita growth))	0.065666	0.002996	21.917	2.00E-16***
D(Log(Labour Productivity))	-0.83188	0.030436	-27.333	2.00E-16***
D(Log(Fossil Fuel Consumption))	0.007489	0.02032	0.369	0.71245
D(Log(Trade Openness))	0.031429	0.010782	2.915	0.00356
D(Log(FDI))	-0.01948	0.004554	-4.277	1.90E-05***
Dummy	-0.00799	0.003727	-2.145	0.03198*
ECT	-0.02101	0.001305	-16.106	2.00E-16***

Long-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Log(Renewable Energy Generation)	-0.01346	0.03344	-0.403	0.6872
Log(GDP per capita growth)	3.33318	0.36609	9.105	2.00E-16***
Log(Labour Productivity)	0.06683	0.27658	0.242	0.80908
Log(Fossil Fuel Consumption)	0.79004	0.08372	9.437	2.00E-16***
Log(Trade Openness)	0.15237	0.2039	0.747	0.45492
Log(FDI)	-1.25278	0.3489	-3.591	0.00033***
Dummy	-0.24814	0.08606	-2.883	0.00394**

, **, * refer to statistical significance at a 10%, 5%, and 1% level respectively.*

Trade openness is no longer statistically significant in the short run, while the log of *GDP per capita growth*, *labour productivity*, and *FDI* are all still statistically significant at a 1% level, with respective coefficient estimates of 0.065 (positive but small), -0.832 (negative and relatively large), and -0.019 (negative but small). The dummy variable is significant at a 10% level and has a small but negative impact on employment.

Labour productivity is no longer statistically significant in the long run, while the log of *GDP per capita growth*, *fossil fuel consumption*, and *FDI*, are still statistically significant at a 1% level, with respective coefficient estimates of 3.333 (positive and very large), 0.790 (positive and large), -1.253 (negative and somewhat large). The dummy variable is significant at a 5% level and has a fairly large negative impact on employment.

Apart from the insignificance of trade in the short run and labour productivity in the long run, our model produces the same results as previously even when accounting for a potential structural break.

9.1.3 Accounting For Potential Multicollinearity

Table: Correlation matrix among independent variables

	<i>GDP per capita growth</i>	<i>Fossil fuel consumption</i>	<i>Primary renewable energy consumption</i>	<i>Productivity</i>	<i>Foreign direct investment</i>
GDP per capita growth	1				
Fossil fuel consumption	-0.129	1			
Primary renewable energy consumption	-0.287	0.536	1		
Productivity	-0.291	0.724	0.574	1	
Foreign direct investment	0.137	0.667	0.311	0.576	1

Table: Short and Long-run Model Estimations (without fossil fuel consumption)

Short-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Intercept	0.300878	0.016162	18.616	2.00E-16***
D(Log(Total Employment))	0.016907	0.041011	0.412	0.680151
D(Log(Renewable Energy Consumption))	-0.00028	0.001111	-0.248	0.804415
D(Log(GDP per capita growth))	0.066891	0.002906	23.022	2.00E-16***
D(Log(Labour Productivity))	-0.83188	0.030436	-27.333	2.00E-16***
D(Log(Trade Openness))	0.028092	0.010799	2.601	0.009289**
D(Log(FDI))	-0.01713	0.00453	-3.781	0.000156***
ECT	-0.00609	0.000347	-17.573	2.00E-16***

Long-Run				
Variable	Estimate	Std.Err	Z Value	Pr(>z)
Log(Renewable Energy Generation)	-0.1524	0.171	-0.891	0.37289
Log(GDP per capita growth)	11.4869	4.4204	2.599	0.00936**
Log(Labour Productivity)	4.6934	1.7995	2.608	0.0091
Log(Trade Openness)	-1.1133	0.8722	-1.276	0.20183
Log(FDI)	-4.3738	2.8608	-1.529	0.1263

*, **, *** refer to statistical significance at a 10%, 5%, and 1% level respectively.