

# Exploring the impact of institutional quality to South Africa's transition to renewables

Inglesi-Lotz, R.

Department of Economics, University of Pretoria, Pretoria, South Africa

Email: [roula.inglesi-lotz@up.ac.za](mailto:roula.inglesi-lotz@up.ac.za)

## Abstract

Motivated by the need for a transition towards cleaner and sustainable energy sources, this study delves into the relationship between institutional quality and South Africa's renewable energy adoption. The objective is to examine how institutional factors influence the share of renewable energy in the country, recognizing that energy transition hinges not only on socioeconomic and technological determinants but also on political economy and institutional variables. This paper proxies institutional quality by the Corruption Perception Index (CPI), Regulatory Quality (REGQUAL), and Government Efficiency (GOV\_EFF), on South Africa's renewable energy share. We find that perceived institutional cleanliness, as measured by a higher CPI, positively affects the share of renewables. This can be attributed to the public's growing association of corruption with government activities and fossil fuel-based electricity generation. Additionally, improved REGQUAL fosters a healthier energy market but paradoxically results in a lower share of renewable energy in the short term. While contributing to stability, government effectiveness can hinder renewables' growth due to established industry interests and short-term priorities. The implications of these findings underscore the complex interplay of political and institutional dynamics in shaping South Africa's energy landscape. This research highlights the need for integrated policies addressing environmental and socioeconomic objectives.

Keywords: Institutions; Energy transition; South Africa

JEL codes: C22, E02, O43, O44, Q28, Q43

## 1. Introduction

Countries globally have intensified their efforts to diversify the energy generation mixes with higher renewable energy shares, appreciating that the power sector is one of the main contributors to air pollution. (AlFarra & Abu-Hijleh, 2012; Apergis et al., 2010; Bellakhal et al., 2019). The renewable energy option has widely been considered the solution to climate change and a possible answer to energy insecurity issues and energy poverty in lower-income countries. Although countries have accepted the necessity of energy transition, they do not all make progress at the same speed. In the early 2010s, most obstacles were standard worldwide, including technical, economic, market and social barriers. Bourcet (2020) mentions that factors affecting this speed include policy and regulatory frameworks, political stability, and the ideological orientation of governments.

The South African economy is not an exception in facing the challenge of balancing economic growth with minimising environmental degradation (Musango et al., 2009). With the country's socioeconomic and political challenges, even after the democratisation and end of apartheid, as well as increasing population and dependence on the global economy, South African policymakers have a difficult task in ensuring optimal use of resources, energy security and access (Department of Energy, 2018). In addition, the corruption and mismanagement in the national utility's management "negated any chance the power utility had to achieve its generation capacity and financial stability goals" (Inglesi-Lotz and Bohlmann, 2022). With such perceptions for the energy policymakers, the road to future energy transition toward renewable energies is not considered a priority on the agenda.

This paper aims to investigate and quantify the impact of institutional quality on the share of renewable energies in the electricity supply mix in South Africa. To do so, a time series econometric analysis will assist in comparing and contrasting the impact of notably the Corruption Perception Index (CPI), the Regulatory Quality (REGQUAL) and the Government Effectiveness (GOVEFF) on the share of renewable energy in the country. The analysis is of essential importance and high relevance, with a direct and major impact on policy considerations. To begin, it addresses the serious and worldwide issue of shifting to renewable energy sources, which aligns with the imperative to combat climate change and strengthen energy security. This is especially important in low-income nations like South Africa, where energy choices have significant socioeconomic and environmental effects. Furthermore, as the globe recognizes the importance of the energy transition, it becomes clear that not all nations are progressing at the same rate, and the fundamental variables causing this difference remain unexplored. This study provides a sophisticated and practical perspective through which policymakers can better understand and manage the significant issues associated with renewable energy adoption. It provides information that can be used to inform the creation of specific policies and strategies, allowing governments to speed energy transition projects while effectively managing socioeconomic and environmental problems.

Several significant criteria led to the decision to focus on South Africa as the context for this study goal. To begin, South Africa is an important case study in the broader global discussion of renewable energy

adoption. The country faces a unique collection of difficulties, including apartheid past, persistent socioeconomic imbalances, and complex political dynamics. These difficulties have a direct impact on energy policy decisions and have the potential to dramatically alter the pace and nature of the energy transition. Second, South Africa's energy landscape is a microcosm of the larger issues confronting lower-income countries, making it an appropriate exemplar for regions grappling with comparable dilemmas of energy security, economic growth, and environmental sustainability. South Africa's selected to focus on corruption, serious problems inside its primary electrical utility, and examples of state capture make it even more relevant. These problems have altered South Africa's energy industry dramatically, emphasizing the crucial role of institutional quality in energy policy and transition. The national utility's widespread inefficiency and corruption have hampered its ability to meet energy generation and financial stability targets, while weakening trust in government institutions. Figure 1 demonstrates South Africa's Energy Transition (Measured in share of renewable energy total final energy consumption %) and Institutional Quality (indices for Corruption Perception Index CCI, Government efficiency, and Regulatory Quality) from 1990 to 2020. The figure shows the decrease in institutional quality the last three decades while the renewable share decreases and stabilizes in general, with only some increasing trends at the end of the sample.

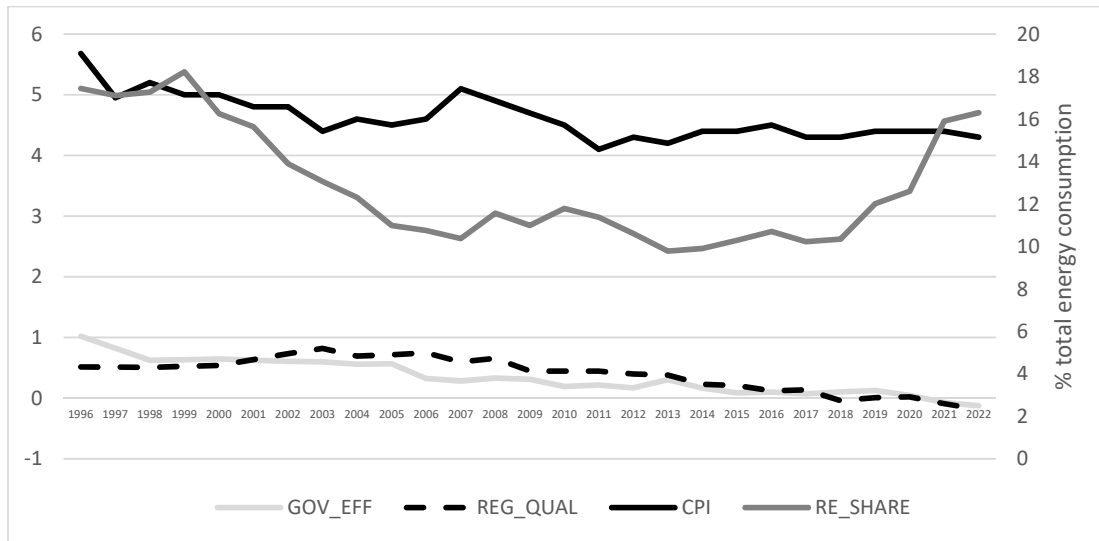


Figure 1: Energy Transition (Measured in share of renewable energy total final energy consumption %) and Institutional Quality (indices for Corruption Perception Index CCI, Government efficiency, and Regulatory Quality) for South Africa 1990 – 2020

Source: World Bank World Development Indicators and World Governance Indicators, BP Statistical Review, Transparency International,

The generalizability of the study's findings and policy is dependent on the alignment of the context with that of South Africa. While the findings are specific to South Africa, the ideas and methodology can be

used as a reference for countries and areas confronting similar energy transition difficulties. Shared characteristics, such as apartheid past, energy access difficulties, and political considerations, make the findings relevant and provide policymakers with guidance. However, it is critical to recognize that the impact of institutional quality on renewable energy integration varies by country. While direct policy translation may not be possible, the study's concepts and methodology provide a valuable template for examining institutional elements' influence on energy transitions in many settings, customized to each context's specific characteristics.

The next chapter briefly presents the current literature debate on energy transitions and the role of institutional quality, followed by a chapter describing the theoretical and empirical methodology. Finally, the empirical results are presented, and the study concludes with policy implications.

## **2. Brief literature review**

Through the years and worldwide, it has been recognised that energy is a fundamental input to economic growth and development. As the South African Department of Energy (Department of Energy, 2018) puts it: "the wheels of the economy" do not turn without energy. Inglesi-Lotz and Pouris (2016) summarised the causality and determinants of this relationship; the literature has not reached a consensus on the magnitude and direction of the causality. This can be attributed to the difference in the type of energy, geographical focus, period, methodology, and datasets used.

Economies have grown to be increasingly dependent on energy for power, manufacturing goods and transportation to the consumers. Access to secure, sustainable and affordable energy, thus, is considered by many one of the most important catalysts for economic development (Wang et al., 2022, Pata and Samour, 2022, Ozturk and Ullah, 2022). The United Nations (UN) Sustainable Development Goals (SDGs) confirm this notion by "devoting" SDG 7 to energy availability and affordability with a strong stressing on the word "clean" (Brown & Cloke, 2017).

The International Renewable Energy Agency (IRENA) defines the energy transition as "*...a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century*" (IRENA, 2021). Measuring the progress of the clean energy transition is difficult, considering the phenomenon's complexities. As the energy sector is responsible for the vast majority of emissions, it is also considered one of the main contributors to climate change. "The International Energy Agency (IEA) 's clean energy transition indicators look beneath the energy sector's contribution to CO<sub>2</sub> emissions to track intermediate indicators underpinning changes in emissions, building up from underlying sector-specific emissions drivers" (IEA, 2019). More specifically, various studies have used indicators such as renewable energy in absolute levels, per capita, or as a share of total energy or electricity. At the same time, the scope can be renewable energy consumption, supply or installed capacity (Bourcet, 2020).

In recent data, the World Economic Forum (WEF), in its *Fostering Effective Energy Transition 2021* report, showed that 92 out of 115 countries increased their energy transition index (ETI) over the last decade (World Economic Forum (WEF), 2021). An energy transition is related in the literature to socioeconomic and environmental benefits (Bohlmann et al., 2019; Consoli et al., 2016; Porter & van der Linde, 1995). Gravelins et al. (2018) discussed that techno-economic studies that dealt with energy transition usually focused on the optimality of gains and costs but left out the social consequences and potentially conflicting priorities by stakeholders. Conversely, socio-technical systems can encompass technological aspects, institutional regulation and business decisions. In South Africa, the effect of a transition to an energy supply mix with a smaller share of coal generation is sensitive to other economic and policy conditions, particularly the reaction of the global coal market example (Bohlmann et al., 2019).

“There are a plethora of determinants of renewable adoption internationally with a lack of consensus in quantitative factors and their magnitude, but a certain agreement on the following: 1) Support policies and programmes, as well as international commitments and agreements such as the Kyoto Protocol, have a positive effect; 2) Lobbying pressure from traditional and pre-existing energy sources have a negative effect; 3) The development and expansion of a local financial sector and the quality of institutions have a mostly positive influence”.(Bourcet, 2020). Although widely used in the literature, the concept of institutions is multi-faceted and not overall wholly understood as it lacks tangibility. A comprehensive but still straightforward definition is attributed to North (1993): "the formal and informal rules of the game and their enforcement characteristics", in that respect, and social interaction. Acemoglu et al. (2004) indicated that economic institutions are essential to financial outcomes. Easterly (2013) considers the effectiveness of the public sector as an integral component of institutional quality.

Many literature theories examine the nexus between governance quality and environmental quality (Omri et al., 2021). The World Governance Indicators (WGI) outline governance as "the institutions and traditions through which the authority in the state is implemented, containing the process of selecting, monitoring, and superseding governments; the government's ability to effectively implement and formulate respect and good policies for the institutions governing their social and economic interactions" (Omri & Ben Mabrouk, 2020). Policymakers internationally are in pursuit of sustainable solutions for the environmental crisis. At the same time, the value of good governance should be seen as the first and primary tool for climate change mitigation (Bos & Gupta, 2019).

Part of the literature considers the energy transition's regulatory context (Bourcet, 2020), stressing the need for public intervention to promote renewable energy use. Brunnschweiler (2010) states that renewable energy projects benefit from general political stability, sound regulatory frameworks, effective governance and secure property rights. Such conditions are measured in various ways, such as through the Economic Freedom Index (Wu and Broadstock, 2015), quality of governance, and the corruption perception index (Cadoret & Padovano, 2016).

"Corruption, a standard measure of government quality, reduces the responsiveness of policies to citizens' preferences and should raise the income level at which environmental protection policies start to be adopted. Corruption reduces the stringency of environmental regulations; yet political instability should offset this effect as it lowers the rate of return on corrupt practices" (Cadoret & Padovano, 2016). Corruption is associated with lobbying activities. Governments finance the deployment of renewable energy in response to multiple political factors. Furthermore, renewable energy investment does not materialise not for lack of willingness but due to complex and lengthy bureaucratic procedures and unpredictable investment volumes due to corruption (Komendantova et al., 2012). Specifically, for the Sub-Saharan African countries, improved regulatory frameworks, better control of corruption and access to finance are positive contributors to renewable energy adoption and its environmental impact (Opeyemi et al., 2019). This was confirmed by Amoah et al. (2020), that disaggregated various aspects of the institutional status of 32 African countries and found that business freedom or, in other words, regulatory efficiency measures have a positive relationship with the share of renewable energy in total consumption. Some studies emphasize the critical role of national institutions in promoting environmentally sustainable development. (Udeagha and Ngepah, 2022). Notably, a study conducted in 47 OIC (Organization of Islamic Cooperation) countries discovered that, except from institutions, all other criteria had a positive link with environmental quality (Ali et al. 2020)). Another study looked at the relationship between a country's diverse energy mix, institutional effectiveness, and ecological sustainability. It was discovered that institutional efficiency has a beneficial influence on ecological sustainability, whereas economic expansion and reliance on nonrenewable energy sources have a negative impact on the environment (Christoforidis and Katrakilidis, 2021).

Amoah et al. (2022) and Amoah et al. (2020) highly stress the uniqueness of socioeconomic, energy and environmental structures of Sub-Saharan African countries. Hence, more particularly, Swilling (2015) evaluated the future perspectives of the energy transition for South Africa, noting that the country's energy system perpetuated existing inequalities leading to even the unequal capacity to mitigate and adapt. Sarkodie and Adams (2018) indicated that the key to the energy system is the political-institutional quality to prepare the country for its social governance and economic readiness to control climate change and its consequences. Gungor et al. (2021) agreed by showing that regulatory quality can benefit carbon emissions mitigation, suggesting thus improvement and strengthening of the quality of the country's political and social institutions. Todd and McCauley (2021) investigated the barriers to the timeous and successful transition away from fossil fuels. Among the findings, they note that most obstacles are of a policy nature. Their analysis identifies government responsibility as the most critical barrier. That comes in line with Gumede (2008), which stresses the role of government to offer strategic leadership in delivering the energy transition, even more in countries such as South Africa, where the responsibility for the energy transition is concentrated in the state-owned enterprises and the government. "Governments have the power to allocate resources, decide national strategy, and pass legislation" (Todd and McCauley, 2021).

The ability of countries to implement costly energy transition programs varies greatly, with considerable policy implications. Those who have insulation or compensation mechanisms should use them strategically,

such as delegating policy creation to independent agencies and combining pay packages to gain political support. Such governments can invest in costly frontier technologies that are not yet cost-competitive with fossil fuels, perhaps resulting in long-term economic advantages. Countries seeking market-led transitions, on the other hand, rely on first-movers to cut the prices of clean technologies through policy, and once cost-competitive, these changes can speed. Governments that lack insulation and compensating mechanisms can still promote transitions through policies that have diffuse and less visible costs, such as public investments in R&D and clean energy implementation. Climate laggards, which are frequently federal governments, might allow subnational jurisdictions to lead energy transitions by exploiting areas of insulation or compensation. These political divergences highlight the varying pace of clean energy transitions and inspire specific policy responses depending on country opportunities and restrictions. (Meckling et al., 2108, Meckling et al. 2022, Vogt-Schilb et al. 2018, Hanto et al. 2022).

Caprotti et al. (2020) describe South Africa's energy policy and practice landscape as highly complex and dynamic, yet also rigid, wasteful, and opaque. This is due in part to apartheid-era institutional and policy route dependency (Marquard, 2006; Steyn, 2001). Nonetheless, regulatory and legislative developments are gradually creating a more RES-friendly policy environment (GreenCape, 2020), while a financial crisis at Eskom, as well as shareholder pressure to divest from coal mining and significant emitters, are pushing incumbents to explore alternatives to coal.

While many studies have investigated the larger problems and drivers of renewable energy adoption, there is a significant lack of research that goes thoroughly into the significance of institutional issues in the South African context. Hanto et al. (2022) examines the reasons that have contributed to coal's prolonged dominance in South Africa's energy market. It also digs into a historical examination of the political and economic issues influencing the move to renewable energy. The study gives unique insights into the intricate network of social, economic, and political influences that have historically shaped the country's energy landscape through a qualitative analysis of semi-structured expert interviews. The findings give insight on essential objectives such as energy supply, profitability in the coal business, environmental and climatic protection, and resolving socioeconomic inequities and job instability. Markard (2018) also proceeded with a qualitative evaluation of the factors of the energy transition (and its speed); these include the complex interaction of multiple technologies, the decline of established business models and technologies, the intensification of economic and political struggles of key factors such as utility companies and industry associations, and major challenges for the overall functioning and performance of the electricity sector (for example, when integrating renewables).

South Africa's unique historical, political, and social intricacies necessitate a focused quantitative investigation, which this study seeks to deliver. By filling this gap, the research contributes to a more comprehensive understanding of the dynamics of renewable energy transitions, providing insights that are not only applicable to South Africa but can also inform similar endeavors in other low-income and developing countries facing similar challenges and complexities.

### 3. Methodology

#### 3.1. Theoretical framework and a priori expectations

This study follows a strand of the literature (Komendatova et al., 2012; Cadoret and Padovano, 2016; Pfeiffer and Mulder, 2013; Verdolini and Vona, 2015; Holdmann et al., 2019) that attributes the delays in renewable energy share increases to the role of national policy frameworks, government efficiency, and a historical dependency to fossil fuels and market structures. Most of these studies approached political factors from the view of investment risk due to the relatively high cost of renewable energy. The current renewable energy technology pricing conditions are changing rapidly, with IRENA (2018) forecasting that renewable energy will cost less than fossil fuels per unit of electricity generation.

The dependent variable of this analysis is RE share in the final gross consumption of South Africa, proxying the country's energy transition to cleaner alternatives. Following Cadoret and Padovano (2016), the explanatory variables are classified into three broader categories (vectors):

- Political economy variables (W):

The political and governance variables will represent the quality of governance, institutional structure, levels of corruption etc. "The theoretical literature suggests the following correlation: a higher quality of governance, proxied by lower levels of corruption, should result in more stringent energy and environmental policies, hence in a higher share of RE" (Cadoret and Padovano, 2016). For robustness purposes, this study uses three alternative measurements of institutional quality and governance: the Corruption Perception Index (CPI) from Transparency International, the Regulatory Quality (REGQUAL) and Government Effectiveness (GOVEFF) from the Worldwide Governance Indicators of the World Bank.

- Economic variables (X)

Vector X includes economic indicators primarily used in the literature, such as GDP per capita. "The expected sign on this covariate is a typical Slutsky equation issue: a higher per capita GDP should stimulate energy consumption, including that produced through RE through an income effect. On the other hand, peaks of demand that are endemic to energy consumption may trigger the substitution of RE-based energy, which is still erratic and difficult to stock, with other sources" (Marques et al., 2010 in Cadoret and Padovano, 2016).

- Energy and environmental variables (Z)

The international crude oil prices and the CO<sub>2</sub> emissions are used to control the country's energy and environmental conditions. "In a contemporary setting, a price increase should depress energy demand, including RE. With time, however, higher energy prices should promote policy choices to reduce energy intensity and dependency; moreover, higher prices may make RE more economically viable, encouraging

investments in RE." (Cadoret and Padovano, 2016). Regarding environmental degradation, increases in CO2 emissions are expected to lead the country's policies to be more directed toward promoting RE adoption.

The regression estimation thus is specified as follows:

$$\ln REshare_{it} = a_0 + a_1 W_t + a_2 X_t + a_3 Z_t + \varepsilon_t \quad (1)$$

Where RE share is the Renewable energy consumption (% of total final energy consumption);  $W_t$  denotes the political economy variables,  $X_t$  represents the vector of economic conditions, and  $Z_t$  is the vector of energy and environmental conditions; where possible, the variables are expressed in natural logs (ln).

### 3.2. Econometric method

Before we proceed with any estimation, all variables' univariate characteristics are tested to establish their order of integration and confirm the validity of the choice of ARDL. The Augmented Dickey-Fuller and the Phillips-Perron tests are used here, ensuring that all variables are non-stationary and of an order of integration of 1 (I(1)).

"To test the presence of a long-run relationship between the variables under investigation, the Autoregressive Distributed Lag (ARDL) approach is used as proposed by Pesaran et al. (2001). The ARDL approach has many advantages over other cointegration techniques. First, the ARDL model performs efficiently in small sample cases, contrary to the method of Johansen (1992), which needs a large sample for validity. Second, the ARDL approach does not require the same order of integration for the cointegration test but allows variables if they are I(0), I(1) or a mixture of both I(0) and I(1), relaxing the statistical constraint that variables should be integrated in the same level. Third, the ARDL method allows for dummy variables in the cointegration test process which is not the case of Johansen's method (in the specific country case that assists with capturing specific characteristics)".

According to Pesaran et al. (2001), Eq. 1 can be written in the unrestricted error correction model (UECM) versions of the ARDL model as follows:

$$\begin{aligned} \Delta \ln REshare_{it} = & a_0 + \sum_{i=1}^p a_1 \Delta \ln REshare_{t-1} + \sum_{i=1}^p a_2 \Delta W_{t-i} + \sum_{i=1}^p a_3 \Delta X_{t-i} + \\ & \sum_{i=1}^p a_4 \Delta Z_{t-i} + \gamma_1 \ln REshare_{t-1} + \gamma_2 W_{t-1} + \gamma_3 X_{t-1} + \gamma_4 Z_{t-1} + u_t \end{aligned} \quad (2)$$

where  $u_t$  is the error term (white noise),  $a_0$  is the intercept term,  $\alpha_i$  ( $i > 0$ ) is the error correction dynamics, and  $\gamma_i$  denotes the long-run dynamics.

Table 1 presents the three model specifications of the study where three different aspects of institutional quality are examined for robustness purposes: the Corruption Perception Index (CPI), the Regulatory Quality (REGQUAL), and the Government Effectiveness (GOVEFF).

*Table 1: Model Specifications*

1	RESHARE ~ CPI, GDPPC, CO2, OILPRICE
2	RESHARE ~ REGQUAL, GDPPC, CO2, OILPRICE
3	RESHARE ~GOVEFF, GDPPC, CO2, OILPRICE

The ARDL Bounds test can identify the long-term relationship between variables after the estimated models. To accomplish this, the F-statistic is calculated under the null hypothesis of no cointegration (no long run), i.e.,  $H_0: I = 0$ , against the alternative  $H_1: I \neq 0$ , and compared to the bound critical values (Pesaran et al., 2001). Consider a scenario in which the projected F-statistic exceeds the upper bound critical value. The null hypothesis of no cointegration is thus rejected, indicating a long-term link between the variables. The null hypothesis of no cointegration implies no long-term association between the variables and is accepted if the calculated F-statistic is less than the lower bound critical value. If the estimated F-statistic falls between the lower and the upper bound critical value, then the test results are inconclusive. When the ARDL Bounds test confirms the existence of cointegration among variables, the impact of long-run and short-run coefficients on the dependent variable is discussed. The goodness of fit of the ARDL model is tested by a number of diagnostic tests on its residuals, such as the Breusch-Godfrey Serial Correlation LM test and the Breusch-Pagan and Godfrey tests for heteroscedasticity. (Inglesi-Lotz and Ajmi, 2021).

### 3.3. Dataset

Table 2 describes the variables' sources, units of measurement and descriptive statistics. All variables are expressed in their natural logarithm format.

*Table 2: Description of variables and Descriptive statistics*

Variable	Name	Units of measurement	Source	mean	median	max	min	std.dev
Renewable Energy Share	LNRE_SHARE	(% of total final energy consumption)	1990 - 2018 WB World Development Indicators 2019-2020 Calculations BP statistical review (RE Generation/Electricity Generation)	2.5985	2.5335	2.9224	2.2805	0.2321
Corruption Perception Index	LNCPPI	scale of 0 to 1, where 0 is highly corrupt and 100 is very clean.	Transparency International	1.5346	1.5041	1.7370	1.4110	0.0836
Regulatory Quality	REGQUAL	Index -2.5 to 2.5	World Bank: Worldwide Governance Indicators	0.3973	0.4492	0.8196	- 0.1851	0.2855
Government Effectiveness	GOVEFF	Index -2.5 to 2.5	World Bank: Worldwide Governance Indicators	0.3464	0.3062	0.8196	- 0.1851	0.2855
Economic Output level (GDP per capita)	LNGDP_PC	US\$ at constant 2015 prices	World Bank - World Development Indicators	8.5839	8.6498	8.7424	8.3593	0.1438
Carbon Dioxide Emissions	LNCO2	Million tonnes of carbon dioxide	BP Statistical review	6.0128	6.0658	6.1653	5.7659	0.1370
Crude oil prices	LNOILPRICE	US dollars per barrel	BP Statistical review	4.0016	3.9594	4.8521	3.0052	0.5219

The table presents first the dependent variable – Renewable energy share (LNRE\_SHARE), then the three variables of the Political Economy vector that will be used one by one in the analysis. The rest of the table presents the Economic, Energy, and Environmental Vectors' variables to be used as control variables in the modelling (Economic output – GDP per capita (LNGDP\_PC), Carbon Dioxide Emissions (LNCO2) and Crude Oil price (LNOILPRICE)). Looking at the correlation coefficients in Table 3, the renewable energy share (LNRE\_SHARE) seems to be positively correlated with Government Effectiveness (GOV\_EFF) and Corruption Perception Index (LNCPPI), but less correlated with the Regulatory Quality (LNREG\_QUAL). The dependent variable is also negatively and highly correlated with all the control variables. The coefficients do not imply causality but indeed indicate a possible relationship.

Table 3: Correlation Coefficients

	LNRE_SHARE	GOV_EFF	REG_QUAL	LNCPI	LNGDP_PC	LNOILPRICE	LNCO2
LNRE_SHARE	1	0.5289923	0.0866791	0.5910125	-0.8149691	-0.6838715	-0.8330654
GOV_EFF	0.5289923	1	0.7510885	0.7500592	-0.8835336	-0.6162226	-0.7872557
REG_QUAL	0.0866791	0.7510885	1	0.4686554	-0.5366088	-0.2103889	-0.4147446
LNCPI	0.5910125	0.7500592	0.4686554	1	-0.7495483	-0.5963774	-0.6954229
LNGDP_PC	-0.8149691	-0.8835336	-0.5366088	-0.7495483	1	0.8290396	0.9487657
LNOILPRICE	-0.6838715	-0.6162226	-0.2103889	-0.5963774	0.8290396	1	0.782195
LNCO2	-0.8330654	-0.7872557	-0.4147446	-0.6954229	0.9487657	0.782195	1

Figure 2 provides a graphical representation of the seven variables of the study. LNRE\_SHARE, LNCPI and LNGOV\_EFF exhibit a downward trend in the sample, while the rest of the variables seemed to increase with marginally explosive behaviour.

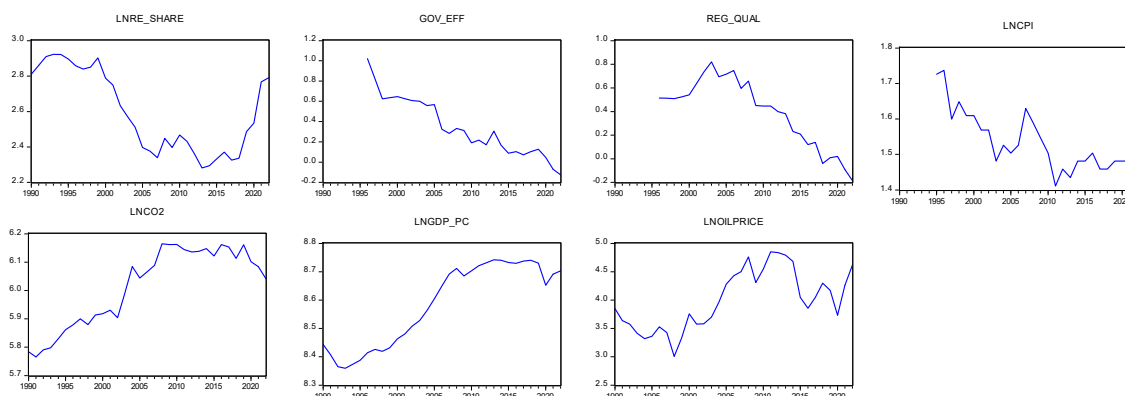


Figure 2: Graphical representation of data

A possible structural break seen in South Africa's statistics in 2008 can be attributed to a number of factors, including the global financial crisis, which had significant effects on both the global and South African economies. This incident might have affected employment, trade balances, and economic indices. The observed structural break may also have been influenced by significant changes in government policies, leadership changes, global commodity price fluctuations, ongoing infrastructure and energy challenges, and changes in demographic and socioeconomic factors. Around 2008, South Africa's data series began to noticeably change as a result of these events and trends, which may have prompted changes in the underlying data generation process. The same period the country experienced the beginning of an ongoing crisis in south Africa's energy sector with load shedding and interruptions in the power supply, which have

had significant economic and social repercussions. Load shedding disrupts business and industrial operations and having a knock-on effect on employment and economic growth. Furthermore, revisions to tariffs and subsidies in energy pricing regulations throughout that time could have affected industrial operations and patterns of energy usage.

#### 4. Empirical results

First, we check the integration order of each variable. Table 4 reports the results of the ADF and ADF with structural breaks. Under the null hypothesis, both test the presence of unit root against stationarity as the alternative hypothesis. The test statistics indicate that all variables are non-stationary at level and rendered stationary at the first difference. Hence, they are an order of integration of  $1 \sim I(1)$ . Therefore, the ARDL is considered valid for this dataset.

Table 4: Unit root test results

	Level			First Difference			Conclusion
	Intercept and trend	Intercept	None	Intercept and trend	Intercept	None	
<b>ADF test</b>							
LNRE_SHARE	0.668	-1.842	-0.424	-4.919***	-1.417	-1.509	I(1)
GOV_EFF	-4.209*	-1.880	-3.412**	-5.096***	-5.245***	-4.521***	I(1)
REG_QUAL	-1.671	1.056	-0.974	-6.856***	-5.671***	-5.178***	I(1)
LNCPPI	-3.095	-2.496	-1.151	-6.982***	-6.744***	-6.490***	I(1)
LNGDP_PC	-0.295	-2.012	2.476	-4.640***	-4.130***	-3.577***	I(1)
LNOILPRICE	-1.891	-1.611	0.633	-5.035***	-5.088***	-5.047***	I(1)
LNCO2	-0.487	-1.991	1.000	-6.150***	-5.306***	-5.194***	I(1)
<b>ADF test (with structural break)</b>							
LNRE_SHARE	-2.429	-2.791	-	-6.360***	-6.057***	-	I(1)
GOV_EFF	-7.145***	-3.393	-	-5.984***	-6.168***	-	I(1)
REG_QUAL	-4.432	-1.122	-	-8.205***	-8.385***	-	I(1)
LNCPPI	-3.841	-3.717	-	-7.557***	-7.625***	-	I(1)
LNGDP_PC	-2.155	-3.448	-	-6.147***	-5.545***	-	I(1)
LNOILPRICE	-4.414	-2.950	-	-5.847***	-5.881***	-	I(1)
LNCO2	-2.815	-4.336*	-	-8.102***	-7.072***	-	I(1)

The next step is to test the presence of long-run relationships among the variables in Models 1-3. In Table 5, the computed value of the F-statistic is equal to 35.740, 4.474 and 4.726 for Models 1, 2 and 3, respectively. In the first two models, the null of no cointegration can be rejected, indicating the long-run relationship among variables.

Table 5: ARDL Cointegration test

Variables		Model 1	Model 2	Model 3
		With LNCPI	With LNREGQUAL	With GOVEFF
F-test		35.740***	4.474**	4.726**
10%	I(0)	2.690	3.03	2.45
	I(1)	3.530	4.06	3.52
5%	I(0)	3.050	3.47	2.86
	I(1)	3.970	4.57	4.01
1%	I(0)	3.810	4.4	3.74
	I(1)	4.920	5.72	5.06

Table 6 presents the ARDL regression output of the three models estimated.

In Model 1, the institutional proxy, LNCPI, has a positive long-run relationship with the dependent variable, LNRE\_SHARE. If the CPI improves by 1%, RE\_SHARE will increase by 0.8256%, ceteris paribus. In Model 2, the institutional proxy, REG\_QUAL, has a negative coefficient for the contemporaneous impact on LNRE\_SHARE., while for model 3 GOV\_EFF also shows a negative and significant coefficient. In all models, the coefficients of the control variables present the same sign and statistical significance, indicating a certain level of robustness. The dependent variable is influenced by its lagged form, either for one period or two or both in all three models. The LNGDP\_PC presents a negative and statistically significant coefficient in the first two models, and in a lagged format in models 1 and 3. At the same time, the carbon dioxide emissions (LNCO2) have a positive and statistically significant coefficient in Models 1, with a mixed impact from its lagged form.

Table 6: ARDL Estimation outputs

Variables	Model 1		Model 2		Model 3	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
LNRE_SHARE(-1)	0.0314	0.8089	0.6408 ***	0.0022	0.4475 *	0.0605
LNRE_SHARE(-2)	-0.3292 *	0.0538	-0.6760	0.1264	-0.8840 **	0.0109
LNCPI	0.8256 ***	0.0007				
LNCPI(-1)	0.3308 *	0.0585				
LNCPI(-2)	0.1211	0.3502				
LNCPI(-3)	0.5619 ***	0.0024				
REG_QUAL			-0.2137 *	0.0922		
REG_QUAL(-1)			-0.0759	0.5942		
REG_QUAL(-2)			0.4441 ***	0.0072		
GOV_EFF					-0.4793 **	0.0123

GOV_EFF(-1)							0.0193	0.9067
LNGDP_PC	-1.4591	***	0.0006	-2.2050	***	0.0010	-0.9756	0.2815
LNGDP_PC(-1)	-3.0689	***	0.0003	-1.3763		0.1490	-2.9721	**
LNGDP_PC(-2)	-1.7355	***	0.0094				-0.9940	0.3718
LNGDP_PC(-3)							1.5046	*
LNCO2	0.7507	***	0.0022	0.1599		0.6512	0.3349	0.4961
LNCO2(-1)	-0.5034	**	0.0386	-1.4565	***	0.0051	-1.2371	***
LNCO2(-2)	0.9218	***	0.0006	1.2154	***	0.0054	0.2465	0.6357
LNCO2(-3)	0.2288		0.2734				-0.2533	0.5837
LNOILPRICE	0.0490	*	0.0708	0.0878		0.2132	0.0771	0.1377
LNOILPRICE (-1)	0.1256	***	0.0019				0.0404	0.5387
LNOILPRICE (-2)	0.0311		0.2515				0.0927	0.2305
LNOILPRICE (-3)	0.0408	*	0.0799				-0.1849	***
DUM2008	0.2068	***	0.0002	0.1637		0.1319	0.3097	0.0001
C	43.9906	***	0.0001	33.0908	***	0.0144	38.6620	0.0001
<i>F-test</i>	<i>35,740***</i>			<i>4,474**</i>			<i>4,726**</i>	
<i>Breusch-Pagan - Godfrey</i>							<i>21.34</i>	<i>0.2114</i>
<i>Heteroskedasticity test</i>	<i>17.476</i>		<i>0.5577</i>	<i>7.731</i>		<i>0.8607</i>		

Note: At the bottom of Table 6, the results of the Breusch-Godfrey Serial correlation and Breusch-Pagan-Godfrey heteroskedasticity show that none of the problems is present in the two Models in question.

## 5. Conclusion and Discussion

The main purpose of this paper is to evaluate how institutional factors affect the South African transition to renewable energies, proxied by the share of renewable energy in the country. The literature confirmed that the existence of appropriate policies and the willingness of policymakers are necessary but not adequate conditions for policy effectiveness and their impact on the overall economy. The "rules of the game" (another word for institutional quality) must be fair and transparent. In this mindset, this paper argues that the energy transition in South Africa does not only depend on socioeconomic and technological factors. The transition's future success and speed depend on political economy and institutional factors. This analysis confirms that institutional factors affect the country's renewable energy share. Following the argumentation from Venter and Inglesi-Lotz (2022), this study also chose to examine various aspects of institutional quality separately, first to evaluate their respective influence and secondly to look at the robustness of the hypothesis. The models of the analysis used the Corruption Perception Index (CPI), the Regulatory Quality (REGQUAL) and Government Efficiency (GOV\_EFF) as proxies for institutional quality. Their coefficients are statistically significant at a contemporaneous level with CPI being positive, REG\_QUAL and GOV\_EFF negative.

From Model 1: the higher the Corruption Perception Index (CPI), the higher the share of renewable energies in South Africa, ceteris paribus. This finding can be interpreted by understanding first the market structure of energy generation in South Africa and secondly the recent corruption debate in the country.

The electricity generation responsibility falls on the vast majority of the state-owned utility, Eskom, and the distribution network is shared between Eskom and the local government (municipalities). The private sector only recently has started participating, albeit at slow rates. The recent State Capture debacle and the more than a decade-long discussion on corruption within Eskom has made the public associate any corruption in the country with government activities and, by association, with fossil fuels (and nuclear) generation of electricity (as this was the traditionally chosen fuel in the past). Hence, the *cleaner* the perceived picture of the institutions, the *cleaner* the country's energy mix. Eliminating corruption would reduce the negative effects of lobbying in the energy sector (fossil fuels established the status quo) and improve the strength of regulatory powers and market dynamics. Better control of corruption may also enhance the attractability of the South African energy sector to local and international investors as the returns would not be interfered with by corruptive practices. This finding agrees with other studies in the literature, such as Komendantova et al. (2012) and Cadoret and Padovano (2016). The findings also show a persistence in the impact of CPI to the share of renewable energy by demonstrating CPI affects RE\_SHARE in a lagged manner too.

Next, model 2 shows that Regulatory Quality impacts the share of renewable energies: the better the regulatory quality of the country, the lower the share of renewable energy in the same period, while the level of regulatory quality two periods ago leads to an increase in the share of renewable energies to total consumption. This finding is again associated with the regulatory activities that primarily focus on a fossil-fuel-dominated energy mix in the country. More practical, transparent and quality regulation leads to better performing energy, particularly electricity market conditions, lowering the willingness to substitute with cleaner, renewable alternatives. By encouraging openness, predictability, and accountability, improved regulatory processes have the potential to boost South Africa's electrical and energy industry, ultimately leading to improvements in resource allocation, market operations, and the assessment of return on investments. Such laws can encourage private sector investment, enhance market performance, and facilitate the integration of renewable energies, all of which will increase the industry's overall sustainability and efficiency. They do this by promoting fair competition and preventing monopolies.

With regard to model 3, Government Effectiveness (GOVEFF) as the proxy for institutional quality shows a negative relationship with the dependent variable. Because stable governments frequently keep close relationships with the conventional energy industry, which can have a considerable impact on policy decisions, higher government effectiveness may result in a smaller share of renewable energy in a nation's energy mix. The promotion of renewable energy sources may be hampered if these established companies, like the fossil fuel industry, fight reforms that threaten their interests. Furthermore, efficient governments can put short-term economic security and energy security ahead of long-term sustainability, which could discourage investments in and provide disincentives for the development of renewable energy sources.

The robust positive, statistically significant and relatively high magnitude of the lagged dependent variable as explanatory in all models demonstrate that the renewable energy share to the total mix is not a condition that can change speedily. The processes to design, procure, approve and implement renewable energy

projects, as the sector has experienced through the recent Bid window periods for renewable energy projects, had been time-consuming and lagging. Such delays might also be attributed to lobbying and corruptive practices that resist changes in the South African energy sector for their own benefit.

GDP per capita negatively influences the renewable energy share: the higher the GDP per capita, the lower the renewable energy share in the examined period, *ceteris paribus*. As discussed in the theoretical expectations, two possible effects of economic growth on adopting renewable energies in action simultaneously exist. The coefficient presents the net effect of the two (Slutsky equation). In this study, a higher GDP per capita triggers substitution of RE-based energy (or not choosing it) due to the need for continuous and uninterrupted energy provision during peak times and the renewables' intermittent nature and lack of storage technologies at a larger scale. It seems this phenomenon overrules the stimulation for adopting renewable energies from the higher income per capita.

The conclusions of the study have a strong resonance with South Africa's economic and energy scenario. South Africa is well-known for relying heavily on coal as a key energy source. The country's long-standing dominance in the energy sector has been deeply rooted in its history, owing to its abundant coal reserves and previous energy policy. However, the negative environmental and health effects of this strong reliance on coal are becoming more apparent. South Africa is dealing with severe air pollution, significant greenhouse gas emissions, and negative health effects from coal-fired power generation. Furthermore, the country is exposed to the consequences of climate change, necessitating an urgent transition to cleaner and more sustainable energy sources.

In the backdrop of severe unemployment and social inequality, South Africa's energy transition is a socioeconomic need as well as an environmental problem. The study's emphasis on how institutional variables influence the pace and success of this shift is especially pertinent to South Africa. The recent State Capture scandal, as well as ongoing talks about corruption within state-owned utility Eskom, have produced a public impression that equates wrongdoing with government activities, and hence with fossil fuel-based energy generation. This exemplifies the intricate interplay of political and institutional elements in changing the energy landscape.

The conclusions made here are situation-specific, mostly applicable to a given time frame, and specifically relevant to the distinctive market structure seen in the energy industry. The findings we have witnessed are a direct result of the market system, which is characterized by state-owned, controlled monopolies. It is critical to understand that these results reflect a snapshot of the current situation and may not necessarily speak to an overarching or eternal truth. The energy industry's landscape is anticipated to alter as energy markets and policy change. Changes in the structure and dynamics of the energy market may result from a variety of factors, including technological developments, changes in public opinion, and developing energy regulations. Since the future might bring about significant changes to this landscape, it is important to interpret our findings even though they may be pertinent and instructive for the present.

Furthermore, within the examined period, South Africa underwent a massive electrification effort from the middle of the 1990s. Higher incomes in the population led to them looking to connect to the national grid (coal-generated electricity) because now they could afford it, and the infrastructure was available. One of the main challenges of low- and middle-income African countries is access to energy, with economies assuming -maybe mistakenly- that the solution needs to be linear "first fix the access, then fix the environmental degradation". This notion leads to these countries following the steps of industrialised countries instead of pursuing solutions that will work in synergy to address both the problems of access and pollution.

As a result, the study's findings serve as a reminder that South Africa's transition to renewable energies is not only an issue of energy policy but is also profoundly entwined with political, social, and economic difficulties. To manage these complex dynamics, policy directives must be developed to ensure that the energy transition meets both environmental and socioeconomic goals. South Africa is at a crossroads where the demand for cleaner energy sources intersects with potential for economic growth and social fairness, and our findings provide important insights into how to navigate this transition effectively within the South African environment.

A number of strategies and directions for more research can be taken into consideration in order to alter the current relationship between institutional quality and energy transition in the future. To create a supportive environment for the energy transition, it is essential to work towards improving institutional quality by fostering transparency, combating corruption, and bolstering the rule of law. To encourage investment in clean energy technology, policymakers should give top priority to the creation of comprehensive and stable renewable energy policies, including feed-in tariffs, tax incentives, and regulatory frameworks. Additionally, pursuing an in-depth investigation on the function of public-private partnerships and the compatibility of energy policies with climate goals can offer insightful information on practical methods for furthering the energy transition. Another direction for future research is to assess how institutions' and policymakers' capacity-building initiatives affect their ability to comprehend and apply sustainable energy policies. A just and equitable transition for all stakeholders can also be achieved through investigating the social and economic effects of energy transition policies. This transition towards a more sustainable energy future will require cooperative efforts from academia, the government, and industry.

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