“Green technology and energy consumption efficiency in Zimbabwe”

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GREEN TECHNOLOGY AND ENERGY CONSUMPTION EFFICIENCY IN ZIMBABWE

Abstract

Environmental pollution is one of the major problems that has become an increasing area of concern globally, leading to the emergence of green energy technology. Research has been conducted on green technology adoption mainly in developed countries. However, there is noticeably limited knowledge about technology adoption and energy consumption in developing countries, for example, Zimbabwe. Thus, this paper seeks to analyze the impact of green technology adoption on energy sector performance in Zimbabwe. The results established that green technology adoption, energy pricing, energy sector investment, and capital structure significantly influence energy consumption efficiency. These results showed a positive relationship between green technology adoption and energy consumption efficiency based on the argument of the substitution possibility effect between green technology and energy demand. The study recommends adopting and identifying the type of green technology to utilize and the timing of investment in green technology. In addition, alternative estimation methods can be adopted to test the robustness of the findings.

Keywords green technology, consumption efficiency, energy consumption, energy demand, environmental pollution

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INTRODUCTION

Across the globe, carbon emission into the atmosphere has been regarded as one of the major factors leading to adverse economic effects. They enhance climate change, which deprives economies' ability to produce the best productivity (Chen et al., 2019). Because of climate change, natural disasters have been experienced worldwide, leading to hunger, poverty, and expanded government expenditure that hinders economic growth (Lee & Huang, 2019). Different countries have introduced carious strategies to ensure that carbon emission is reduced in industries and in homes so that the negative impacts of climate change are kept at bay. These include adopting green technologies (Jiang et al., 2021).

The requirement for environmental protection and rivalry among energy companies has changed the direction and discourse within the green economy domain (Juwarkar et al., 2009; Kattel & Mazzucato, 2018). These developments boosted emerging green industries, production, and operation. Further, there has been the evolution of environmental protection as part of the global economy. The world is worried about increasing energy consumption demand. This concern creates new energy generation methods that pay much attention to green technology adoption and utilization. However, many energy companies continue to use the traditional ways of energy generation. Additionally, the contribution of green technology to energy consumption efficiency is still unclear.

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Extant literature reflects that green technology adoption can lead to energy consumption efficiency and optimal general mix. These consumption efficiencies can be achieved through optimal pricing.

Green technology adoption by energy sector companies can help mitigate environmental pollution and increasingly lead to improved national power generation. The adoption of green technology has the potential to improve energy efficiency in developing countries. Therefore, green technology adoption by energy sector companies is a tantrum to the trend of global economic development.

The study seeks to analyze the impact of green technology and energy efficiency in Zimbabwe. The paper is necessary to refer emerging issues to enterprises and governments to make relevant decisions.

1. LITERATURE REVIEW

Green technology has been hailed as an advancement from outdated energy technology dependent on renewable resource methodology (Broaddus-Shea et al., 2019; Peng et al., 2020). The energy innovations arose from organizations needing to reduce costs due to escalating energy prices (Jiang et al., 2021). Developing countries still need to catch up and face challenges in new technology, capital equipment, and management skills to implement green technologies. Technological development has more significant benefits for the developing countries than ever before. The challenges associated with using fuel energies present a clarion call for developing countries to adopt green technologies (Saryal, 2018; Gage & Dunn, 2010; Fosnacht et al., 2017).

According to Jiang et al. (2021), green technology denotes technologies used primarily in organizations deemed environmentally friendly based on their production process or supply chain. Adopting green technologies is driven by various factors, such as business eagerness that allows reduced carbon emission and pollution and prevents losing biodiversity and ecosystem services. However, in some countries, this has been far and few between as economic development continues to be far from reach as they continue to suffer from the consequences of climate change due to many factors, such as a lack of knowledge on the significance of green technologies (Low et al., 2009; Hashim et al., 2020; Sichone, 2003). This prompted several developed countries worldwide to foster the embracing of green technologies, mainly in the forestry sector, to drive economic growth preserving the natural environment (Lawson, 2015; Hadebe, 2022). According to Lawson (2015), green technologies refer to advanced technologies in the form of robots and machines that are now being used in the manufacturing processes of production plants. Such environmentally friendly companies emit minimal quantities of hazardous gasses, such as carbon dioxide and carbon monoxide.

Sweden is among the top countries that have achieved economic development through adopting green technologies in various sectors (such as forestry and manufacturing). It has achieved that through technological innovations in manufacturing sectors that have reduced carbon emissions, hefty fines for carbon emitters, and carbon offsets programs in the energy sector (Ssekamatte, 2018; World Bank, 2018). World Bank (2018) also alluded that the 2.2% average economic growth in Sweden between 2018 and 2021 are a result of the country's high usage of robots and advanced machinery in the production processes of timber and food respectively, the adoption of renewable energy, education programs and the use of electric buses, smart roads, and urban farming. Other countries that have managed to achieve economic growth through green economy include Germany, Switzerland, Japan, Norway, and New Zealand (Low et al., 2009).

In Zimbabwe, greenhouse gas emission has been on the rise due to various factors, such as the use of old production equipment in the manufacturing sector and the use of old and poorly serviced public road transportation. Carbon emissions in Zimbabwe are also increased by a number of factors, such as the use of charcoal and the cutting down of trees in rural areas for domestic use purposes, contributing to climate change (Noko, 2011; Dube & Mapfudza, 2020). The Zimbabwean forestry sector includes companies in various businesses such as timber production and soil remedi-

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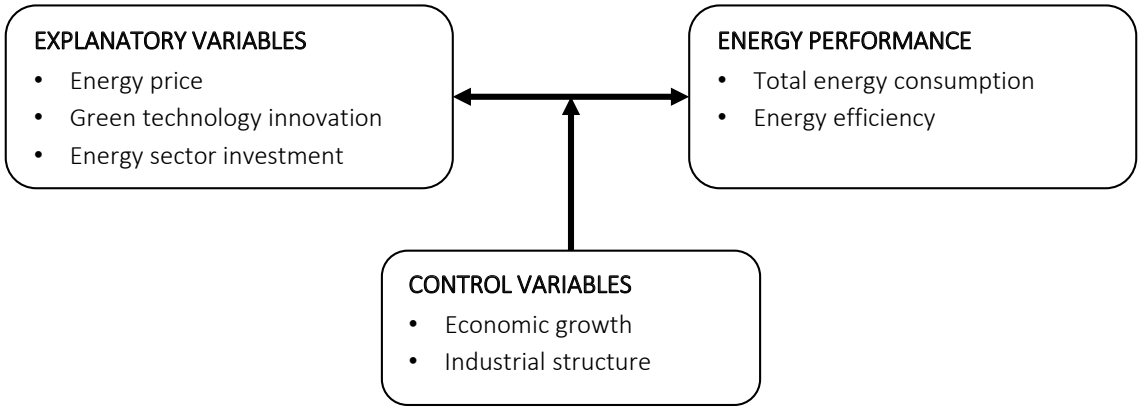

Figure 1. Conceptual framework

ation, including Allied Timbers, Hunyani Forests, Wattle company, and Mutare board and paper mills. According to Dube and Mapfudza (2020), the companies in forestry in Zimbabwe have been ranked number one among the country's greenhouse gas emitters, contributing over 50% of overall greenhouse gas emissions, followed by the energy and agriculture sectors.

The government of Zimbabwe has introduced several initiatives meant to enhance electricity generation since the power supply is the mainstay of the country's development, as enunciated in the country's development agenda. Resources for these various power projects remain the main challenge given the country's limited fiscal space bedeviling.

Achieving economic development is a critical goal that should be addressed in an economy due to the benefits it provides to a country, such as improving living standards for the population. In Zimbabwe, economic development is halted by various factors, including high levels of greenhouse gas emissions, which have led to climate change, and a series of weather hazards, such as tropical cyclones. The country also experienced a recession between 2020 and 2021, stopping economic development, and the country's living standards continued to fall (Moyo & Besada, 2008; Chigudu, 2021). Less attention is being paid to the green economy to foster economic development, although various researchers have shown that green technology fosters economic development. Based on this background, this study analyzes the impact of green technology in the forestry sector on economic development in Zimbabwe. Therefore, this study seeks to assess the impact of green technology on the energy sector performance in Zimbabwe.

Investments in the energy sector companies are expected to improve energy use efficiency. This study discusses the effect of green technology adoption on total energy consumption, a proxy of energy efficiency. The moderating effect of capital structure and the gross domestic product is also investigated, and how these affect energy consumption while controlling for the industrial structure variable. Based on different theoretical perspectives and a literature review, a conceptual framework (Figure 1) is developed to test the hypotheses:

H1: Green technology adoption improves energy consumption efficiency.

H2: Optimal energy pricing in the energy sector reduced total energy consumption demand.

H3: Investment in energy infrastructure increase energy efficiency and utilization.

2. METHODOLOGY

This paper reviews and collects data from the annual integrated reports of selected energy sector companies to evaluate the effect of green technology adoption on energy sector consumption in Zimbabwe.

The assumptions underpinning the study include innovation significantly influencing total factor productivity non-linearly. The threshold effect of

the study is determined by the country's developmental status (King, 2022; Hafer, 2022). Based on the Hausman test, the study adopts the random effect model to assess green technology's effect on energy consumption efficiency. Eleven energy sector firms were used in the study, chosen based on the completeness of data for the study period (2016–2022).

The empirical model defines the link between the endogenous and exogenous variables. In this study, the dependent variables are energy consumption efficiency, while the independent variables are green technology adoption, energy price, economic growth, capital structure, and energy structure industrial structure (Table 1).

The conceptual model equation is given by:

$$EE = f\left(GTI, IS, DI, GDP, CS, PR\right). \quad (1)$$

The variables were converted to natural logarithms before estimating the model. This was meant to standardize the data and obtain regression coefficients as elasticities. The model is then specified as follows:

$$\begin{aligned} \ln EE_{it} &= \alpha_0 + \delta_1 \ln GTI_{it} + \delta_2 \ln GDP_{it} + \\ &+\delta_3 \ln IS_{it} + \delta_4 \ln DI_{it} + \delta_5 \ln CS_{it} + \\ &+\delta_6 \ln PR_{it} + \varepsilon_{it}, \end{aligned} \quad (2)$$

where α is an intercept; *GTI* is green energy, where adoption of renewable energy is utilized as a proxy of green energy; *EE* refers to energy efficiency; *DI* is a sectorial investment; *IS* represents industrial structure; *PRI* denotes energy prices per unit; and *GDP* is gross domestic product; i – companies (1, 2 …n); t – time period (2016–2022); δ – Regression coefficients and ε – Error term.

Table 1. Definition of variables

Variables	Definition	Measurement
	Dependent variable	
EE	Energy efficiency	Total energy consumption
	Independent variables	
PR	Energy price	Purchase price indexes of power
IS	Industrial structure	The share of the output value of secondary industry in GDP
DI	Energy sector investment	The ratio of direct investment to energy sector
GTI	Green technology	Green patent applications and adoption
	Control variables	
GDP	Economic growth	Per capita GDP
CS	Capital structure	The hierarchical coefficient of industrial size

3. RESULTS AND DISCUSSION

The analysis of the data was done using Eviews version 11 statistical software. The results of the study are presented in Tables 2-3. Descriptive statistics are used to summarize all categorical data.

The Hausman test results (Table 2) show that the random effect model is preferred. From the results, the p-value is large (more than 0.05) and concludes that the data suit the random effect model. The random effect model takes cognizance of the aspect heterogeneity, capturing the inter-study variation.

The F test was used to determine whether the variables used in the model are jointly significant (Table 3). The F-test yielded a statistic of 25.33 (0.000), which showed that the model is statistically significant, implying a relationship between the variables. An overall R-squared of 0.8625 showed that about 86.25% of the variations in total energy consumption can be explained by the variations in the independent variables. The estimated standard deviation of u (sigma_u = 7.819354) and e (sigma_e = 17.7734) showed that the model is significant. A rho = 0.16216566 showed the share of the variance in total energy consumption explained by the individual effects. The results showed that individual sector effects can explain around 16.21%.

The study predicted that green technology adoption improves energy consumption, thereby reducing demand for total energy consumption. The coefficient on green technology adoption is negative and significant ($\beta = -0.7965$; $p < 0.095$). Thus, Hypothesis 1 is supported. Hypothesis 2 predicted that optimal energy pricing in the energy sector reduced energy total energy consumption demand

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Table 2. Hausman fixed random

Variable	Coefficients		(b – B) Difference	sqrt(diag (V_b – V_B)) S.E.
	(b) fixed	(B) random		
Energy price	2.392469	1.290971	1.101498	.5711879
Industrial structure	3.931598	3.516495	.4151036	.8720024
Energy sector investment	.0180866	.0203297	–.002243	.0015945
Green technology	–.796515	–.7684336	–.0280813	.1654718
Gross domestic product	1.763965	1.580546	.183419	.1763171
Capital structure	.2996612	.2966364	.0030248	.0218604

Table 3. Regression results

Variable	Coefficient	Standard error	t-statistic	Probability
Energy price	2.392469	2.146572	1.81	0.0279**
Industrial structure	3.931598	2.743993	1.43	0.168
Energy sector investment	.0180866	.0059556	3.04	0.007***
Green technology	–.796515	.4537128	–1.76	0.095*
Gross domestic product	1.763965	1.39035	1.27	0.220
Capital structure	.2996612	.1710587	1.75	0.096*
_cons	228.6016	39.66263	5.76	0.000
sigma_u	7.819354		–	
sigma_e	17.7734		–	
rho	0.16216566		–	
F (6, 19)	25.33		–	
Prob. > F	0.0000		–	
R-squared	within	0.8889		
	Between	0.2954	–	
	Overall	0.8625	–	

Note: ***, **, * denote significance at 1%, 5%, and 10%, respectively.

and hence is positively associated with energy efficiency. The positive signed coefficient ($\beta = 2.392$, $p < 0.0279$) on energy price supported Hypothesis 2. Hypothesis 3 predicted that investment in the energy sector is positively associated with energy efficiency. The positive signed coefficient ($\beta = 16.88$, $p < 0.001$) on gender composition supports this hypothesis.

The study set a positive relationship between green technology adoption and energy consumption efficiency based on the argument that green technology adoption does have a substitution effect on energy demand. Results in Table 3 show that green technology adoption, optimal energy pricing, energy sector investment, and capital structure significantly influence total energy consumption, a proxy of energy use efficiency. However, industrial structure and gross domestic product did not have a statistically significant effect on energy efficiency. The study hypothesized a significant positive relationship between green technology and energy efficiency based on the argument that carrying out green technology innovation can lessen ecological contamination and endlessly improve corporate performance. Efficiency in energy use can be enhanced by mechanisms that reduce the pollution of the atmosphere.

Energy sector capital arrangement plays a crucial part in reconciling green technology innovation and total energy consumption. Green technology adoption and innovation enhance economies of scale (Abrahams et al., 2020; Campbell et al., 2020). Continuous green technology innovation and the popularization of innovative outputs are conducive to improving energy sector efficiency, and on the other hand, green innovation can also form a "technical compensation" effect (Das & Imon, 2016; Imam, 2019; Jamal et al., 2020). The adoption of green technology could help to promote the realization of high technology and reduce energy consumption in the production process of energy and may also improve their inno-

vation performance with high efficiency and low energy consumption (Jang & Collinge, 2020; Kim & Lee, 2021).

The improvement of green technology innovation on the performance of energy sector enterprises needs to be mediated by the energy capital structure. It means that green technology innovation directly affects the performance improvement of energy companies. There is also an indirect effect of green technology innovation, energy consumption, and capital structure. The study findings showed the existence of substitution possibilities between green technology and total energy consumption, a result in agreement with previous studies (Abdullah et al., 2016). However, these results contradict Wang et al. (2022), who found a significant positive relationship between industrial structure and energy efficiency.

The study showed a positive and significant relationship between capital structure and total energy consumption. These findings are consistent with the general expectation of a significant (positive) relationship between these variables. These results support Abdullah et al. (2016), who also found that companies with more capital structure are more efficient than energy companies with low capital structure.

Research on the effect of green technology on energy efficiency was motivated by renewed interest evinced due to recent energy sector developments. Increased attention to performance and energy use efficiency has led to many companies focusing more on adopting and investing in green technology. The underlying assumption is that following these programs would improve total energy consumption efficiency.

CONCLUSION

Energy consumption efficiency is usually associated with economic development, especially in developing countries. Hence, the concept of green technology adoption is an essential aspect for the economy, businesses, and investors. The estimation results with the random fixed effect panel data model provided more empirical evidence on the effect of green technology adoption on energy consumption efficiency in Zimbabwe from 2016 to 2022.

The research results established that the major significant determinants of energy consumption efficiency are optimal pricing, sectoral investment, green technology adoption, and capital structure in the energy sector. The study further established substitution possibilities between green technology adoption and total energy consumption. The analysis also showed a significant negative relationship between green technology investment and total energy use.

Policymakers should continue monitoring developments in the energy sector so that green technology adoption increases. This means all anti-competitive policies should be removed to allow free play of market forces. As a suggestion for future studies, the study recommends in-depth research using more robust methodologies for robustness and showing if adopting green technology impacts energy sector performance, which could be a potential driver.

AUTHOR CONTRIBUTIONS

Conceptualization: Julius Mukarati, Leward Jeke, Abel Sanderson.
Data curation: Julius Mukarati, Leward Jeke.
Formal analysis: Julius Mukarati.
Resources: Abel Sanderson.
Software: Julius Mukarati.
Supervision: Leward Jeke.
Validation: Leward Jeke.
Writing – original draft: Leward Jeke, Abel Sanderson.
Writing – review & editing: Abel Sanderson.

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