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The Effect of Clean Energy Financial Investment on Carbon Reduction

Abstract. *Accounting and finance are intricately intertwined with the global quest for environmental sustainability by applying accounting and finance tools for carbon reduction initiatives. Clean energy financial investment is one of the many alternative tools through which accounting contributes to carbon reduction. Accordingly, this paper analysed the impact of separate and integrated clean energy investment alternatives on carbon reduction. Data on clean energy financial investment and carbon emission per capita were collected from the International Energy Agency (IEA) and Our World in Data archives, respectively. Data was analysed by using multiple pooled OLS to evaluate the impact of individual clean energy financial investments on carbon reduction and the impact of integrating the various clean energy financial investment alternatives on carbon reduction separately. Findings show that individual clean energy financial investments may not separately offer desired carbon reduction, hence, albeit some negative coefficients, individual clean investments showed no significant impact on carbon reduction. However, furthering the test by pooling all the clean energy financial investment alternatives shows a significant negative effect of clean energy financial investment on carbon reduction at a P-value of 0.05. This shows that an integration of different alternatives of clean energy financial investment may offer an enhanced reduction of carbon emission, which outweighs the effect of relying on a single clean energy investment alternative. The findings offer significant insight for policy makers' future strategies towards a combination of multiple clean energy financial investments. Furthermore, the findings from this paper are a further testament that accounting and finance are connected with the global quest for environmental sustainability through the application of accounting and financial investment tools in conducting clean energy financial investment.*

Keywords: *environmental sustainability, renewable energy, carbon emission, financial investment, accounting and finance tools.*

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Вплив фінансових інвестицій в чисту енергетику на скорочення викидів вуглецю

Анотація. *Бухгалтерський облік і фінанси тісно переплітаються з глобальним прагненням до екологічної стійкості шляхом застосування бухгалтерських і фінансових інструментів для ініціатив зі скорочення вуглецю. Фінансові інвестиції в чисту енергетику є одним із багатьох альтернативних інструментів, за допомогою яких бухгалтерський облік сприяє зменшенню викидів вуглецю. У цій статті проаналізовано вплив окремих та інтегрованих інвестицій у чисту енергетику на скорочення викидів вуглецю. Дані про фінансові інвестиції в чисту енергетику та викиди вуглецю на душу населення були зібрані з архівів Міжнародного енергетичного агентства (МЕА) та наукового онлайн-видання Our World in Data відповідно. Дані були проаналізовані за допомогою кількох об'єднаних звичайних найменших квадратів, щоб оцінити вплив окремих фінансових інвестицій у чисту енергетику на зменшення викидів вуглецю та окремий вплив інтеграції різних альтернатив фінансових інвестицій у чисту енергію на скорочення викидів вуглецю. Отримані дані свідчать, що окремі фінансові інвестиції в чисту енергетику окремо можуть не забезпечувати бажаного скорочення викидів вуглецю, отже, хоча спостерігаються деякі негативні коефіцієнти, окремі інвестиції в чисту енергетику не показали значного впливу на скорочення викидів вуглецю. Проте, подальше тестування шляхом об'єднання всіх альтернатив фінансових інвестицій у чисту енергетику показує значний негативний їх вплив на скорочення викидів вуглецю. Отже, інтеграція різних альтернатив фінансових інвестицій у чисту енергетику*

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може посилити скорочення викидів вуглецю, що переважує ефект від використання єдиної альтернативи інвестицій у чисту енергетику. Дані цього дослідження дають краще розуміння для майбутніх стратегій політиків щодо поєднання кількох фінансових інвестицій у чисту енергетику. Крім того, отримані результати додатково свідчать, що бухгалтерський облік і фінанси пов'язані з глобальним пошуком сталого розвитку навколишнього середовища.

Ключові слова: *екологічна стійкість, відновлювана енергія, викиди вуглецю, фінансові інвестиції, інструменти обліку та фінансів.*

INTRODUCTION

Financial availability and investment are important catalysts for achieving strategic goals of green and sustainable development (Raghutla et al., 2021; Ran & Zhang, 2023). Carbon reduction is a vital component of global sustainable development goals. Its importance is multifaceted, especially given the human contribution to carbon emissions (Rosa & Dietz, 2012); hence, the imperative for humans to invest significant green finance toward clean energy production to assist in curtailing carbon emissions and the attendant danger implicit in unbridled greenhouse gas emissions (Amighini et al., 2022). The International Energy Agency (IEA) highlights that within the past five years, a one US dollar investment in fossil fuel was accompanied by one US dollar investment in clean energy; however, current data by IEA suggests that the picture has improved (Figure 1). Accordingly, the IEA 2023 data report suggests that currently, for every US dollar investment in fossil, there is an attendant 1.8 US dollar investment in clean energy (IEA, 2023a).

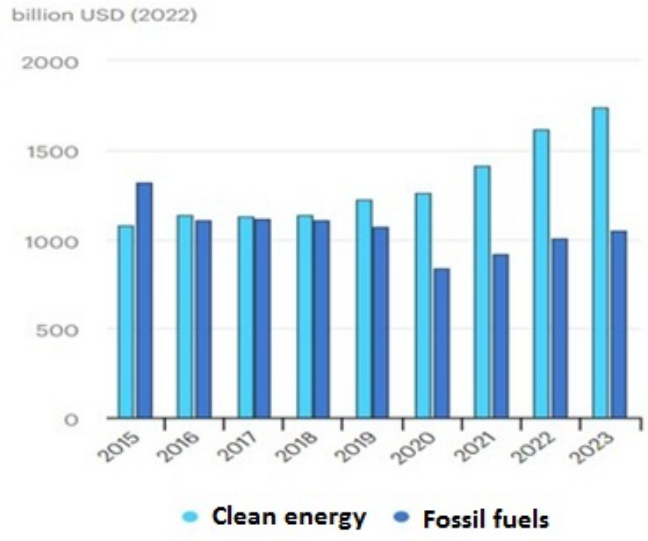

Figure 1. **Global Energy Investment in Clean Energy and Fossil Fuels, 2015-2023**
Source: IEA (2023a, p. 1).

The urgency of the global carbon emission problem, as highlighted by the Global Carbon Budget (2023), cannot be overstated. It reveals that despite global policies aimed at carbon emissions reduction, global carbon emissions have reached a new record level in 2023. This alarming trend underscores the need for more than just policies; it necessitates proven pragmatic actions to curb the escalating carbon emissions. Green finance is viewed as a potent catalyst in global efforts toward carbon reduction (Zavodov, 2012; Wan et al., 2022; Ran & Zhang, 2023).

While recent research has provided some insights, a significant gap exists in understanding the impact of different types of clean energy investments on carbon reduction. Most studies have confirmed the link between financial investment in renewable energy and reduced greenhouse gas emissions (Zhang et al., 2022; Raghutla et al., 2021). However, the long-term efficacy of clean energy financial investment, particularly its potential to catalyze carbon reduction, remains unclear. This paper aims to fill this gap by examining the effects of various clean energy investments on carbon reduction. The findings of this study could provide valuable information for policy and industrial practices in clean energy investments for carbon reduction.

LITERATURE REVIEW

Extant empirical research provides mounting confirmatory albeit mixed results on the link between investment in clean energy and carbon emissions (Zhang et al., 2022; Raghutla et al., 2021; Saidi & Omri, 2020). To investigate the effectiveness of renewable energy in stimulating economic growth and reducing carbon emissions in 15 significant nations that heavily rely on renewable energy, Saidi and Omri (2020) employed growth and environmental functions. They used a vector error correction model (VECM) and fully modified ordinary least squares (FMOLS) estimation methods.

The results of the FMOLS approach show how beneficial renewable energy is for raising economic growth and lowering carbon emissions. Furthermore, the Granger causality test VECM provides numerous significant insights: The feedback hypothesis is supported by the following findings: (i) economic growth and renewable energy have a bidirectional causal relationship in both the short and long runs; (ii) CO2 emissions and renewable energy do not have a causal relationship in the long run, but there is a bidirectional causal relationship in the short run; and (iii) economic growth and CO2 emissions have a bidirectional relationship in both the short and long runs (Saidi & Omri, 2020).

A quantile regression model was employed by Zhang et al. (2022) to evaluate the impact of digital and green finance on environmental conservation. Their results from the panel quantile regression show that investments in renewable energy, green financing, and technical innovation are crucial in lowering CO2 emissions. On the other hand, variables including trade, foreign direct investment, energy consumption, and economic expansion cause CO2 emissions to rise. The impact of stock market capitalization, R&D spending, and foreign direct investment (FDI) inflows on the demand for clean energy in key investing countries is examined by Raghutla et al. (2021). The research spans the years 1996 to 2017. Their results show that spending on research and development and FDI inflows have a significant impact on encouraging the use of clean energy. Furthermore, it has been noted that the use of renewable energy not only increases economic growth but also significantly reduces carbon emissions. Moreover, there is a notable inverse relationship between CO2 emissions and research and development spending, as well as foreign direct investment inflows (Raghutla et al., 2021).

Panel ordinary least squares and fixed-effect panel quantile regression (PQR) were utilized by Akram et al. (2020) in their study to examine the various effects of renewable energy and energy efficiency on carbon emissions. Their results showed that different quantiles have different influential elements affecting emissions. Importantly, energy efficiency emerges as a consistent champion, decreasing emissions at every quantile, with the 90th quantile showing the largest mitigation benefit. Conversely, renewable energy also shows a significant decrease in emissions, especially at the 10th quantile. Although using nuclear energy does help reduce emissions, its effects become noticeable around the 50th quantile (Akram et al., 2020).

Granger causality analysis was used by Pilatowska and Geise (2021) to examine how renewable energy affects carbon reduction. Their research identified two periods of the diffusion of renewable energy sources and differences in the causation patterns between nations. They found that during France's and Spain's boom phase, clean energy usage had a greater impact on reducing emissions. The research shows that CO2 emissions have not significantly decreased in the chosen nations or globally despite the notable expansion of renewable energy sources and aggressive mitigation programs (Pilatowska & Geise, 2021).

Naeem et al. (2023) investigated the impact of several variables on carbon emissions in 24 OECD nations from 2000 to 2020. The researchers concentrated on developing renewable energy sources, increasing biocapacity, expanding access to clean energy, and implementing environmental legislation. Their analysis showed that emissions may be significantly reduced by using clean fuels, technology, and renewable energy sources. On the other hand, they discovered that the current policies and the growth of biocapacity were responsible for the rise in emissions. Additionally, Naeem et al. (2023) research revealed a bidirectional association between emissions and every one of these variables, suggesting the existence of a feedback loop. The results further highlight the significance of improving regulations to maximize biocapacity infrastructure, ease the shift to greener technologies, and encourage the expansion of renewable energy sources. The geodetector method was employed by Shi et al. (2023) to provide quantitative research on the impact of renewable energy production and consumption on China's overall carbon emissions. The three main criteria the researchers used to calculate the carbon quota were comprehensiveness, efficiency, and responsibility. Their investigation's findings demonstrate that the amount of electricity generated by clean energy has the greatest influence over carbon emissions.

Zheng et al. (2021) conducted inter-provincial panel data from 2008 to 2017, subjected to path analysis and a quantile regression model to evaluate the effect of renewable energy generation on carbon emissions in China. The study's conclusions highlight two important findings. First, the growth of renewable energy reduces the intensity of carbon emissions. More specifically, carbon emission intensity falls by 0.028%–0.043% for every 1% increase in the growth of renewable energy. Second, as the quantile regression analysis results show, the inhibitory effect of developing renewable energy on carbon emissions differs across different levels.

RESEARCH METHOD

The paper applied a quantitative approach in analysing the effect of clean energy financial investment on carbon reduction. The paper applied two sets of data covering the independent variable (clean energy financial investment) and the dependent variable (carbon emission). Global data was used in each set. The data on clean energy financial investment and carbon emission per capita were collected from the International Energy Agency (IEA) and Our World in Data archives, respectively (IEA, 2023b; Our Word in Data, 2023). Data was analysed by using multiple pooled OLS to evaluate the impact of individual clean energy financial investments on carbon reduction and the impact of integrating the various financial investment alternatives separately.

RESULTS

The results in Table 1 and Table 2 provide important insight to the literature on renewable energy investment on carbon emissions reduction and highlight that

businesses may conduct their financial investments through a balanced financial mix of investments to achieve overall goal of global emissions reduction. In Table 1, an OLS analysis results shows the coefficient of individual independent variables (namely the different types of renewable energy. It is important to note that although the renewable energy types as individual variables show no significant impact, but greater percentage of the renewable energy types show negative relationship with global emissions. These are renewable energy power, battery storage, and nuclear energy. The negative coefficients on these renewable energy sources show that increase in investment on these sources may lead to a reduction in global emissions – which is an important part of sustainable energy goal of SDA.

Table 2 presents a slightly different but significant dynamic that future researchers could consider when evaluating key concepts related to renewable energy investment. Firstly, as envisaged in this follow-up analysis a pooling together of all the variables appear to provide a joint strength which impacts significantly on global emission reduction. Both the P-value and coefficients in Table 2, show a joint investment in different renewable energy types and a pooling together of their joint impacts assists in overall negative and significant effect on global emissions. The negative coefficient thus shows that when all the renewable energy investment types are combined, it may provide a joint reduction in emissions. Hence, given the bourgeoning of renewable energy investment, it may be more effective to diversify into different aspects of renewable energy rather than focus only on one or two types of renewable energy.

Table 1. **OLS, using observations 2015-2023 (T = 9)**
Dependent variable: Global Emissions

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	5.64575	0.873469	6.4636	0.00751	***
Renewablepower	-0.00204766	0.00148591	-1.3781	0.26198	
Batterystorage	-0.00688012	0.0500352	-0.1375	0.89934	
Nuclear	-0.00651252	0.0165788	-0.3928	0.72070	
Electric_vehicl	0.00651142	0.00672041	0.9689	0.40406	
lowenergy_fuel	0.00702902	0.0558821	0.1258	0.90786	

Table 2. **Fixed-effects, using 45 observations**
Included 5 cross-sectional units
Time-series length = 9
Dependent variable: Global Emissions

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	4.75028	0.0331019	143.5050	<0.00001	***
Renewableenergy	-0.000523246	0.000266608	-1.9626	0.05685	*

CONCLUSION

This paper extends the prior research question that sought to know whether clean energy financial investment may bolster reductions in carbon emission (Özdurak, 2021) in seeking to explore this important global concept and the attendant relationship. The paper adopted a global perspective given the apparent ripple dynamics of clean energy financial investment and carbon reduction across the world's regions. Hence, this paper differs from existing research as it employs global data on clean energy financial investment and rate of carbon reduction.

Data on clean energy financial investment and carbon emission per capita were collected from the International Energy Agency (IEA) and Our World in Data archives, respectively. Data was analysed by using multiple pooled OLS to evaluate the impact of individual clean energy financial investments on carbon reduction and the impact of integrating the various financial investment alternatives separately. The results from the statistical analysis disclose important insights, which includes amongst others, engagement in isolated clean energy financial investments may not separately offer desirable achievement in carbon reduction. Accordingly, despite the manifestation of some negative coefficients, separate clean financial investments showed no significant impact on carbon reduction. Conversely, further analysis with a pooling together of all the clean energy financial investments indicates a significant negative effect of clean energy financial investment on carbon reduction at a P-value of 0.05. This further result indicates that a mixture of different alternatives of clean energy financial investment may provide an improved reduction in carbon emission that emanates from clean energy investment. Therefore, financial investment efforts in clean energy may not be conducted in isolation – there is potential for a better result when a group of alternative clean energy financial investments are combined together. This is why experts assert that financial feasibility is crucial to the achievement of clean energy and the attendant carbon reduction (Zavodov, 2012; Wan et al., 2022; Ran & Zhang, 2023).

These unique findings are imperative for policy insights and provide an agenda for further research on clean energy financial investment and carbon emissions. Furthermore, the findings from this paper are a further testament that accounting and finance are connected with the global quest for environmental sustainability through the application of accounting and financial investment tools in conducting clean energy financial investment. Hence, the paper also provides important academic study material in business schools for sustainability accounting and finance studies.

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