Does green finance affect renewable energy development in Singapore?

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Abstract

Purpose – Given the importance of green finance in a discussion of energy efficiency and clean energy, it is critical to evaluate its implications for the growth of renewable energy. This study examines the impact of green finance on renewable energy development in Singapore.

Design/methodology/approach – The dynamic ordinary least squares (DOLS) regression was used in this work to test such a connection.

Findings – Using the DOLS for the period 2000–2020, it was discovered that green finance aids renewable energy development in Singapore. Additionally, the findings revealed that economic growth, oil prices, energy consumption, carbon dioxide emissions and institutional factors are all positively associated with renewable energy growth, resulting in a boost in renewable energy development.

Research limitations/implications – Hence, as a result, the monetary authorities of Singapore, such as financial institutions, non-governmental organisations and corporations, should prioritise renewable energy projects under green finance initiatives to boost renewable energy growth. This may assist in raising investment flows to green projects; hence, accelerating the adoption of renewable energy.

Originality/value – Increased Singapore's initiatives to accelerate green finance have prompted this study to examine the research question of whether green finance has a significant impact on renewable energy growth. Thus, to the best of the authors' knowledge, this will be the first empirical study to explore the impact of green finance on renewable energy growth in the case of Singapore.

Keywords Green finance, Renewable energy development, Singapore, OLS

Paper type Research paper

1. Introduction

Today, for the sake of environmentally sustainable development, the adoption of green finance is blossoming as a strategy to meet the needs of environmentalism and capitalism at the same time. Green finance is a type of structured financial activity that includes banking, microcredit, investing and insurance, which was established to promote the growth of green projects and enhance environmental outcomes (Jeucken, 2010; Park and Kim, 2020; Barua and Aziz, 2022). It is expected that the development of green finance will aid in achieving economic and ecological benefits by efficiently utilising resources, mitigating climate change and supporting environmental improvement. As a result, green finance is gaining traction as the world moves towards a more sustainable future.

Now, the focus on green finance is gaining and rapidly growing across all regions. From Europe to North America to Asia, the global issuance of green bonds and green loans increased to US$264bn in 2021, up more than 50% from the prior year

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(Darrieux *et al.*, 2020; The Climate Bonds Initiative, 2022). Whilst Europe continues to be the leading continent in terms of green finance, Asia–Pacific accounts for 23% of global volumes and has been steadily increasing from 2014 to 2021 (Darrieux *et al.*, 2020; The Climate Bonds Initiative, 2022). In 2021, the ASEAN countries' cumulative green finance issuance accounted for a considerable share of the Asia–Pacific region's total issuance, according to the ASEAN Green Finance State of the Market report. Thailand, Singapore, Vietnam, Malaysia, the Philippines and Indonesia are the six largest Association of Southeast Asian Nations (ASEAN) countries engaging in green finance, allocating more to building, energy, transportation and water-related projects (Darrieux *et al.*, 2020; The Climate Bonds Initiative, 2022). As shown in Figure A1 [1], Singapore appears to be the leading ASEAN country in the green finance sector, with significant growth in the issuance of green finance loans and bonds. Notably, Singapore's green finance proceeds are substantially invested in building projects such as green buildings and building energy efficiency to assist environmental improvement in the face of climate change.

In addition to green finance issuance in the ASEAN, Table A1 [1] illustrates green finance issuance in Singapore during the last three years, according to the climate bond initiative report. Green loans account for roughly half of all green finance issues, with loans accounting for nine of the 14 deals in 2019. As per the climate bond initiative report, about 43% of the total green funding granted has been dedicated to encouraging sustainable construction designs and green technologies to reduce environmental impacts and push environmental sustainability in Singapore (Darrieux *et al.*, 2020); for instance, a $1.95bn green financing has been secured to refinance the office and retail components of Marine One to conserve energy and efficiency. Marine One plans to use green financing to develop innovative technologies such as energy-saving building management systems, heat and power recycling as well as rainwater collection for irrigation, all of which will assist the environment (Darrieux *et al.*, 2020). Besides, Singapore's green funding is distributed to the energy industry to become one of the world's most carbon-efficient countries. For example, the National University of Singapore issued SDG 300 m in green bonds to finance green projects related to green building, renewable energy infrastructure, pollution prevention and control as well as sustainable management of natural resources and water (Darrieux *et al.*, 2020). Sunseap Group became the first renewable energy company in Asia to secure green financing to install solar power systems on the rooftops in Singapore, ranging in size from 100 kW to 5 MW (Darrieux *et al.*, 2020). It is Singapore's largest clean energy project, aiding the economy in strengthening the capacity and capitalising on the opportunities presented by sustainability megatrends, such as the increasing adoption of renewable energy and decarbonisation solutions.

However, in the process of approaching greener energy, Singapore still has a long way to go in transitioning to sustainable energy, which encompasses all renewable energy sources. To date, Singapore has transitioned to natural gas for cleaner power generation and increased the use of solar energy using roofs and reservoirs, both promising renewable energy sources for Singapore. However, as shown in Figure A2 [1], the share of renewable energy in power generation has remained extremely low since 1990 compared to nonrenewable energy sources such as oil, gas and coal. At the same time, according to a report by Powering the World, Singapore relies on fossil fuels more than any other country, with traditional fuel sources accounting for 98% of its entire energy supply (Largue, 2021). As is known to all, one common goal of green finance is to support the development of renewable energy and energy efficiency, which in turn decouples inclusive economic growth from environmental deterioration. Through financial assistance and investments, especially created to help preserve the environment, green finance plays a significant role in facilitating the financing of renewable energy

initiatives. Green finance, as an example, allocates funds for the development and implementation of renewable energy projects, such as solar, wind, hydroelectric and geothermal, amongst other types of renewable energy infrastructure. This helps to overcome the upfront costs of renewable energy projects, making them more commercially viable, especially in underprivileged areas. In addition, green finance provides instruments such as loan guarantees, insurance products and risk-sharing agreements that attract financial institutions and investors to invest in renewable energy projects, helping to reduce the financial risks associated with such investments. In turn, it supports the growth and expansion of renewable energy projects and enhances sustainable development. These discussions raise an important question that needs to be answered by scholars: Does green finance in Singapore affect the transition to renewable energy? The reason for this is that Singapore is one of the ASEAN countries leading in green finance and has grown significantly but has not yet achieved a full transition to renewable energy. Thus, this study seeks to answer this question empirically by examining the impact of green finance on renewable energy development in Singapore from 2000 to 2020. To prevent the omitted variable problems, additional economic, environmental and institutional variables, such as carbon emissions, economic growth and oil prices, were included in the economic estimating model.

2. Literature review

A growing number of researchers are focusing on the impact of economic, environmental and institutional variables on renewable energy. However, the results of those studies are sometimes contradictory due to differences in methods, approaches, variables and countries. From the perspective of economic variables, many previous studies have looked at the impact of income (Marques *et al.*, 2010; Ohler and Fetters, 2014; Omri and Nguyen, 2014; Tugcu and Topcu, 2018; da Silva *et al.*, 2018; İçen and Tatoğlu, 2021; Uzar, 2020; Mukhtarov *et al.*, 2022; Shahbaz *et al.*, 2022; Villanthenkodath and Velan, 2022), oil prices (Van Ruijven and Van Vuuren, 2009; Aguirre and Ibikunle, 2014; Omri and Nguyen, 2014; Reboredo, 2015; Lin and Omoju, 2017; da Silva *et al.*, 2018; Murshed and Tanha, 2021; Sahu *et al.*, 2022) on renewable energy. The empirical work on the link between renewable energy and economic growth by Ohler and Fetters (2014), Omri and Nguyen (2014), Tugcu and Topcu (2018), da Silva *et al.* (2018), İçen and Tatoğlu (2021), Shahbaz *et al.* (2022) as well as Villanthenkodath and Velan (2022), indicated that economic growth improves the viability of the renewable energy sector. In the case of Marques *et al.* (2010), Uzar (2020) and Mukhtarov *et al.* (2022), the findings revealed that economic growth is not significant to renewable energy consumption as economic growth provides more wealth, which leads to higher demand. More demand needs greater productivity, which necessitates increased energy consumption, the most readily available being fossil-based energy. Concerning the impact of oil prices on renewable energy consumption, Van Ruijven and Van Vuuren (2009), Aguirre and Ibikunle (2014), Reboredo (2015), Lin and Omoju (2017), Murshed and Tanha (2021) as well as Sahu *et al.* (2022) argued that an increase in oil prices leads to a rise in the trend of switching from traditional to renewable energy. The findings support the assertion that higher oil prices encourage more investment in renewable energy, which is a viable alternative to crude oil. Contrary to past studies that have found a positive impact, a group of studies has shown the detrimental role of oil prices in oil-exporting countries (Marques *et al.*, 2010; Omri and Nguyen, 2014; da Silva *et al.*, 2018). Higher oil prices in oil-exporting countries lead to increased consumption of conventional energy due to available resources and local subsidies, which demotivates renewable energy consumption.

In terms of environmental variables, several studies have focused on carbon dioxide emissions and energy consumption, both of which influence renewable energy

consumption (Marques *et al.*, 2010; Aguirre and Ibikunle, 2014; Omri and Nguyen, 2014; da Silva *et al.*, 2018; Uzar, 2020; Bourcet, 2020). Carbon dioxide emissions are a major driving force behind increased renewable energy and improved environmental quality. Marques *et al.* (2010), Aguirre and Ibikunle (2014), da Silva *et al.* (2018) and Uzar (2020) investigated the influence of carbon emissions on renewable energy in G7 countries, European countries, global, India, sub-Saharan Africa, developing and developed countries, respectively, expressing concern about climate change from the release of large amounts of CO2 that accelerated the adoption of renewable energy. On the other hand, Marques and Fuinhas (2011) analysed the drivers promoting renewable energy in European countries, contending that carbon emissions hinder renewable energy consumption. This indicates that a greater level of emissions is insufficient to justify switching to renewables. Another important environmental factor is energy consumption. Previous research has shown that increased energy consumption promotes the development of cleaner energy sources, which in turn promotes the transition to renewable energy sources (Carley, 2009; da Silva *et al.*, 2018; Nguyen and Kakinaka, 2019; Bourcet, 2020). Energy consumption is a measure of a country's energy needs, implying that rising energy demand from population growth and economic development will lead to increased renewable deployment. The authors who studied renewable energy growth, such as Aguirre and Ibikunle (2014) and Pfeiffer and Mulder (2013), shared the opposite viewpoint that energy use harms renewable energy. Increasing demand for energy supply may persuade people to use cheap fossil fuels instead of renewables.

In addition, another remarkable study by Marques and Fuinhas (2012), Kilinc-Ata (2016), Uzar (2020), Belaid *et al.* (2021), Li and Shao (2021), and Saadaoui (2022) highlighted the link between institutional factors and renewable energy consumption. Economic freedom, government effectiveness, regular quality, rules of law and property rights are examples of institutional factors that might be important in stimulating the development of the renewable energy sector. For example, Uzar (2020) looked at the impact of policies in the case of renewable energy, concluding that policies like incentives, trade freedom, legal and property rights as well as patents encourage technological innovation in renewable energy. Such innovations in renewable energy contribute significantly to the expansion of renewables, resulting in increased renewable energy consumption. However, Cheon and Urpelainen (2012) argued that institutional factors impede the growth of renewable energy, resulting in a drop in renewable energy consumption since stringent regulations and policies impede renewable energy development and reduce renewable energy consumption.

Green finance is frequently mentioned as an important tool for increasing renewable energy growth. At its simplest, green finance is a structural financial activity designed to encourage the development of green projects that result in better environmental outcomes, such as renewable energy development. One can see from the existing literature that few scholars have delved into the issues of green finance and renewable energy. Zhang and Wang (2021), Shang *et al.* (2023), Lee *et al.* (2023), Li and Umair (2023) and Tang and Zhou (2023) for China, Tolliver *et al.* (2020) for 66 countries, Polzin and Sanders (2020) for Europe, Liu *et al.* (2021) for the United States of America, Rasoulinezhad and Taghizadeh-Hesary (2022) for the top ten countries that support green finance and Alharbi *et al.* (2023) for 44 countries have explored the relationship between green finance and renewable energy. According to these studies, green finance positively contributes to clean energy development and reduces climate change and environmental threats. For instance, Zhang and Wang (2021) in China and Polzin and Sanders (2020) in Europe, investigated the impact of green finance on environmental protection in the context of renewable energy development. Their findings emphasised that attracting private investors through green finance may make a significant contribution to the development of sustainable renewable energy. Shang *et al.* (2023) studied

how green finance influenced green energy in the China's tourism industry from 1992–2021 by employing the autoregressive distributed lag approach. In the long run, they discovered that green finance has a positive impact on the deployment of green energy but has no impact on the short run. Similar findings were made by Rasoulinezhad and Taghizadeh-Hesary (2022), who discovered that green bonds effectively support green energy projects and lower CO2 emissions. In the short run, there was no causal relationship between these variables. Hence, Table A2 [1] summarises previous studies on green finance and renewable energy by stating their findings as well as whether Singapore was included in their sample.

In light of this, whilst a few scholars have analysed the effect of green finance on accelerating renewable energy development, only Alharbi *et al.* (2023) have assessed whether the introduction of green finance is an effective weapon in Singapore for renewable energy growth.

Alharbi *et al.* (2023) showed that green finance promotes the development of renewable energy using a wide sample of 44 countries, including Singapore, for the years 2007–2020. Whilst Alharbi *et al.* (2023) showed that green finance promotes renewable energy generation across a broad sample of 44 countries, including Singapore; it does not fully capture the context of Singapore. Panel studies with a number of countries, such as those with different income levels, geographical locations and developmental stages, offer valuable insights into the association between green finance and renewable energy on the global level. Alharbi *et al.* (2023) may, however, overlook the unique dynamics that each country provides. Looking at the ability of green finance to accelerate the adoption of renewable energy, Singapore faces specific problems and opportunities due to its unique characteristics, including its small size, geographic location and economic structure. For instance, Singapore's small land area makes it challenging to build largescale renewable energy infrastructure by looking into innovative options like the offshore wind farms and rooftop solar installation. Although Singapore's tropical environment presents prospects for solar energy, intermittent cloud cover and a limited amount of available land require the use of efficient and adaptive renewable energy technology to maximise energy production in Singapore. Thus, the current study intends to close this gap by using ordinary least squares (OLS) regression to explore the impact of green finance on the explicit growth of renewable energy in Singapore from 2016 to 2020.

3. Data and methodology

The data used in this study were annual figures for the period 2000–2020. Given the restricted data sources on green financing, only 20 years of data were used for Singapore. Table A3 [1] provides details of independent and dependent variables in terms of notation, data sources and definition.

The proposed empirical model in this study, followed a functional form based on the existing studies (Murshed and Tanha, 2021; Sahu *et al.*, 2022; Shahbaz *et al.*, 2022; Villanthenkodath and Velan, 2022):

$$REN_t = f(GDP_t, GF_t, \varepsilon_t) \tag{1}$$

$$REN_t = f(OILPR_t, GF_t, \varepsilon_t) \tag{2}$$

$$REN_t = f(CO2_t, GF_t, \varepsilon_t) \tag{3}$$

$$REN_t = f(EU_t, GF_t, \varepsilon_t) \tag{4}$$

$$REN_t = f(GE_t, GF_t, \varepsilon_t) \tag{5}$$

$$REN_t = f(RL_t, GF_t, \varepsilon_t) \tag{6}$$

where REN_t represents renewable energy growth, GDP_t is economic growth, $OILPR_t$ indicates oil price, $CO2_t$ is carbon emissions, EU_t is energy use, GE_t is government effectiveness, RL_t is the rule of law and GF_t is green finance. All the independent and dependent variables were converted into natural logarithms to improve the credibility of the regression results. Thus, Eqs (7)–(12) were illustrated using natural logarithms (*ln*) in an empirical model as follows:

$$ln\,REN_t = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnGF_t + \varepsilon_t \quad (7)$$

$$ln\,REN_t = \beta_0 + \beta_1 lnOILPR_t + \beta_2 lnGF_t + \varepsilon_t \quad (8)$$

$$ln\,REN_t = \beta_0 + \beta_1 lnCO2_t + \beta_2 ln\,GF_t + \varepsilon_t \quad (9)$$

$$ln\,REN_t = \beta_0 + \beta_1 lnEU_t + \beta_2 lnGF_t + \varepsilon_t \quad (10)$$

$$ln\,REN_t = \beta_0 + \beta_1 lnGE_t + \beta_2 lnGF_t + \varepsilon_t \quad (11)$$

$$ln\,REN_t = \beta_0 + \beta_1 lnRL_t + \beta_2 lnGF_t + \varepsilon_t \quad (12)$$

where subscripts t represents the time period (2016–2020), ε_t represents stochastic error terms, β_0 is constant and β_1 until β_7 are the parameters to be predicted. The OLS method was used to estimate Eqs (7)–(12), which also assisted in the correction of heteroscedasticity.

4. Results and discussions

4.1 Descriptive analysis

First, all independent and dependent variables were subjected to a preliminary assessment of the descriptive analysis. Table A4 [1] demonstrated that the presented model's variables were normally distributed, with standard skewness of ±1.96 and standard kurtosis of ±3. The dependent variable's skewness was 0.1347 and the kurtosis was 1.2592, showing that the data on renewable energy growth in Singapore is distributed normally. The variable of renewable energy in Singapore was similar to the average of 1.3041, whereas the average of green finance was 5.9934. A descriptive analysis of research variables revealed that the standard deviation in green finance is greater than the deviations in renewable energy growth. Compared to green finance, renewable energy growth deviates less.

Following that, the correlation matrix was employed to perform a correlation test to observe any potential for multicollinearity between the independent and dependent variables (Table A5 [1]). Green financing and renewable energy growth have a positive correlation, whereas renewable energy growth was negatively correlated with government effectiveness. In summary, all of the coefficients were low, indicating no possibility of multicollinearity between the independent and dependent variables.

4.2 Baseline regression (OLS regression)

In terms of study methodology, this study investigates the relationship between renewable energy growth and green finance in Singapore between 2000 and 2020 using the OLS as baseline regression. Table A6 [1] presents the contents of the baseline regression results linking dependent variables and independent variables. The F-value was significant at a 5 and 1% level of significance, whilst the R^2 and adjusted R^2 statistics were greater than 56% for all estimated equations.

According to the OLS regression results, the economic growth coefficient was positive and significant at the 5% level, implying that economic growth in Singapore increases renewable energy adoption. These findings are consistent with those of prior research such as Tugcu

and Topcu (2018), da Silva *et al.* (2018), İçen and Tatoğlu (2021), Shahbaz *et al.* (2022) and Villanthenkodath and Velan (2022), which discovered that higher economic growth stimulates the development of renewable energy. A 1% increase in economic growth boosted renewable energy by 1.6721%. The findings suggest that economic growth promotes renewable energy growth as it allows Singapore to manage the costs associated with developing renewable energy, such as the cost of technologies and public policies governing renewables. For instance, innovations in technology, including those related to renewable energy, are often a result of economic growth. Higher economic growth in Singapore allows it to devote more funds to renewable energy research and development, which could lead to the development of new technologies such as more effective solar cells, cutting-edge wind turbines or innovations in energy storage systems. These technological developments may help the renewable energy sources grow further. Besides, higher economic growth may encourage private sector investment in renewable infrastructure or increase funding from the government for renewable energy projects. These investments may help the country expand its adoption of renewable energy. Thus, Singapore's economic development may assist in the development of renewable energy.

In the case of Singapore, where the coefficient value of the oil price is 0.2382 and significant at 10%, the oil price confirmed a significant positive association. This demonstrates that a 1% increase in oil prices increases renewable energy growth by 0.2382%. Oil is used to generate almost 95% of electric power, which is then transformed into gasoline and gas. An increase in the price of oil causes Singapore to shift towards renewable energy since the conversion of oil to gasoline and gas becomes more expensive as the price of oil rises. From another perspective, when oil prices climb, it informs businesses and investors that there is a higher risk and volatility related to energy supplies based on fossil fuels. Long-term investments in traditional energy infrastructure may become less confident due to rising market uncertainty. Given the more consistent and predictable returns offered by renewable energy projects, investors may redirect their funds to renewable energy projects, thus promoting renewable energy growth. As a result, some prior studies, in line with this study's findings, showed that renewable energy has experienced significant growth due to rising oil prices (Reboredo, 2015; Lin and Omoju, 2017; Murshed and Tanha, 2021; Sahu *et al.*, 2022).

The results revealed a positive relationship between carbon dioxide emission and renewable energy growth. A 1% increase in carbon emissions boosted the incentive to switch to renewable energy by 3.0658%. Because of its effects on the environment, a rise in carbon emissions exacerbates concerns about climate change. People are increasingly encouraged to switch to cleaner, renewable energy sources like solar, wind and hydropower, which can lower overall carbon emissions and combat climate change. For instance, an increase in carbon emissions often leads to an increase in air pollution, which can be harmful to the public's health. In turn, it makes Singapore more aware of the need to enhance air quality and reduce hazardous emissions, thus encouraging the development of renewable energy sources with low emissions. Hence, this finding is consistent with the study of Marques *et al.* (2010), Aguirre and Ibikunle (2014), da Silva *et al.* (2018) and Uzar (2020).

Besides, it was observed that energy use was positively related to renewable energy growth in Singapore at a 1% significance level. Based on the significant pressure on the level of energy supply, it can be said that energy consumption is a driver of increased renewable energy growth. As a country strives to meet its population's energy needs, it may boost the incentive to shift to renewable energy sources. According to statistics, a 1% increase in energy consumption would cause a country to invest 0.6669% more in renewables. This result is in line with da Silva *et al.* (2018), Nguyen and Kakinaka (2019) and Bourcet's (2020) findings, stating that energy consumption assists the growth of renewable energy sources.

When it comes to institutional factors such as the rule of law and government effectiveness, each percentage increase led to a 1.8607 and 0.5266% increases in renewable

energy growth, respectively. By creating a conducive institutional environment, the rule of law and government effectiveness can help to boost renewable energy growth. Meanwhile, subsidies, quota policies, research and development, feed-in tariffs, green certificates and technology push policies are more effective in promoting renewable energy technologies and innovation and are likely to result in increased growth of renewable energy. Similar findings have been reported by Uzar (2020), Belaid *et al.* (2021), Li and Shao (2021) and Saadaoui (2022), who discovered that institutional factors increase a country's percentage of renewable energy. The government funding is allocated to energy storage and smart grid technologies, which increase the dependability and adaptability of renewable energy sources. Also, effective governance makes it easier to build renewable energy markets and regulatory frameworks, such as carbon pricing or renewable energy certificates, providing financial incentives for the adoption of renewable energy sources and accelerating the expansion of the renewable energy sector.

Looking for the core variable, this study realised that the effect of green finance on the growth of renewable energy was positive in the case of Singapore. The green finance coefficient ranged from 0.03 to 0.599, which signifies that green finance caused an increase in renewable energy growth by 0.03–0.599%. The results of regression analysis showed a significant and novel feature of this study. Despite Singapore's low share of renewable energy, the analysis revealed a positive relationship between green finance and renewable energy. This breakthrough discovery emphasises the revolutionary potential of targeted financial assistance and risk reduction offered by green finance. In addition, it implies that green finance accelerates the switch to renewable energy, especially in a challenging environment marked by a lack of available land and technical constraints. This study adds to the body of knowledge by demonstrating how effectively the green financing works to promote renewable energy deployment and utilisation. These results provide encouragement and motivation for quickening the switch to renewable energy, highlighting the necessity of ongoing funding and support of green finance as essential drivers of sustainable growth in Singapore.

Green finance can help promote renewable energy development and utilisation by supporting green energy projects such as wind, biomass, solar and hydropower as well as renewable energy technology innovations. Green finance tools such as green bonds are well suited to channel substantial capital into renewable energy owing to the fact that green bonds are more likely to finance projects that promote environmental sustainability and a low-carbon economy, such as renewable energy infrastructure, energy-efficient buildings and clean transportation. This finding resonates with those of Tolliver *et al.* (2020) for 66 countries, Polzin and Sanders (2020) for Europe, Nguyen *et al.* (2021) for Europe and Liu *et al.* (2021) for the United States of America. In Singapore's scenario, the government is in an effort to issue $35bn in green bonds by 2030 to fund clean energy project development, such as renewable energy and energy efficiency projects, to minimise the number of planet-warming gases produced. The funds generated from these bonds, for example, can be used to fund investments in clean energy technology, the development of new renewable energy facilities or the energy-efficient upgrading of existing infrastructure. Green finance expedites the adoption of renewable energy sources by offering specialised financial resources. In Singapore's scenario, the issuance of green bonds is accompanied by precise criteria and reporting requirements to guarantee accountability and transparency in the use of money, which increases investor confidence by clearly outlining the environmental advantages of the funded projects and how they can help cut carbon emissions. As a result, green finance mechanisms lower perceived risks whilst attracting a broader range of investors to projects related to renewable energy.

The robustness of the results was further checked using the fully modified least squares (FMOLS). The findings are similar to the results by the DOLS, as shown in Table 1.

	(1)	(2)	(3)	(4)	(5)	(6)
lnGF	0.7133***	0.5435**	0.1401*	0.2115*	0.2554**	0.2083*
	(3.96)	(2.35)	(2.08)	(2.26)	(2.33)	(2.09)
lnGDP	0.1532**	–	–	–	–	–
	(2.23)					
lnOILPR	–	0.3850**	–	–	–	–
		(2.24)				
lnCO2	–	–	0.3247**	–	–	–
			(2.29)			
lnEU	–	–	–	0.2076**	–	–
				(1.99)		
lnGE	–	–	–	–	1.0972**	–
					(2.23)	
lnRL	–	–	–	–	–	0.2908***
						(2.40)
cons	0.8339***	1.7320***	0.8611***	0.6121***	0.4695**	3.3780**
	(5.36)	(8.70)	(3.27)	(4.09)	(3.30)	(3.27)
R^2	0.78	0.84	0.86	0.93	0.86	0.84
F	7.33	4.83	3.32	3.78	2.37	2.76

Note(s): Asterisks *, ** and*** denote the 10, 5 and 1% levels of significance, respectively. Figures in ( ) stand for *t*-statistics
Dependent variable: lnREN
Source(s): Created by authors

Table 1.
Fully modified least squares (FMOLS) estimations

5. Conclusion

Green finance is currently gaining attraction as a tool for guiding businesses and industries towards more environmentally sustainable practices. Singapore has been at the forefront of this trend, aggressively encouraging the expansion of green finance. Nevertheless, this raises the question of whether green finance promotes renewable energy growth. Thus, the main objective of the current study is to investigate the effect of green finance on renewable energy growth in Singapore from 2000 to 2020. The OLS regression was used in this work to test such a connection.

The novel findings of this study offer substantial evidence of the positive influence of green finance on Singapore's adoption of renewable energy. The analysis highlighted the effectiveness of green finance in accelerating the transition towards renewable energy by allocating funds for the development and implementation of renewable energy projects and reducing the financial risks associated with renewable energy investments. In terms of control variables, economic, environmental and institutional factors were seen as significant determinants affecting renewable energy growth in Singapore. Economic growth, oil prices and government effectiveness, for example, all have a favourable impact on renewable energy development, assisting the expansion of renewable energy in Singapore.

Regarding policy implications, this study's findings provide Singapore with the following implications in light of its attempt at a sustainable energy future: (1) The Singaporean Government needs to prioritise the creation and enhancement of green financing structures, such as investment funds and green bonds, to attract more private investments in the renewable energy sector. This can be accomplished by offering financial incentives, simplifying rules and promoting collaborations between financial institutions, project developers and governmental organisations. For instance, Singapore can launch the Renewable Energy Funding Scheme (REFS) to provide funding options, especially suited for renewable energy projects. The program not only offers financial assistance but also simplifies the financing of renewable energy projects, encouraging collaboration between

financial institutions, project developers and government organisations in the renewable energy sector; (2) An effective regulatory structure is essential for green finance and development of renewable energy, which involves setting specific targets for renewable energy generation, setting up attractive feed-in tariffs or pricing structures and reducing procedures to speed up project development and funding. Implementing a feed-in tariff scheme would allow the government to set competitive and attractive feed-in tariff rates that encourage project developers to participate in renewable energy generation. The feed-in tariff scheme lowers the financial risks related to renewable energy projects by providing stable and predictable cash streams over a predetermined length of time.

The main limitation of this study is the lack of green finance data for Singapore, which necessitated the use of only 20 years and the OLS regressions for the analysis. However, it offers original results and opens new avenues for future research. Future research can investigate the impact of green finance on renewable energy growth by expanding the number of countries explored based on the data availability.

Note

1. Please see it on the Online Appendix.

References

Aguirre, M. and Ibikunle, G. (2014), "Determinants of renewable energy growth: a global sample analysis", *Energy Policy*, Vol. 69, pp. 374-384, doi: 10.1016/j.enpol.2014.02.036.

Alharbi, S.S., Al Mamun, M., Boubaker, S. and Rizvi, S.K.A. (2023), "Green finance and renewable energy: a worldwide evidence", *Energy Economics*, Vol. 118, 106499, doi: 10.1016/j.eneco.2022.106499.

Barua, S. and Aziz, S. (2022), "Making green finance work for the sustainable energy transition in emerging economies", *Energy-Growth Nexus in an Era of Globalization*, Elsevier, pp. 353-382.

Belaid, F., Elsayed, A.H. and Omri, A. (2021), "Key drivers of renewable energy deployment in the MENA region: empirical evidence using panel quantile regression", *Structural Change and Economic Dynamics*, Vol. 57, pp. 225-238, doi: 10.1016/j.strueco.2021.03.011.

Bourcet, C. (2020), "Empirical determinants of renewable energy deployment: a systematic literature review", *Energy Economics*, Vol. 85, 104563, doi: 10.1016/j.eneco.2019.104563.

Carley, S. (2009), "State renewable energy electricity policies: an empirical evaluation of effectiveness", *Energy Policy*, Vol. 37 No. 8, pp. 3071-3081.

Cheon, A. and Urpelainen, J. (2012), "Oil prices and energy technology innovation: an empirical analysis", *Global Environmental Change*, Vol. 22 No. 2, pp. 407-417, doi: 10.1016/j.gloenvcha.2011.12.001.

da Silva, P.P., Cerqueira, P.A. and Ogbe, W. (2018), "Determinants of renewable energy growth in Sub-Saharan Africa: evidence from panel ARDL", *Energy*, Vol. 156, pp. 45-54, doi: 10.1016/j.energy.2018.05.068.

Darrieux, O., Wong, L. and Kristensen, M. (2020), "Green finance in Singapore and ASEAN: opportunities and challenges", EUROCHAM Position Paper, European Chamber of Commerce, Singapore.

İçen, H. and Tatoğlu, F.Y. (2021), "The asymmetric effects of changes in price and income on renewable and non-renewable energy", *Renewable Energy*, Vol. 178, pp. 144-152, doi: 10.1016/j.renene.2021.06.012.

Jeucken, M. (2010), *Sustainable Finance and Banking: the Financial Sector and the Future of the Planet*, Earthscan Publications, London.

Kilinc-Ata, N. (2016), "The evaluation of renewable energy policies across EU countries and US states: an econometric approach", *Energy for Sustainable Development*, Vol. 31, pp. 83-90, doi: 10.1016/j.esd.2015.12.006.

Largue, P. (2021), "Singapore relies on fossil fuels more than any other country – study", available at: https://www.powerengineeringint.com/coal-fired/singapore-relies-on-fossil-fuels-more-than-any-other-country-study (accessed April 2022).

Lee, C.C., Wang, F. and Chang, Y.F. (2023), "Does green finance promote renewable energy? Evidence from China", *Resources Policy*, Vol. 82, 103439, doi: 10.1016/j.resourpol.2023.103439.

Li, S. and Shao, Q. (2021), "Exploring the determinants of renewable energy innovation considering the institutional factors: a negative binomial analysis", *Technology in Society*, Vol. 67, 101680, doi: 10.1016/j.techsoc.2021.101680.

Li, C. and Umair, M. (2023), "Does green finance development goals affects renewable energy in China", *Renewable Energy*, Vol. 203, pp. 898-905, doi: 10.1016/j.renene.2022.12.066.

Lin, B. and Omoju, O.E. (2017), "Focusing on the right targets: economic factors driving non-hydro renewable energy transition", *Renew Energy*, Vol. 113, p. 105, doi: 10.1016/j.renene.2017.05.067.

Liu, N., Liu, C., Da, B., Zhang, T. and Guan, F. (2021), "Dependence and risk spillovers between green bonds and clean energy markets", *Journal of Cleaner Production*, Vol. 279, 123595, doi: 10.1016/j.jclepro.2020.123595.

Marques, A.C. and Fuinhas, J.A. (2011), "Drivers promoting renewable energy: a dynamic panel approach", *Renewable and Sustainable Energy Reviews*, Vol. 15 No. 3, pp. 1601-1608, doi: 10.1016/j.rser.2010.11.048.

Marques, A.C. and Fuinhas, J.A. (2012), "Are public policies towards renewables successful? Evidence from European countries", *Renewable Energy*, Vol. 44, pp. 109-118, doi: 10.1016/j.renene.2012.01.007.

Marques, A.C., Fuinhas, J.A. and Manso, J.P. (2010), "Motivations driving renewable energy in European countries: a panel data approach", *Energy Policy*, Vol. 38 No. 11, pp. 6877-6885, doi: 10.1016/j.enpol.2010.07.003.

Mukhtarov, S., Mikayilov, J.I., Maharramov, S., Aliyev, J. and Suleymanov, E. (2022), "Higher oil prices, are they good or bad for renewable energy consumption: the case of Iran?", *Renewable Energy*, Vol. 186, pp. 411-419, doi: 10.1016/j.renene.2021.12.135.

Murshed, M. and Tanha, M.M. (2021), "Oil price shocks and renewable energy transition: empirical evidence from net oil-importing South Asian economies", *Energy, Ecology and Environment*, Vol. 6 No. 3, pp. 183-203, doi: 10.1007/s40974-020-00168-0.

Nguyen, K.H. and Kakinaka, M. (2019), "Renewable energy consumption, carbon emissions, and development stages: some evidence from panel cointegration analysis", *Renewable Energy*, Vol. 132, pp. 1049-1057, doi: 10.1016/j.renene.2018.08.069.

Nguyen, T.T.H., Naeem, M.A., Balli, F., Balli, H.O. and Vo, X.V. (2021), "Time-frequency comovement among green bonds, stocks, commodities, clean energy, and conventional bonds", *Finance Research Letters*, Vol. 40, 101739, doi: 10.1016/j.frl.2020.101739.

Ohler, A. and Fetters, I. (2014), "The causal relationship between renewable electricity generation and GDP growth: a study of energy sources", *Energy Economics*, Vol. 43, pp. 125-139, doi: 10.1016/j.eneco.2014.02.009.

Omri, A. and Nguyen, D.K. (2014), "On the determinants of renewable energy consumption: international evidence", *Energy*, Vol. 72, pp. 554-560, doi: 10.1016/j.energy.2014.05.081.

Park, H. and Kim, J.D. (2020), "Transition towards green banking: role of financial regulators and financial institutions", *Asian Journal of Sustainability and Social Responsibility*, Vol. 5 No. 1, pp. 1-25, doi: 10.1186/s41180-020-00034-3.

Pfeiffer, B. and Mulder, P. (2013), "Explaining the diffusion of renewable energy technology in developing countries", *Energy Economics*, Vol. 40, pp. 285-296, doi: 10.1016/j.eneco.2013.07.005.

Polzin, F. and Sanders, M. (2020), "How to finance the transition to low-carbon energy in Europe?", *Energy Policy*, Vol. 147, 111863, doi: 10.1016/j.enpol.2020.111863.

Rasoulinezhad, E. and Taghizadeh-Hesary, F. (2022), "Role of green finance in improving energy efficiency and renewable energy development", *Energy Efficiency*, Vol. 15 No. 2, p. 14, doi: 10.1007/s12053-022-10021-4.

Reboredo, J.C. (2015), "Is there dependence and systemic risk between oil and renewable energy stock prices?", *Energy Economics*, Vol. 48, pp. 32-45, doi: 10.1016/j.eneco.2014.12.009.

Saadaoui, H. (2022), "The impact of financial development on renewable energy development in the MENA region: the role of institutional and political factors", *Environmental Science and Pollution Research*, Vol. 29 No. 26, pp. 1-12, doi: 10.1007/s11356-022-18976-8.

Sahu, P.K., Solarin, S.A., Al-Mulali, U. and Ozturk, I. (2022), "Investigating the asymmetry effects of crude oil price on renewable energy consumption in the United States", *Environmental Science and Pollution Research*, Vol. 29 No. 1, pp. 817-827, doi: 10.1007/s11356-021-15577-9.

Shahbaz, M., Rizvi, S.K.A., Dong, K. and Vo, X.V. (2022), "Fiscal decentralisation as new determinant of renewable energy demand in China: the role of income inequality and urbanisation", *Renewable Energy*, Vol. 187 March, pp. 68-80.

Shang, Y., Zhu, L., Qian, F. and Xie, Y. (2023), "Role of green finance in renewable energy development in the tourism sector", *Renewable Energy*, Vol. 206, pp. 890-896, doi: 10.1016/j.renene.2023.02.124.

Tang, X. and Zhou, X. (2023), "Impact of green finance on renewable energy development: a spatiotemporal consistency perspective", *Renewable Energy*, Vol. 204, pp. 320-337, doi: 10.1016/j.renene.2023.01.012.

The Climate Bonds Initiative (2022), "Interactive data platform", available at: https://www.climatebonds.net (accessed March 2022).

Tolliver, C., Keeley, A.R. and Managi, S. (2020), "Policy targets behind green bonds for renewable energy: do climate commitments matter?", *Technological Forecasting and Social Change*, Vol. 157, 120051, doi: 10.1016/j.techfore.2020.120051.

Tugcu, C.T. and Topcu, M. (2018), "Total, renewable and non-renewable energy consumption and economic growth: revisiting the issue with an asymmetric point of view", *Energy*, Vol. 152, pp. 64-74, doi: 10.1016/j.energy.2018.03.128.

Uzar, U. (2020), "Is income inequality a driver for renewable energy consumption?", *Journal of Cleaner Production*, Vol. 255, 120287, doi: 10.1016/j.jclepro.2020.120287.

Van Ruijven, B. and Van Vuuren, D.P. (2009), "Oil and natural gas prices and greenhouse gas emission mitigation", *Energy Policy*, Vol. 37 No. 11, pp. 4797-4808, doi: 10.1016/j.enpol.2009.06.037.

Villanthenkodath, M.A. and Velan, N. (2022), "Can educational attainment promote renewable energy consumption? Evidence from heterogeneous panel models", *International Journal of Energy Sector Management*, Vol. 16 No. 6, pp. 1017-1036, doi: 10.1108/ijesm-06-2021-0015.

Zhang, B. and Wang, Y. (2021), "The effect of green finance on energy sustainable development: a case study in China", *Emerging Markets Finance and Trade*, Vol. 57 No. 12, pp. 3435-3454, doi: 10.1080/1540496x.2019.1695595.

Further reading

Batrancea, L., Rathnaswamy, M.K. and Batrancea, I. (2021), "A panel data analysis on determinants of economic growth in seven non-BCBS Countries", *Journal of the Knowledge Economy*, Vol. 13 No. 2, pp. 1-15, doi: 10.1007/s13132-021-00785-y.

International Energy Agency (IEA) (2022), "Data and publications", available at: https://webstore.iea.org/statistics-data (accessed April 2022).

World Bank (2022a), "World development indicators", available at: http://data.worldbank.org/indicator (accessed March 2022).

World Bank (2022b), "Worldwide governance indicators", available at: http://data.worldbank.org/data-catalog/worldwide-governance-indicators (accessed March 2022).

Appendix
The supplementary material for this article can be found online.

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