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Investigating the effects of renewable energy utilization towards the economic growth of Sri Lanka: A structural equation modelling approach

Chamila H. Dasanayaka[a,**], Yasith S. Perera[b,c], Chamil Abeykoon[b,*]

[a] Business School, University of Cumbria, Paternoster Row, Bowerham Rd, Lancaster, LA1 3JD, UK
[b] Northwest Composites Centre and Aerospace Research Institute, Department of Materials, Faculty of Science and Engineering, The University of Manchester, Oxford Road, M13 9PL, Manchester, UK
[c] Department of Textile and Apparel Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka

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ABSTRACT

With the rapid depletion of natural resources and increased environmental pollution, nations across the world are in a desperate need of achieving the common goal of sustainable development. Combustion of fossil fuels along with other human activities over the past few decades have resulted in increased greenhouse gas emissions leading to the climate change and the multi-scale pollution of land, air and water that the world is experiencing today. Hence, the focus has now been shifted towards the sustainable and renewable energy sources while prompting a circular economy. Being one of the island nations of South Asia, Sri Lanka has also aligned the country's economic strategies with the global trends and aims to be a 100% sustainable energy dependent nation by 2050. Consequently, there has been a gradual rise in the renewable energy establishments in the country over the past two decades. This study aims to analyze the influence of these establishments on the economic growth of the country, using a structural equation modelling approach. A conceptual model was formulated to represent the relationships between the renewable energy consumption and the key economic indicators, and also a path analysis was carried out to explore the relationships among the variables. The fit of the conceptual model to the secondary data collected related to the economic and energy indicators was established using a number of statistical fit indices such as the Chi-square, absolute fit indices and the root mean square error of approximation. The results indicate that there is no significant direct effect of the renewable energy consumption on the GDP of Sri Lanka yet, but there is an indirect positive effect through capital formation and also an indirect negative effect through trade balance. Hence, it is clear that renewable energy establishments have to be promoted through incentives/policies that lead to capital accumulation via increased renewable energy consumption. Moreover, the analysis and the findings presented in this study can be related and are applicable to many of the emerging economies across the globe.

1. Introduction

Over the recent years, there has been an increased attention towards the sustainability of the planet Earth due to the escalation of adverse consequences happening across the globe which question the well-being of this planet, such as global warming, melting of glaciers which are a few thousand years old, extinction of some species, adverse natural hazards (i.e. flooding, storms, landslides, tsunamis, etc.), increased pollution levels of air/waters/land, and then more recently the global pandemics. According to the 5th Assessment Report (Core Writing Team et al., 2014) presented by the Inter-governmental Panel on Climate Change (IPCC), increased greenhouse gas emissions due to human activities since the pre-industrial era, has been the main cause of cracking the balance of global climate and weather patterns. Deforestation, fossil fuel combustion, agriculture and other industrial activities have contributed to a significant increase in the content of carbon dioxide, methane, nitrous oxide and chlorofluorocarbons in the Earth's atmosphere ("The Causes of Climate Change," 2021). Eventually, the climate change causes global warming, droughts, heat waves, sea level rise, and poses risks for food security and human health.

The IPCC reported that the CO_2 emissions from fossil fuel combustion and industrial processes constituted up to 78% of the total greenhouse gas emission increase during the period of 1970–2010 (Edenhofer et al.,

* Corresponding author.
** Corresponding author.
E-mail addresses: chamila.dasanayaka@uni.cumbria.ac.uk (C.H. Dasanayaka), yasiths@uom.lk (Y.S. Perera), chamil.abeykoon@manchester.ac.uk (C. Abeykoon).

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Abbreviations

IPCC	Inter-governmental Panel on Climate Change
RE	Renewable Energy
TB	Trade Balance
IEA	International Energy Agency
PV	Photovoltaics
SLSEA	Sri Lanka Sustainable Energy Authority
ARDL	Autoregressive Distributed Lag
EU	European Union
CF	Capital Formation
GDP	Gross Domestic Product
SEM	Structural Equation Modelling
ASEAN	Association of Southeast Asian Nations
ADF	Asymptotic Distribution-Free
χ^2	Chi-square
GFI	Goodness of Fit Index
AGFI	Adjusted Goodness of Fit Index
SRMR	Standardized Root Mean Square Residual
NFI	Normed Fit Index
CFI	Comparative Fit Index
IFI	Incremental Fit Index
RFI	Relative Fit Index
TLI	Tucker-Lewis Index
RMSEA	Root Mean Square Error of Approximation

2014). This highlights the significance of the negative impacts caused by fossil fuel combustion on the climate change. Furthermore, the fossil fuel energy sources are predicted to deplete within the next few decades, and hence the whole world may be dragged towards an energy crisis (Höök and Tang, 2013). Therefore, the scientists across the globe are now investigating on possible new sustainable energy sources while trying to optimize the efficiency of the sustainable energy sources that are already in use (such as solar, wind and hydro), with the target of a fossil fuel free energy future.

Renewable energy (RE) refers to the energy flows that are continuously replenished by natural processes (Hersh, 2006). Unlike fossil fuel, the RE sources manage to replenish the amount depleted due to consumption, within a short time frame. These RE sources comprise wind, solar, geothermal, biomass, hydropower, ocean RE technologies (such as tidal, wave and ocean thermal), hydrogen-related energies and so forth (Moselle et al., 2010). Despite the considerable increase of establishments of RE technologies across the world during the last five decades, still they cover only about 10% of the world's total energy demand (Haseeb et al., 2019). Among these RE sources, hydropower has been the dominant RE source so far where the Three Gorges Dam in China is the world's largest hydropower station with a massive generating capacity of up to 22,500 MW ("The 10 biggest hydroelectric power plants in the world," 2013), while the Amazon river along with other water sources contribute of up to 80% of the energy generation of the South American nations. The emerging economies in Asia, Africa and Latin America utilize a significant proportion of traditional biomass-based sources such as wood chips or pellets to meet their energy needs for daily household activities (Gonzalez-Salazar et al., 2014). However, wind, solar, geothermal energy, and modern bioenergy currently produce only about 4% of the total global energy requirements (Moselle et al., 2010). Hence it is apparent that the world still largely depends on non-RE sources (i.e., oil, coal, natural gas, etc.) which adversely contribute to the global carbon footprint and the climate change. Therefore, most of the countries across the globe have already made their move to shift more and more towards RE sources and then the ultimate collective global target is to design a 100% renewables-based energy future by terminating all non-RE related sources by the year 2050 (Aqeel and Sabihuddin Butt, 2001).

The enormous capacity and the ability to be replenished make RE sources an attractive alternative to non-RE sources and obviously they have the potential to fully meet the global energy requirement although technologies are not yet developed enough to harness these energies efficiently and economically in the required capacities to cater the total global energy demand. It has been predicted that the abundance of solar energy itself is more than enough to cater for all the current total global energy needs as it is easily accessible by any nation. However, unfortunately technologies are not yet developed enough to harness the solar energy in such capacities. Moreover, around two-third of the earth is covered by water sources, which presents numerous opportunities to harvest RE via ocean waves, tidal range, salinity levels/gradients, ocean thermal energy, and so forth. These sources never run out as they can replenish, and they are harmless to the environment as well (Bélaïd and Youssef, 2017). However, establishing RE technologies should still be quite challenging compared to most of the non-RE establishments. Technological limitations, large investment costs, and the required large-scale infrastructure to harness sufficiently large energy capacities have hindered the rapid growth of RE technologies not only in developing nations but also in some of the developed nations as well.

Nonetheless, many previous researches and reports (Chien and Hu, 2007; Fang, 2011) have emphasized that the promotion of RE utilization should lead to the development of environmental, economic and social aspects of a nation. By being able to meet the entire energy requirement of the country through the promotion of RE technologies, economies across the world can save import expenses which would otherwise be spent on non-RE sources (which can be a significant portion of the annual budget of a country), while improving the trade balance (TB). Expansions of RE establishments should create new employment and investment opportunities and then this should directly promote the social and economic development of any economy. Hence, these benefits have driven most of the economies to formulate strategies to attain sustainable development via the promotion of RE establishments. Following these global trends and needs, Sri Lanka aims to discontinue the utilization of non-RE sources by the year 2050, and then to be fully dependent on sustainable energy sources to meet the nation's energy needs.

This study aims to analyze Sri Lanka's RE potential while identifying the triggers and barriers for the development of RE establishments. Also, this should help Sri Lanka to oversee the effectiveness of its 2050 plan of being a 100% green energy nation by 2050. For this purpose, it is essential to understand how RE utilization has contributed to the socio-economic growth/development of the country so far, and also to study on other potential capabilities of expanding RE establishments while identifying the related triggers and barriers in terms of both social and economic aspects. The findings of this study should be invaluable for the country to make decisions/directions on implementing its 2050 green energy plan while allowing policy makers to introduce new policies and also to align the existing energy and environment related policies to realize the ambitious target of being 100% carbon neutral. On the other hand, the analysis and findings of this study should be invaluable for any other country that encourages the use of RE sources to achieve the collective global plan of being carbon neutral at least by 2050.

1.1. *The current renewable energy profile of Sri Lanka*

Sri Lanka is a South Asian island nation located in the Indian Ocean. It has witnessed a rapid economic growth since the end of the thirty-year long civil war that came to an end in 2009. The country's traditional agrarian economy has now been overtaken by an industrialised urban economic culture which has contributed to a significant increase of the nation's energy demand/needs over the past few decades (Hasan, 2019). The Ceylon Electricity Board reports provide evidence to this gradual boost of the energy demand in Sri Lanka (Samarasekara et al., 2019), where the demand has been rising approximately by 5% per year, over the past few years.

Sri Lanka has a reasonably long history of harnessing RE dating back to the latter part of the 19th century, particularly when some tea plantation companies installed small scale hydropower establishments for fulfilling the electricity needs of their tea processing factories, during the British colonial era. Consequently, the power generation capacity of the country gradually developed mainly based on water sources where the country's total energy supply was based on hydro power by the early 1990s (Silva and Silva, 2016). This domination is further evident by the electricity generation data by different energy sources in Sri Lanka, reported by the International Energy Agency (IEA), for the period 1990–2018 (see Fig. 1(a)) ("Data and Statistics," 2021a). However, the demand for energy in Sri Lanka has grown significantly over the past two decades and the power generated from hydropower plants alone was not sufficient to meet the rising demand. Consequently, the share of electricity generated from oil and coal-based power plants increased and as can be seen from Fig. 1(b) and (c), and Fig. 2, these non-RE sources gradually became the dominant energy sources in Sri Lanka.

As evident from Fig. 1(d) and (e), the contribution from non-conventional RE sources such as solar photovoltaics (PV) and wind towards electricity generation has been very small during the 1990s and the early 2000s. But since the establishment of the Sri Lanka Sustainable

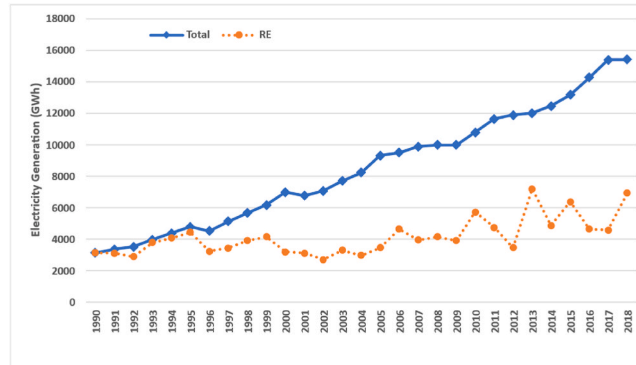


Fig. 2. Electricity generation in Sri Lanka since 1990.

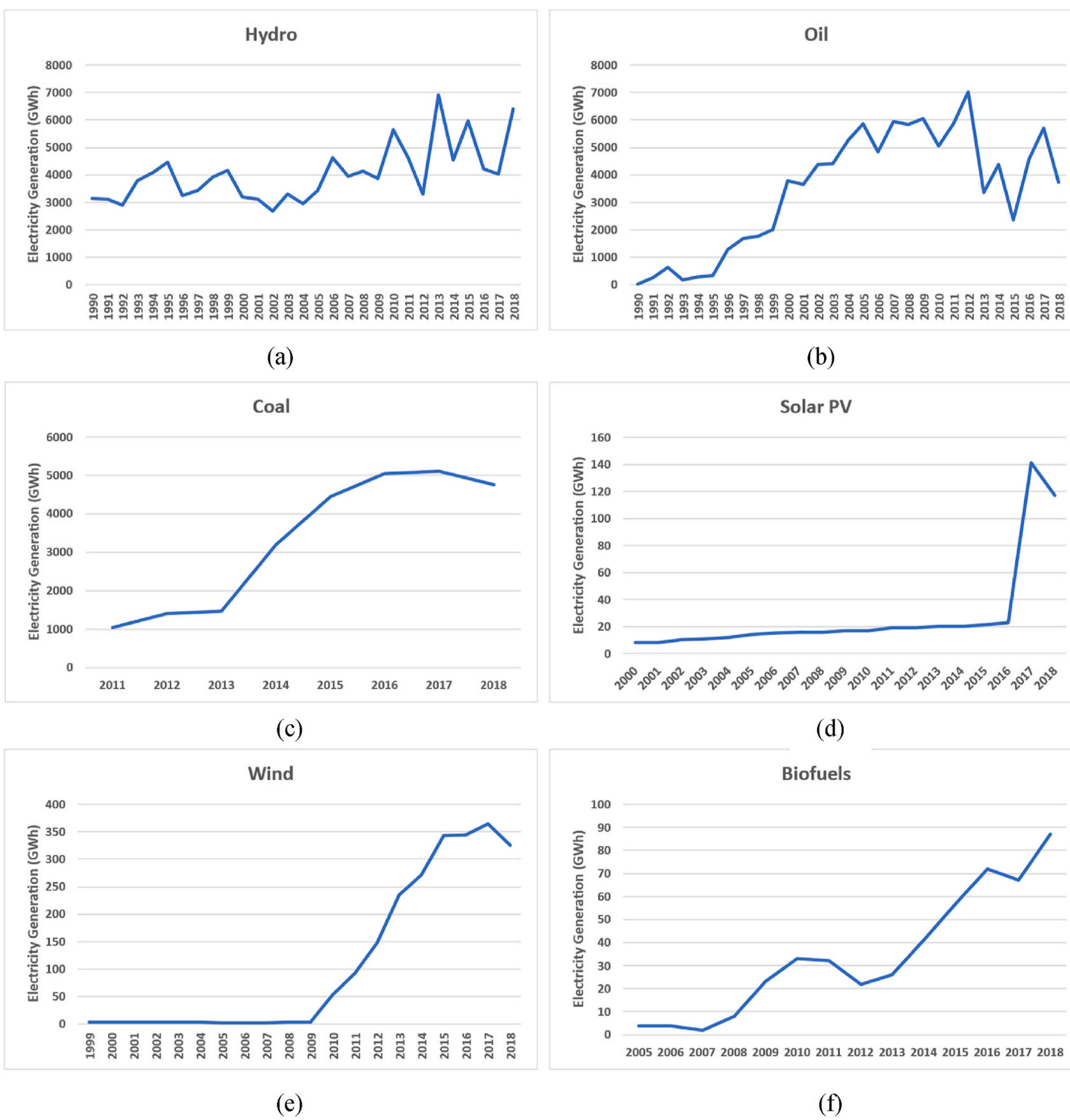


Fig. 1. Electricity generation by source in Sri Lanka since 1990 (a) Hydro (b) Oil (c) Coal (d) Solar PV (e) Wind (f) Biofuels.

Energy Authority (SLSEA) ("Inception," 2021) in 2007, a significant rise in these RE sectors can be seen. The 'Soorya Bala Sangramaya' programme (which translates to 'Battle for solar energy') launched by the SLSEA in 2016 has boosted the contribution of solar PV power generation (see Fig. 1(d)) to the national grid (Annual Report 2018, 2019). In Sri Lanka, biofuels have mostly been used in household activities such as cooking and only a small proportion has been consumed in generating electricity (see Fig. 1(f)).

However, as of 2019 (see Fig. 3), still more than half (approximately 65%) of the electricity demand of the nation was met through non-RE sources (coal: 34% and oil: 31%) whereas the remaining 35% was generated using renewables (hydro: 30% and other renewables: 5%) (Statistical Digest 2019; 2020). According to these energy related figures, it is clear that at present, Sri Lanka is greatly dependent upon non-renewable conventional energy sources which could cause serious long-term consequences in both ecological and economic terms, leading to a future crisis.

Since the 1990s, the country has been forced to search for alternative energy sources to meet the growing energy needs of the nation with the escalation of the household energy demand and gradual industrialisation of the economy (SRI LANKA ENERGY SECTOR DEVELOPMENT PLAN FOR A KNOWLEDGE-BASED ECONOMY 2015–2025, 2015). As a step towards this, the Sri Lankan government developed a number of new energy establishments to expand the country's energy generation network with both RE and non-RE sources, however the priority was given mainly to fossil fuels (i.e., coal and diesel) based power plants. With the gradual increase of non-RE establishments, emissions of CO_2 in Sri Lanka along with other greenhouse gases have been increasing over the years, where this has marked a massive 250% increase of CO_2 emissions only for the last two decades (see Fig. 4) ("World Development Indicators," 2021).

As a result, the need for utilizing more and more RE sources, while terminating the use of non-RE sources has drawn the attention of the authorities. However, as a developing/emerging economy, Sri Lanka has been observing challenges when establishing RE generation related infrastructure due to their high level of capital/initial costs. As was mentioned by the Sri Lankan energy authority, the current major challenges to the country's energy sector are: high cost of energy/electricity; increasing energy demand across the country for both industrial and domestic use; the transport sector's 100% dependency on the imported fossil fuel oil; the lack of local capacities for energy sector related research and technological improvements; traditional institutional structure not geared to tackle emerging challenges within the energy sector; the necessity of large scale investments to develop energy-related infrastructure; unsustainable energy usage patterns; and the lack of technologies and motivation to minimize energy losses and wastage (SRI LANKA ENERGY SECTOR DEVELOPMENT PLAN FOR A KNOWLEDGE-BASED ECONOMY 2015–2025, 2015). Regardless of these challenges, the country has a plan in place to expand the energy generation capacities to be a self-sufficient nation in terms of the nation's energy needs by 2030 and then eventually to be a fully carbon neutral nation by 2050 (Singh et al., 2017), and the related details are illustrated in Fig. 5.

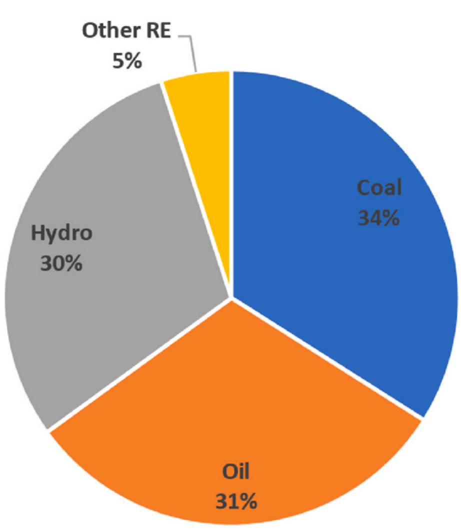


Fig. 3. Electricity generation by source in 2019 in Sri Lanka.

With the on-going technological advancements and global incentives/motivation towards the green energies, it can be anticipated that the installation cost of RE establishments and infrastructure would progressively decrease over the coming years (Withanaarachchi et al., 2014). In the mission of being fully carbon neutral, one of the key future targets of Sri Lanka is to expand the wind and solar energy generation capacities by a significant level. Being a small country which is just 400 miles north of the equator with no significant seasonal changes in the climate, the Sri Lankan land enjoys plenty of constant level of sunlight all over the year, and the country's typical irradiation map is presented in Fig. 6(a) ("Global Solar Atlas," 2021). Hence, it is clear that Sri Lanka has a great potential in harnessing energy from solar and hydrogen-based energy sources. A recent report by Perera (2016) claimed that Sri Lanka has the potential of harnessing 32% of the country's total annual energy needs (i.e. of around 10,500 GW) through solar power, although the country has developed solar establishments to recover only 0.01% of that potential so far.

A map illustrating the wind power potential across Sri Lanka is presented in Fig. 6(b). The prediction made relating to the wind energy potential of the country shows that there is an area of around 4800 km^2 (i.e., 4100 km^2 across the land and another 700 km^2 around lagoons) with good levels of wind capacities in and around the country. If a generation potential of 5 MW per km^2 is assumed (according to the energy conservation fundamentals/assumptions), the overall wind capacity potential of the country could support a total installed capacity of 24,000 MW. Thanks to prospective future developments in wind energy related technologies, it has been estimated that Sri Lanka would be able to harness wind energy across an area of more than 11,000 km^2 across both land and lagoon areas allowing the country to harness a significant portion of its energy needs via wind (Maduranga and Lewangamage, 2018).

In addition to the abundance of solar and wind potential, being an island nation located in the Indian Ocean, Sri Lanka has an amazing coastline around the country (which is 1340 km in length) (Arachchige et al., 2017) together with a large ocean territory (i.e. the Sri Lankan Exclusive Economic Zone which is approximately 6.7 times of the country's land area as shown in Fig. 7 (Arachchige et al., 2017) which could be well-suited for locating off-shore wind and ocean-based RE establishments.

At present, hydro, wind and solar are the dominant RE sources in Sri Lanka covering approximately 30%, 2% and 1%, of the total energy generation of the country respectively ("Data and Statistics," 2021a). Although there are several other possible RE sources, their potentials have not yet been identified, while some of them are still in initial stages of evaluation. Up to 10 geographical locations have been recognized, which may have some potential for geothermal energy, but they might not support for large scale energy generation (Kulasekara and Seynulabdeen, 2019). Also, ocean based (i.e., wave, tidal and salinity gradient) RE potential is abundant to Sri Lanka being an island nation (Karunarathne and Walpalage, 2013; Lokuliyana et al., 2020); however, establishment of these involves huge initial capital costs and hence may not be realistic yet. Moreover, latent heat energy storage based RE (e.g., use of phase change materials to generate electricity) should also be an option to Sri Lanka but no or little attention has been made on this area.

As was mentioned, Sri Lanka has planned to discontinue all the conventional non-RE energy sources by 2050 and this should save around US$18–19 billion for the country's economy that would

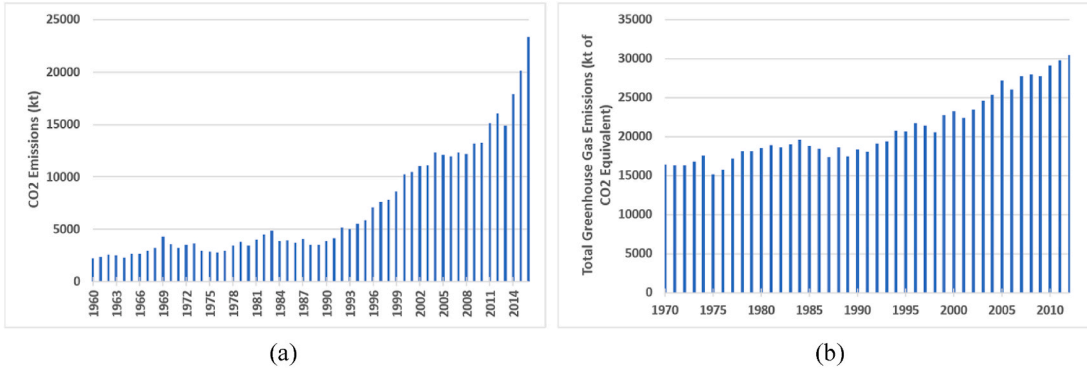


Fig. 4. Greenhouse gas emissions in Sri Lanka (a) CO_2 emissions (b) Total greenhouse gas emissions.

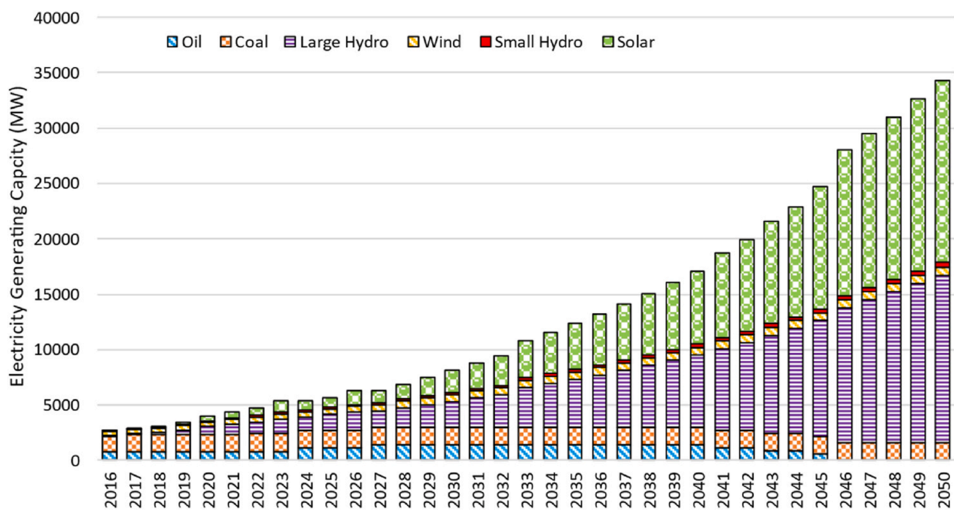


Fig. 5. Expected electricity generation mix of Sri Lanka by 2050.

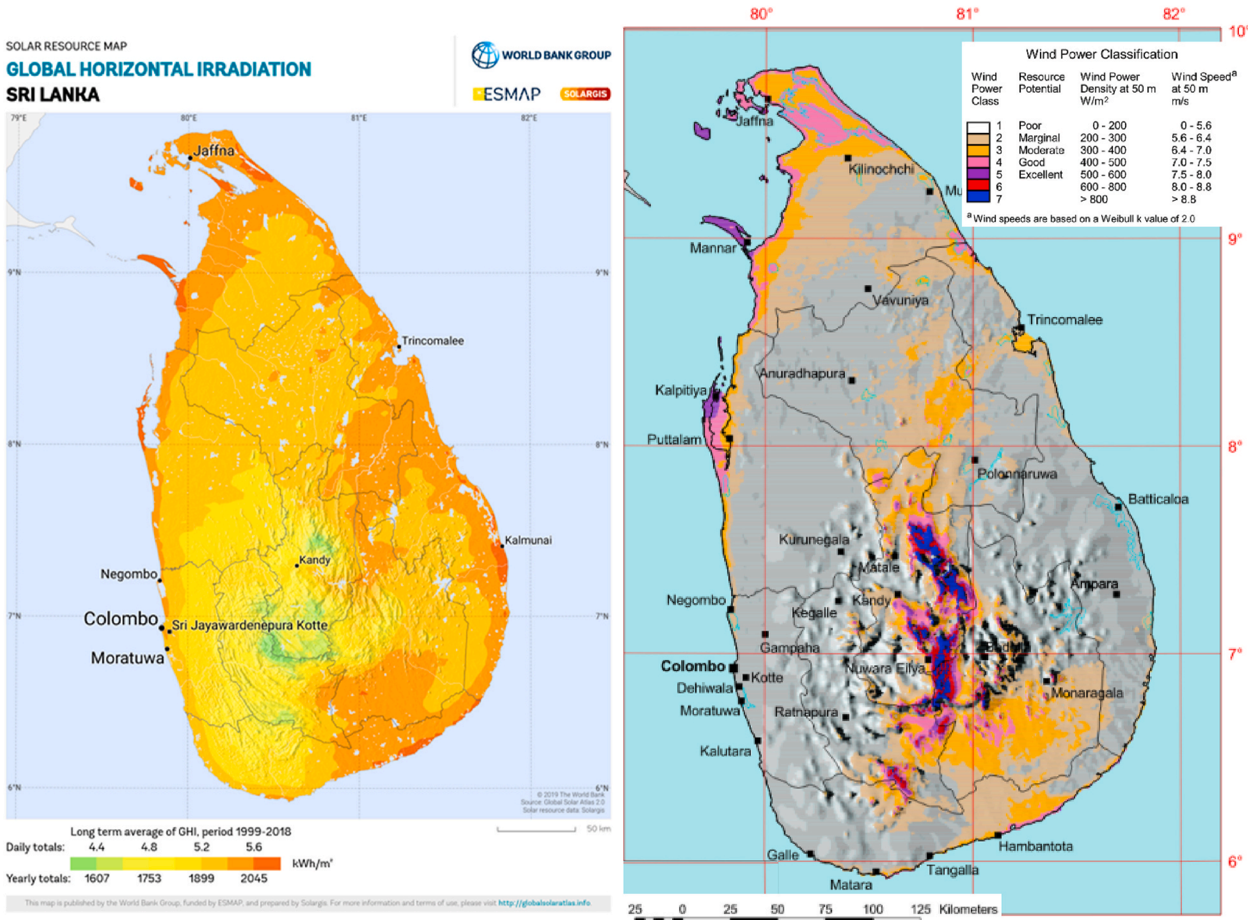
otherwise be spent on fuel oil and coal. In terms of import expenses, this should be a huge saving to the country's annual budget and these funds should be spent particularly for securing a sustainable future for the country.

1.2. Existing literature on investigating the effects of renewable energy utilization on emerging/developing economies

During the past couple of decades, RE generation capacities and related technologies around the world have remarkably advanced, where wind and solar energy generation establishments have an overall annual growth rate of 27%, and 42%, respectively (Scarlat et al., 2015). The development of RE technologies have been fuelled by their potential socio-economic paybacks such as the possible control of the risk of global warming, clean water/air, new employment/investment opportunities, improved quality of life, and the support to reduce (or discontinue) non-RE generation associated imports, etc. (Agterbosch et al., 2009; Economou, 2010). However, the promotion of RE technologies in emerging economies may present certain challenges (Cansino et al., 2011; Dogan and Seker, 2016). A few examples for such challenges are the possible high capital and maintenance costs, administrative challenges, issues in obtaining approvals (such as long waiting times), poor coordination among operators, and the lack of communication among responsible channels/authorities. In order to tackle these challenges, promotional strategies such as allocating adequate funds for RE related research, introducing tax/monetary incentives, establishing green certificates (as an incentive for using RE), and imposing stricter rules/regulations on the generation and consumption of non-RE associated energy sources as well as their harmful emission levels can be introduced. Additionally, the motivation/acceptance of the society towards the use of RE should be affected by some factors such as the high cost of RE supply compared to non-RE; the lack of awareness on modern RE facilities and related benefits; bureaucratic concerns/problems; inefficiencies and weaknesses of national legal frameworks; the possible complexities in licensing policies/procedures; planning difficulties/concerns; lack of impartiality; and mistrust towards some investors (Guo et al., 2014; Oikonomou et al., 2009).

Over the recent years, with the escalation of alarming concerns such as the climate change, an increased attention/motivation has been paid towards the RE sources as a potential option or way forward in mitigating such adverse issues while satisfying the energy demands towards the economic development/growth of nations. Accordingly, modelling the possible relationship/s between the economic growth and RE utilization in both emerging and developed economies has been reported in the recent literature. The majority of these previous studies generally investigated the effects of strategies and policies for energy management on the economic growth of a certain country.

Destek and Sinha (2020) analyzed the causal relationships between the economic growth and energy consumption, involving four types of hypotheses. The growth related hypothesis assumes a unidirectional causality from energy usage to economic growth, whereas the conservation hypothesis assumes a unidirectional causality in the opposite direction. The feedback hypothesis indicates a bidirectional causality between the two indicators, while the neutrality hypothesis assumes that the two indicators are independent of each other. Studies that investigated each of these hypotheses for investigating the possible



(a) (b)

Fig. 6. (a) The global horizontal irradiation map of Sri Lanka ("Global Solar Atlas," 2021) (b) The wind resource map of Sri Lanka (Heimiller, 2006).

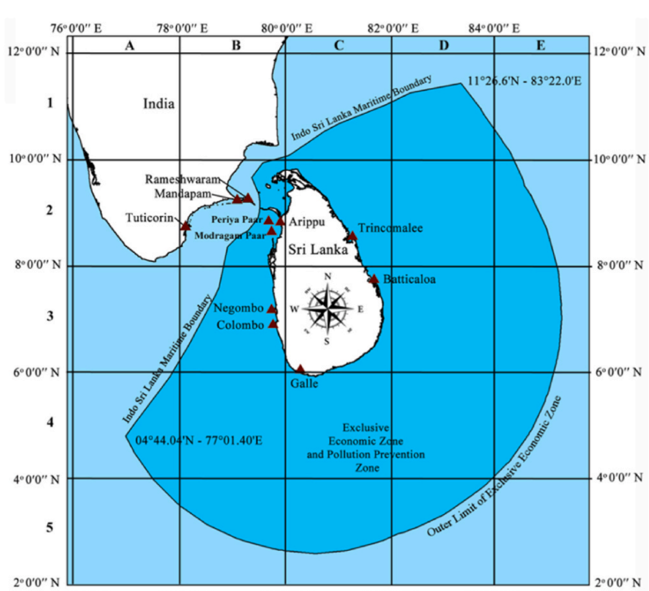


Fig. 7. Map of the Sri Lankan exclusive economic zone (Arachchige et al., 2017).

relationship/s between RE consumption and economic growth of different countries and regions can be found in the literature, but no general agreement can be observed among these findings. The outcomes of some of these studies are discussed below.

Hossain and Saeki (2012) selected five different panels based on the World Bank's income groupings for 76 countries for a period of 48 years (from 1960 to 2008) and studied the dynamic causal relationship between the electricity/energy consumption and economic growth of those panels. For the high income, upper middle-income and global panels, the authors reported the existence of a bidirectional causality between the electricity consumption and economic growth. For the lower middle-income panels, they observed a unidirectional short-run causality. Moreover, they claimed that no causal relationship was observed between these two indicators for low-income panels. Furthermore, a recent study by Doytch and Narayan (2021) examined the impact of non-RE and RE consumption on the economic growth, differentiating between manufacturing and services growth based on a dynamic panel of countries. Accordingly, they found that the RE consumption enhances the growth in high-growth sectors in high-income economies, (i.e. the services sector) and the manufacturing sector in middle-income economies. In another study, Ozcan and Ozturk (2019) researched the links between RE consumption and economic growth of 17 emerging economies for a period of 26 years (1990–2016), employing a bootstrap panel causality test. As per the results, the neutrality hypothesis could be observed for all of the countries considered except for Poland, which confirmed the growth hypothesis. The authors claimed that, due to the nonexistence of causality from RE demand/consumption to economic growth, energy mitigating strategies/policies do not have any considerable adverse impacts on the growth rates of the economy of these emerging economies, except for Poland.

Akadiri et al. (2019) verified a positive and significant long-term relationship among the RE consumption, environmental sustainability and economic growth, using an autoregressive distributed lag (ARDL) methodology. The ARDL method was applied to a set of panel data for the period 1995–2015, pertaining to 28 European Union (EU) countries. The real gross fixed capital formation (CF), carbon emissions and other environmental factors were recognized as key deterministic factors for the long-term economic growth of the EU countries. Moreover, the authors established a long-term bidirectional causal relationship among the RE consumption, economic growth and other growth determinants, by employing the Granger non-causality in heterogeneous panel reported by Dumitrescu and Hurlin (2012). Based on these findings, the authors claimed that the use of RE sources in the EU countries would reliably mitigate the environmental pollution. In another study, Koçak and Şarkgüneşi (2017) analyzed nine Black Sea and Balkan countries using the heterogeneous panel causality estimation techniques reported by Dumitrescu and Hurlin (2012) and the results suggested the existence of a significant relationship between the RE consumption and the long-term economic growth of these countries.

Bélaïd and Youssef (2017) studied the dynamic causal relationships between CO_2 emissions, renewable and non-renewable electricity consumption, and the economic growth of Algeria using an ARDL co-integration approach, for the period 1980–2012. The results suggested that the long-term effects of non-renewable electricity consumption associated with the economic growth have a negative impact on the quality of the environment. In contrast, the environmental impact of RE consumption was found to be positive. Moreover, a unidirectional causality relationship was observed from the Gross Domestic Product (GDP) to non-RE consumption, during the short run. Salim and Rafiq (2012) showed that in Brazil, China, India and Indonesia, the RE consumption is significantly determined by the income and the pollutant emissions in the long-term, while in Philippines and Turkey it was determined by the income. Moreover, the authors reported a bidirectional causality between RE and income, and between RE and pollutant emissions, in the short-term.

Cho et al. (2015) claimed that a unidirectional causality exists from economic growth to RE consumption in developed countries, while a bidirectional causality can be observed between the two indicators in under-developed countries. It indicates that increased RE consumption will contribute to an economic growth only in under-developed countries. Hence, the authors proposed the implementation of selection and concentration strategies for the developed countries, and intensive promotion policies for the under-developed countries. Amri (2017) established a unidirectional causality from RE consumption to economic growth in Algeria, in the long run. However, the results indicated that the RE consumption does not have a significant effect on enhancing the economic growth. Bhattacharya et al. (2016) investigated the impact of RE consumption on the economic growth of 38 top RE consuming countries, using heterogeneous panel techniques. The results revealed that the RE consumption has a significant positive influence on the economic growth of 57% of the countries considered. A negative relationship was observed for four countries including India, Ukraine, the US and Israel, while no significant relationship was identified for eleven countries.

Fan and Hao (2020) employed the unit root test, co-integration test, vector error-correction model, impulse response function analysis, and Granger causality test to analyze the relationships between the RE consumption, foreign direct investments and the GDP of 31 provinces of China for the period 2000–2015. As per the results, long-term stable equilibrium relationships were established between the GDP per capita, foreign direct investment per capita, and the RE consumption per capita. No significant causality was observed between the foreign direct investments and the RE consumption in the short-term. However, the authors claimed that in the long run, a modest slowdown in the GDP growth and the foreign direct investment will lead to a significant boost in the RE usage in China. Furthermore, recent studies (Ogbonnaya et al., 2019a; 2019b; 2019c) analyzed the RE potential of Nigeria, which is an emerging as well as the largest economy of the African continent, for extending solar and hydrogen based RE sources.

Considering the strong relationship between RE utilization and sustainable economic growth, research and development work related to these areas are currently evolving at a promising rate. Most of the reported studies involved mixed methodologies with both qualitative and quantitative approaches. However, quantitative approaches are prevailing as the main objective of most of these previous studies was to investigate the possible short-term and long-term causal relationship/s between the RE utilization and the sustainable economic development and/or the contribution of the RE utilization towards the economic growth. Moreover, regression analyses (such as distributed-lag models) have also been utilized to analyze time series data. Most of these previous studies have reported a bidirectional causality between the non-RE utilization and GDP in the long run, and a unidirectional relationship in the short run.

To broaden the knowledge on links between the economic growth and RE utilization relating to emerging economies, this study aims to evaluate the current position of Sri Lanka's RE profile (an emerging/developing economy in the South Asian region) which is targeting to go Net Zero by 2050. On the other hand, apart from the economic development and the financial strength of a particular country, its RE potential can strongly depend on its geographical location and features. While solar energy might be the dominant RE source of one country, it might be the hydro or wind energy for another. Hence, this is also something important to be explored along with the economic power of a nation.

1.3. Existing literature on applications of structural equation modelling to analyze renewable energy related aspects

In order to examine how the RE utilization contributes towards improving the GDP of Sri Lanka, a structural equation modelling (SEM) approach was used in this study. SEM is a statistical methodology which graphically illustrates a series of structural equations that represent a hypothesized model. This hypothesized model is then statistically tested to determine its degree of consistency with the data (Byrne, 2016). Most of the previous works on using SEM approaches on RE technologies have been focused on assessing the influence of attitude and awareness related factors on the use of RE sources.

Using an SEM approach, Khan et al. (2020) established that, in the Association of Southeast Asian Nations (ASEAN) member countries, the use of RE in logistics leads to improved environmental performance. This in turn reduces the public health expenditure due to less pollution, while creating better export opportunities to environmentally friendly countries. Ultimately, they contribute to a sustainable economic growth. Demirbag and Yilmaz (2020) employed SEM in identifying the relationships among the knowledge levels, risk perceptions and the intention of pre-service teachers to use RE sources. Pre-service teachers were chosen on the basis that they play an important role during their careers in raising public awareness regarding RE sources. In a similar study, Genç and Akilli (2019) investigated the correlation between RE knowledge and sub-dimensions of attitude towards RE, of pre-service teachers, using SEM. Based on the results, the authors established positive relationships between RE knowledge and attitudes of pre-service teachers towards RE. Djurisic et al. (2020) analyzed the effects of knowledge and perception of consumers on the behavior towards RE sources in Montenegro, using SEM. Based on the findings, the authors proposed carrying out promotional campaigns for improving the awareness of consumers about RE sources, in order to drive consumers to spend more on them. Emmann et al. (2013) employed SEM in identifying the factors that influence the farmers' acceptance of biogas innovation in Germany. The results suggested a strong positive impact on the acceptance by 'personal innovativeness', while it was hindered by 'individual attitude towards biogas' and 'externalities'. In another research, SeetharamanMoorthy et al. (2019) studied the social, economic, technological and regulatory barriers that hinder the growth of RE establishments. Based on the results from an SEM approach, the authors claimed that social, technological and regulatory barriers showed a direct influence, while the economic barriers have had an indirect impact on the deployment of RE establishments.

Chien and Hu (2008) analyzed the data collected in 2003 relating to 116 countries to explore the effects of RE on the GDP, based on an SEM approach. Contrary to the expectation of RE having an import substitution effect, the results indicated that there was no significant impact on TB by RE. Furthermore, it was established that there was no significant direct influence by the use of RE on the GDP, but a significant indirect influence was observed through CF. However, the 116 nations that were analyzed comprised of both developed and under-developed economies. Hence, if analyzed individually, the RE establishments in developed countries may affect the GDP differently to those in under-developed countries. Consequently, the RE policies also have to be aligned with those differences. Therefore, in the present study, the focus was limited only to the Sri Lankan economy and the commercially available IBM SPSS AMOS software was employed in carrying out a path analysis using SEM.

2. Methodology

2.1. Theoretical background

The first step of an SEM approach is to formulate a hypothesized theoretical model relating to the study. For example, in a previous study Doytch and Narayan (2021) developed an empirical model based on an endogenous growth framework, to investigate the effect of both renewable and non-renewable energy on the economic growth. To develop the theoretical model of the present study, only the effect of RE consumption on the economic growth was considered, as the non-RE consumption was not the focus of this study. The theoretical background of this study is as follows.

The GDP of a country can be estimated employing either the 'expenditure approach' or the 'value-added approach'. Chien and Hu (2008) recommended using the 'expenditure approach' for evaluating the effect of renewables on the GDP, as the input substitution effect of renewables might have a direct impact on TB. According to the 'expenditure approach' the GDP of a country can be estimated as given in Eq. (1).

$$GDP = C + I + G + X - M \quad (1)$$

C is the final household consumption expenditure, I is the gross domestic capital formation, G is the general government final consumption expenditure, X is the exports and M is the imports. The difference between the exports and imports (X-M) is termed TB.

Renewables were incorporated into the model, considering two ways in which the use of RE could lead to an increase in the GDP of a country, as suggested by Domac et al. (2005). Firstly, RE establishments create business expansions and new employment opportunities, that lead to an improved GDP. Secondly, the increased use of RE could lead to an import substitution of energy, which in turn can have direct and indirect effects on the TB and the GDP of a country.

The hypothesized model for determining the effect of renewables on the GDP of Sri Lanka was formulated based on the theory discussed above. The initial SEM model based on this hypothesized model created using the IBM SPSS AMOS software is illustrated in Fig. 8. The unobserved variables e1-e5 in Fig. 8 represent the residuals. The equations that govern the hypothesized model can be found in the work by Chien and Hu (2008). It should be noted that the variable G in Equation (1) was eliminated in order to avoid multicollinearity among the variables (Chien and Hu, 2008).

This study used sample data reported between 1990 and 2018 over a period of 29 years, related to the above discussed variables of the Sri Lankan Economy. Data for GDP, household consumption (HC), CF, TB, energy imports (EI) and RE consumption were collected from the World Development Indicators database of the World Bank ("World Development Indicators," 2021) and the IEA database ("Data and Statistics," 2021b).

2.2. Data pre-processing

Data pre-processing is an important aspect of SEM as missing data, outliers and the existence of multicollinearity among the variables could

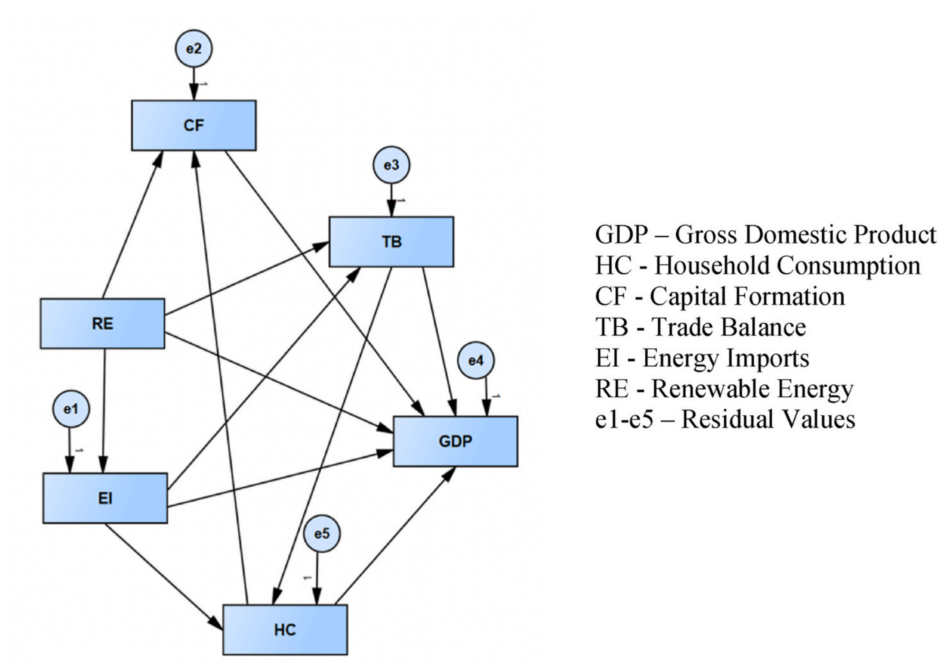


Fig. 8. The initial SEM model based on the hypothesized model.

lead to inaccurate SEM results and consequently researchers may reject an accurate model. The sample data collected belong to the period 1990–2018, hence the dataset consists of 29 data points (for 29 years). Despite the availability of data for the economic indicators since 1975, data related to the RE consumption are only available from 1990 onwards. Fig. 9 illustrates the trends of each indicator over the considered period, while Table 1 summarizes the descriptive statistics of the dataset. In Fig. 9, the variation of TB was plotted as net imports, since the imports exceeded the exports, in all the years. This is also evident from the negative value for the mean of the TB in Table 1. All the variables were rescaled before feeding the data to the AMOS software, in order to ensure that all the data were on a similar scale.

2.2.1. Outlier assessment

Detection and removal of univariate and multivariate outliers is a crucial aspect of data pre-processing as outliers are sensitive to regression analysis and could lead to inaccurate SEM results (Dhakal, 2017). Fig. 10(a) illustrates the boxplots of the normalized data used for univariate outlier detection. It is evident that there are no univariate outliers, as none of the data points lie outside the whiskers of the boxplots. Fig. 10(b) illustrates a multivariate outlier assessment performed using a scatter plot of Cook's distance (Cook, 1977). A data point can be considered to be an outlier, if the Cook's distance is greater than 1 (Dhakal, 2017). The results indicate that all the data points lie within a Cook's distance of 1. Hence it is clear from Fig. 10(b), that there are no

Table 1
Descriptive statistics of the dataset.

Indicator	Mean	Standard Deviation
GDP/10^9 (Current US$)	36.5940	28.6044
Household Consumption/10^9 (Current US$)	25.1495	19.2638
Trade Balance/10^9 (Current US$)	−3.2137	2.5530
Capital Formation/10^9 (Current US$)	10.8835	9.5901
Energy Imports/10^6 (tonnes of oil equivalent)	3.8056	1.5990
Renewable Energy Consumption/10^6 (tonnes of oil equivalent)	4.7230	0.4927

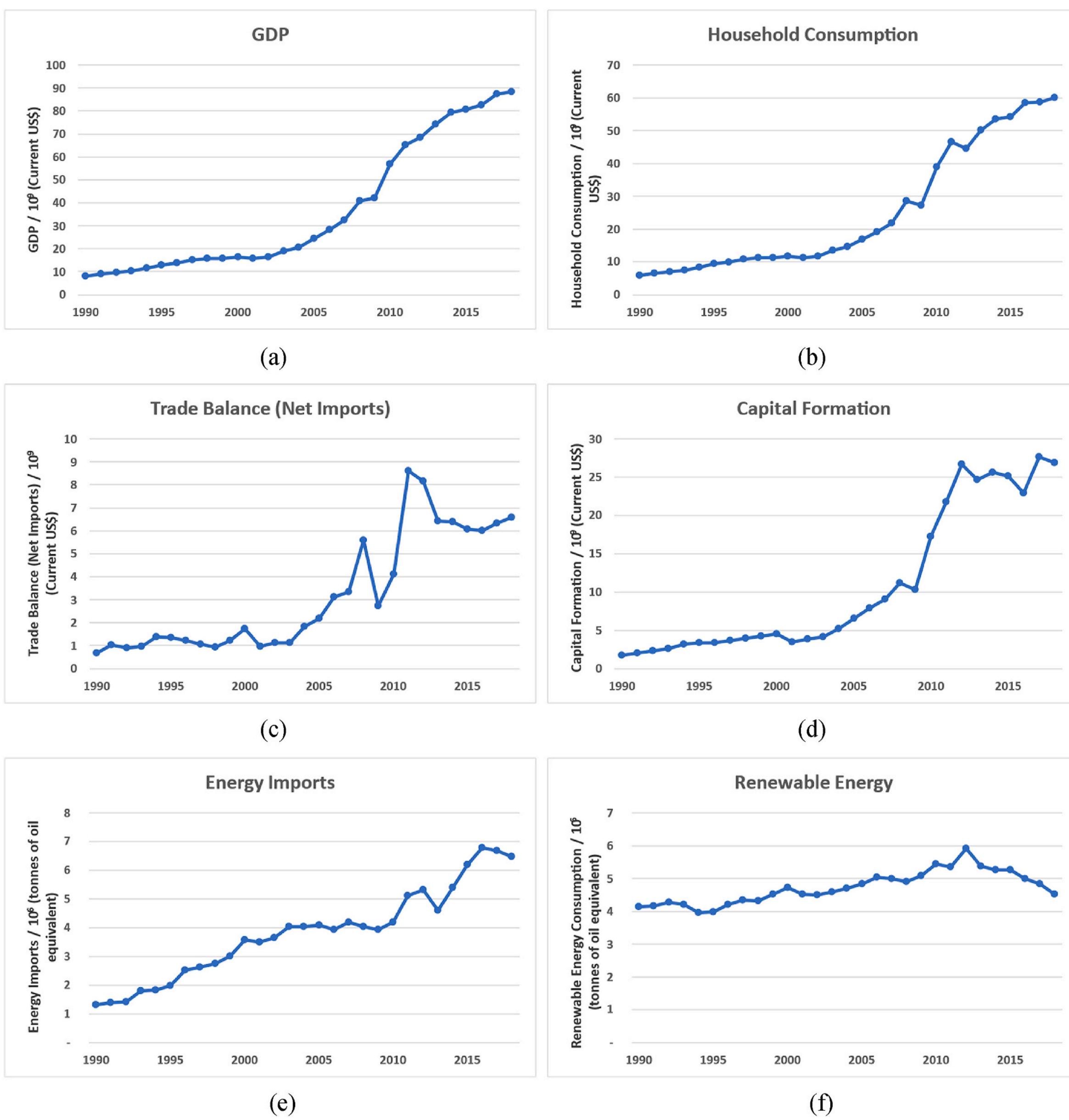


Fig. 9. Variation of economic and energy indicators over the period of 1990–2018 (a) GDP (b) Household Consumption (c) Trade Balance (d) Capital Formation (e) Energy Imports (f) Renewable Energy.

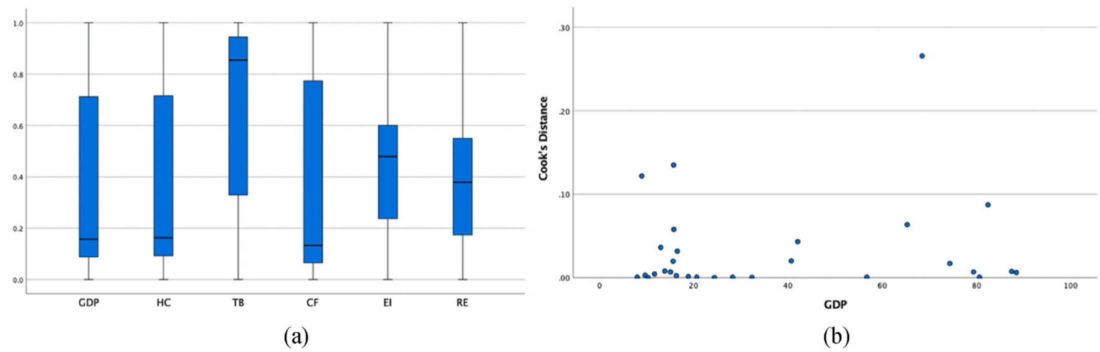


Fig. 10. Outlier Assessment: (a) Boxplots for univariate outlier detection (b) Scatter plot of Cook's Distance for multivariate outlier detection.

multivariate outliers that could adversely affect the SEM results.

2.2.2. Normality test

Since, the SEM is performed using the maximum likelihood estimation (Byrne, 2016), it is necessary to establish the normality of the dataset used. The boxplots in Fig. 10(a) shows that all the variables exhibit a certain degree of skewness. Hence, a normality test was performed to assess whether the degree of normality of the dataset is sufficient for performing the SEM. The results of the normality test are shown in Table 2.

According to West et al. (1995), a dataset is considered to show a significant deviation from normality if the magnitude of the kurtosis value is greater than 7. Based on the results shown in Table 2, the variables do not exhibit a significant departure from univariate normality, even though a certain degree of negative kurtosis exists in each variable. However, there is a high multivariate kurtosis value of 19.115, which suggests that the dataset is significantly multivariate non-normal. Multivariate kurtosis creates serious problems in SEM analysis and the results obtained using the maximum likelihood estimation would not be reliable (Byrne, 2016). An alternative would be to use the Asymptotic Distribution-Free (ADF) estimation (Browne, 1984) instead of the maximum likelihood estimation, but it is believed that this method is not suitable for small datasets (West et al., 1995). Hence, bootstrapping techniques (Kline, 2016) were used in evaluating the model.

3. Results and discussion

The results of the SEM models are summarized in Table 3. The initial SEM model was termed Model 1, while Models 2 and 3 refer to the subsequent models that were obtained after modifying the initial SEM model (i.e. Model 1), in order to improve the model fit. The calculated unstandardized regression weights of the models are shown in Table 4.

The initial SEM model (i.e. Model 1) with the calculated standardized regression weights is illustrated in Fig. 11. The model has a Chi-square (χ^2) value of 12.798 with 3 degrees of freedom (see Table 3). A probability level of 0.005 indicates that the model does not have a good fit to the data. However, the literature suggests that the χ^2 estimate should be considered along with other goodness of fit indices, as the χ^2 estimate may be affected by several factors such as the sample size (Byrne, 2016).

Table 2
Normality test results.

Variable	Skewness	Kurtosis
GDP	0.755	−1.116
HC	0.769	−1.091
TB	−0.769	−0.926
CF	0.796	−1.153
EI	0.216	−0.651
RE	0.420	−0.391
Multivariate		19.115

Table 3
The results provided by the SEM models.

Fit Index		Model 1	Model 2	Model 3
Chi-square	Chi-square	12.798	3.225	3.260
	Degrees of freedom	3	2	3
	Probability level	0.005	0.199	0.353
SRMR		0.021	0.018	0.018
Absolute Indices of Fit	GFI	0.883	0.966	0.965
	AGFI	0.184	0.639	0.757
Baseline Comparisons	NFI	0.972	0.993	0.993
	RFI	0.858	0.946	0.964
	IFI	0.978	0.997	0.999
	TLI	0.887	0.979	0.997
	CFI	0.977	0.997	0.999
RMSEA	RMSEA	0.342	0.148	0.056
	Closeness of Fit	0.007	0.222	0.385
	LO 90	0.164	0.000	0.000
	HI 90	0.544	0.432	0.328

The goodness of fit index (GFI) and the adjusted goodness of fit index (AGFI) are absolute indices of fit (Hu and Bentler, 1995), and values close to 1 indicate a good fit of the hypothesized model to the data. A GFI value of 0.883 is not indicative of a strong fit, and a low AGFI value of 0.184 further suggests that the model fits poorly. Moreover, it should be noted that, GFI and AGFI can be significantly influenced by the sample size (Fan et al., 1999). However, a standardized root mean square residual (SRMR) value of 0.021 indicates a good model fit, as a value less than 0.05 is preferred.

The normed fit index (NFI) (Bentler and Bonett, 1980) is a widely used incremental fit index, but it has a tendency of underestimating the fit in small sample sizes. The comparative fit index (CFI) (Bentler, 1990) addresses this issue by taking into account the sample size. For both NFI and CFI, values greater than 0.95 are preferred. As per the results of Model 1, a good model fit is suggested by the high NFI and CFI values of 0.972 and 0.977 respectively (see Table 3). The incremental fit index (IFI) (Bollen, 1989) also addresses the issue of sample size associated with the NFI and a value of 0.978 in Model 1 indicates a good fit. However, a relative fit index (RFI) (Bollen, 1986) of 0.858 and a Tucker-Lewis index (TLI) (Tucker and Lewis, 1973) of 0.887 are not suggestive of a very strong fit, as the values are less than 0.95.

The root mean square error of approximation (RMSEA) is another popular fit index used to assess the model fit. Generally, values less than 0.05 are preferred and an RMSEA of 0.342 (see Table 3) is indicative of a poor model fit. However, it should be noted that Hu and Bentler (1999) claimed that small sample sizes have a tendency of over-rejecting true population models. A closeness of fit of 0.007 (see Table 3) further provides evidence for a poor model fit, where a value greater than 0.5 is preferred (Jöreskog and Sörbom, 1996).

Based on the results shown in Table 3, it can be concluded that, even though high NFI, IFI and CFI values as well as a low SRMR value are

Table 4
Unstandardized regression weights of the SEM models.

Path	Model 1			Model 2			Model 3		
	Estimate	Standard Error	Probability Level	Estimate	Standard Error	Probability Level	Estimate	Standard Error	Probability Level
EI ← RE	2.347	0.424	<0.001	2.347	0.424	<0.001	2.347	0.424	<0.001
TB ← RE	−2.164	0.697	0.002	−2.110	0.678	0.002	−2.110	0.678	0.002
TB ← EI	−0.830	0.215	<0.001	−0.853	0.204	<0.001	−0.853	0.204	<0.001
HC ← TB	−4.209	0.688	<0.001	−4.209	0.692	<0.001	−4.209	0.692	<0.001
HC ← EI	5.408	1.099	<0.001	5.408	1.110	<0.001	5.408	1.110	<0.001
CF ← RE	1.896	0.860	0.028	2.681	0.911	0.003	2.681	0.911	0.003
CF ← HC	0.456	0.022	<0.001	0.428	0.024	<0.001	0.428	0.024	<0.001
GDP ← TB	0.728	0.178	<0.001	0.728	0.199	<0.001	0.733	0.199	<0.001
GDP ← HC	1.239	0.058	<0.001	1.239	0.063	<0.001	1.247	0.052	<0.001
GDP ← CF	0.639	0.110	<0.001	0.639	0.130	<0.001	0.631	0.124	<0.001
GDP ← RE	0.883	0.578	0.126	0.883	0.559	0.114	0.931	0.545	0.087
GDP ← EI	0.050	0.240	0.834	0.050	0.253	0.843	–	–	–

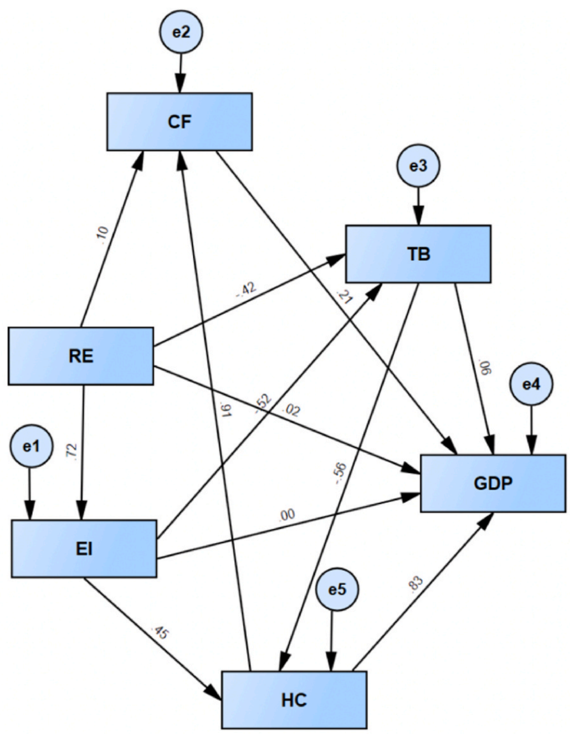


Fig. 11. Model 1 with estimated standardized regression weights.

suggestive of a good fit, the remaining fit indices (i.e. GFI, AGFI, RFI, TLI and RMSEA) as well as the significant χ^2 value do not provide satisfactory evidence to confirm a strong fit of Model 1 to the data. Therefore, in order to improve the fit of the model, modifications needed to be done to Model 1. For this, evidence for model misspecification was investigated. AMOS provides modification indices and standardized residuals which are quite useful in identifying model misspecifications.

The highest modification index reported by AMOS for Model 1 was 6.416, which corresponded to a possible covariance between the error terms e2 and e3, related to the variables CF and TB, respectively. It means that, if the covariance between the error terms e2 and e3 were to be freely estimated, the overall χ^2 value would reduce by about 6.416. However, the inclusion of this additional parameter to the SEM model should be done only if it is meaningful. As both the variables CF and TB have a strong correlation with the exogenous variable RE, it could be possible for their corresponding error terms to have a high covariance between them. Based on this justification, Model 1 was modified such that the covariance between those error terms would be freely estimated in the subsequent analysis. The resultant model after the modification was termed Model 2 (see Fig. 12) and its results after calculating the estimates are summarized in Table 3. The estimated unstandardized regression weights are shown in Table 4.

From Table 3, it is evident that the modification has considerably reduced the χ^2 value to 3.225 with 2 degrees of freedom. The probability level of 0.199 (which is greater than 0.05) suggests that this χ^2 value is non-significant and hence gives an indication of a good model fit. A high GFI value of 0.966 suggests a great fit of the model compared to the GFI value of 0.883 of Model 1. The AGFI value has considerably increased to 0.639, from 0.184 in Model 1, but still is not indicative of a good fit. All the other fit indices comprising the NFI, RFI, IFI, TLI and CFI are indicative of excellent model fit with values of 0.993, 0.946, 0.997, 0.979 and 0.997 respectively. However, an RMSEA value of 0.148 indicates a poor model fit.

As discussed above, the assessment of the SEM results of Model 2 shows that the non-significant χ^2 value along with the small SRMR value and high GFI, NFI, RFI, IFI, TLI and CFI values are suggestive of a strong model fit, while the AGFI and RMSEA values are not satisfactory. Hence,

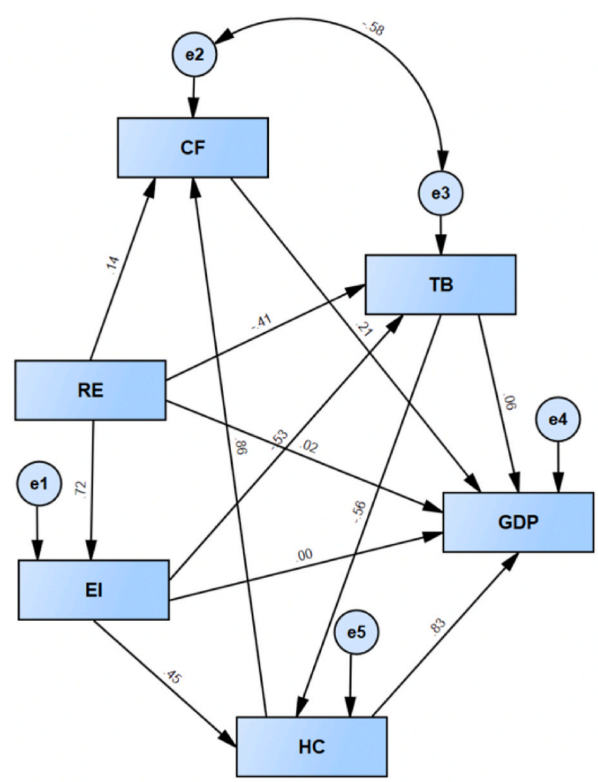


Fig. 12. Model 2 with estimated standardized regression weights.

it was decided to look into the possibility of further improving the model fit.

According to Table 4, all the paths in Model 2 are significant at the 0.05 probability level except for two paths. The path from EI to GDP and the path from RE to GDP failed to achieve the significance level. Hence, in order to further improve the model fit, it was decided to drop the path from EI to GDP as it was the least significant path. The resultant model is termed Model 3 (see Fig. 13). The estimated unstandardized regression weights are shown in Table 4.

As per the fit indices shown in Table 3, the non-significant χ^2 value of 3.260 and the small SRMR value of 0.018, along with the high values of GFI, NFI, RFI, IFI, TLI and CFI of Model 3, are indicative of a model with excellent fit to the data. Even though the value of AGFI is still 0.757, it has improved significantly, compared to the value of 0.184 in Model 1. Furthermore, the RMSEA has reduced significantly to a value of 0.056. Although a value less than 0.05 is preferred with a closeness of fit value greater than 0.5, the RMSEA value of Model 3 can be considered to be acceptable. However, a wide 90% confidence interval of 0–0.328 (see Table 3) with a small sample size of 29, may suggest that the RMSEA estimate is imprecise (Byrne, 2016). Taking all these into account, even though the RMSEA value is not highly desirable, based on the other fit indices discussed above, along with a non-significant χ^2 value, it can be concluded that Model 3 exhibits a good fit to the data. Hence, no further modifications were done to Model 3.

Table 5 summarizes the standardized residual covariances for Model 3 (only half of the values are given due to the symmetrical nature of the data). Values greater than 2.58 would indicate large deviations from a good fitting model (Byrne, 2016). However, it is evident from Table 5 that all the residual covariance values are well below this cutoff value, indicating that there are no model misspecifications.

As discussed in Section 2.2.2, it is clear from Table 2 that the dataset used in this study exhibits multivariate non-normality. The Bollen-Stine bootstrapping technique (Bollen and Stine, 1992) was used to address this issue. It evaluates the correctness of the hypothesized model, without assuming that the data is normally distributed (Byrne, 2016). The bootstrapping results reported a p-value of 0.603 (>0.05), indicating a good fit of the model to the data.

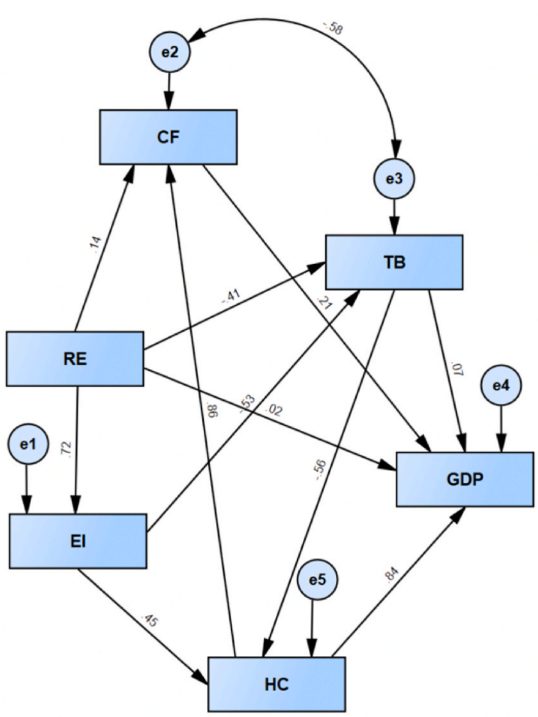


Fig. 13. Model 3 with estimated standardized regression weights.

Table 5
Standardized residual covariances.

	RE	EI	TB	HC	CF	GDP
RE	0.000					
EI	0.000	0.000				
TB	0.000	0.028	−0.027			
HC	−0.221	−0.015	0.028	−0.021		
CF	−0.187	−0.028	0.031	−0.034	−0.043	
GDP	−0.225	−0.015	0.028	−0.027	−0.039	−0.032

Based on the results of Model 3 shown in Table 4, it can be seen that all the paths, except the path from RE to GDP are significant at the 0.05 probability level. As expected from the theory, the TB, HC and CF have a strong positive correlation with the GDP of Sri Lanka. Furthermore, strong positive correlations can be observed between EI and HC, RE and CF, and HC and CF, while strong negative correlations can be observed between RE and TB, EI and TB, and TB and HC. However, a strong positive correlation is observed between RE and EI, although EI is expected to decrease with increasing RE consumption. Chien and Hu (2008) claimed that this may be explained by the fact that, when a country has a high energy demand, it still imports more energy, while consuming more renewables as well.

It is evident from Table 4 that there is no strong direct correlation between the RE consumption and the GDP of Sri Lanka. Even though, this result is not directly aligned with the results of the study by Narayan and Doytch (2017), who mentioned that the total RE consumption of low and lower middle income countries contributes to the economic growth, this finding is in agreement with the work by Mahmoodi and Mahmoodi (2011), where the authors reported that no causality exists between the RE consumption and the economic growth of Sri Lanka. This is also in agreement with the results of Zeb et al. (2014), where the authors showed that there is no cointegrating relationship between the RE consumption and the GDP through a Granger causality test. The results further confirm the findings of Chien and Hu (2008), where the authors showed that there is no significant direct influence of the RE consumption on the GDP, through an SEM approach based on data related to 116 economies including Sri Lanka. This is expected considering that Sri Lanka is a developing nation, which still depends on a large amount of non-RE sources, but this might change over time with the addition of new renewable establishments to the national energy supply. RE consumption in Sri Lanka may not have yet reached a stage where it would directly influence the economic growth of the country.

However, the results indicate that a strong positive correlation exists between renewables and CF as well as between CF and GDP, which is consistent with the results of the studies by Chien and Hu (2008) and Rahman and Velayutham (2020). As per this relationship, increased use of RE leads to an increase in CF, which in turn contributes to the economic growth of the country. This suggests that the RE consumption has an indirect positive impact on the GDP of Sri Lanka. However, contrary to the expectation, a significant negative correlation was observed between RE and TB. The significant positive correlation between RE and EI as well as the significant negative correlation between RE and TB indicate that RE does not have an import substitution effect. These results are in agreement with the work by Chien and Hu (2008).

Considering both these factors, it is clear that the implementation of policies that lead to capital accumulation through increased use of RE, would be the ideal strategy for Sri Lanka. Due to the negative correlation between RE and TB, increasing the TB would not be a suitable approach to promote RE establishments. Hence, the government should provide incentives to increase the CF. These incentives could be in the form of government subsidies or tax reliefs to promote the development of RE establishments in the country. Furthermore, necessary measures should be taken to allow the RE technologies to easily penetrate the market.

4. Conclusions

The results of this study suggest that the RE establishments in Sri Lanka have a significant effect on the GDP of the country. However, this is not a direct effect, which may be explained by the fact that Sri Lanka is still a developing nation, which heavily relies on non-RE sources at present. The positive significant correlation between RE and CF, and the negative significant correlation between RE and TB imply that the RE establishments may cause both favorable and adverse effects on the GDP of Sri Lanka. It should be noted that the policy makers should focus on implementing policies that result in increased CF through the use of RE in order to maximize the economic growth. Moreover, RE policies that increase the TB could have negative effects on the economic growth while they could literally lead to the sustainable economic growth of the country.

Overall, this analysis indicates that Sri Lanka's RE profile is not at a strong position to influence the country's economy to a significant level. This should be the case for many of the other emerging economies worldwide. Hence, for any nation, it is really important to thoroughly investigate their RE potential and then to understand the possible triggers and barriers of promoting both the RE generation and use. Then, rules and regulations should be reviewed and introduced to eliminate any possible barriers while providing incentives relating to RE generation and use. In this case, the formation of public–private partnerships is essential for further development of the RE sector. As an incentive for encouraging the participation of the private sector, providing tax incentives as well as providing interest-free or low-interest financial support to finance such projects would be important and timely. However, some of the main barriers identified in developing countries could be highly diverse and they might be associated with political, social and economic sectors. These diverse issues can be tackled/reduced by incorporating policies which tend to minimize the risk related to such projects and the initial capital cost. Moreover, each and every nation should adhere to global policies, agreements and guidelines on reducing the harmful emission and pollution to restore the balance of our nature before it is too late to do so.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Agterbosch, S., Meertens, R.M., Vermeulen, W.J.V., 2009. The relative importance of social and institutional conditions in the planning of wind power projects. Renew. Sustain. Energy Rev. 13 (2), 393–405. https://doi.org/10.1016/j.rser.2007.10.010.

Akadiri, S. saint, Alola, A.A., Akadiri, A.C., Alola, U.V., 2019. Renewable energy consumption in EU-28 countries: policy toward pollution mitigation and economic sustainability. Energy Pol. 132, 803–810. https://doi.org/10.1016/j.enpol.2019.06.040.

Amri, F., 2017. The relationship amongst energy consumption (renewable and non-renewable), and GDP in Algeria. Renew. Sustain. Energy Rev. 76, 62–71. https://doi.org/10.1016/j.rser.2017.03.029.

Annual Report 2018, 2019. Sri Lanka Sustainable Energy Authority.

Aqeel, A., Sabihuddin Butt, M., 2001. The relationship between energy consumption and economic growth In Pakistan. Asia-Pacific Dev. J. 8 (2), 101–110.

Arachchige, G.M., Jayakody, S., Mooi, R., Kroh, A., 2017. A review of previous studies on the Sri Lankan echinoid fauna, with an updated species list. Zootaxa 4231 (2), 151–168. https://doi.org/10.11646/zootaxa.4231.2.1.

Bélaïd, F., Youssef, M., 2017. Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: assessing the evidence from Algeria. Energy Pol. 102, 277–287. https://doi.org/10.1016/j.enpol.2016.12.012.

Bentler, P.M., 1990. Comparative fit indexes in structural models. Psychol. Bull. 7, 238–246. https://doi.org/10.1037/0033-2909.107.2.238.

Bentler, P.M., Bonett, D.G., 1980. Significance tests and goodness of fit in the analysis of covariance structures. Psychol. Bull. 88 (3), 588–606. https://doi.org/10.1037/0033-2909.88.3.588.

Bhattacharya, M., Paramati, S.R., Ozturk, I., Bhattacharya, S., 2016. The effect of renewable energy consumption on economic growth: evidence from top 38 countries. Appl. Energy 162, 733–741. https://doi.org/10.1016/j.apenergy.2015.10.104.

Bollen, K.A., 1986. Sample size and bentler and Bonett's nonnormed fit index. Psychometrika 51, 375–377. https://doi.org/10.1007/BF02294061.

Bollen, K.A., 1989. A new incremental fit index for general structural equation models. Socio. Methods Res. 17, 303–316. https://doi.org/10.1177/0049124189017003004.

Bollen, K.A., Stine, R.A., 1992. Bootstrapping goodness-of-fit measures in structural equation models. Socio. Methods Res. 21, 205–229. https://doi.org/10.1177/0049124192021002004.

Browne, M.W., 1984. Asymptotically distribution-free methods for the analysis of covariance structures. Br. J. Math. Stat. Psychol. 37, 62–83. https://doi.org/10.1111/j.2044-8317.1984.tb00789.x.

Byrne, B.M., 2016. In: Structural Equation Modeling with AMOS : Basic Concepts, Applications, and Programming, third ed. Routledge, New York and London.

Cansino, J.M., Pablo-Romero, M. del P., Román, R., Yñiguez, R., 2011. Promoting renewable energy sources for heating and cooling in EU-27 countries. Energy Pol. 39, 3803–3812. https://doi.org/10.1016/j.enpol.2011.04.010.

Chien, T., Hu, J.L., 2007. Renewable energy and macroeconomic efficiency of OECD and non-OECD economies. Energy Pol. 35, 3606–3615. https://doi.org/10.1016/j.enpol.2006.12.033.

Chien, T., Hu, J.L., 2008. Renewable energy: an efficient mechanism to improve GDP. Energy Pol. 36, 3045–3052. https://doi.org/10.1016/j.enpol.2008.04.012.

Cho, S., Heo, E., Kim, J., 2015. Causal relationship between renewable energy consumption and economic growth: comparison between developed and less-developed countries. Geosyst. Eng. 18, 284–291. https://doi.org/10.1080/12269328.2015.1053540.

Cook, R.D., 1977. Detection of influential observation in linear regression. Technometrics 19, 15–18. https://doi.org/10.1080/00401706.1977.10489493.

Core Writing Team, Pachauri, R.K., Meyer, L.A., 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva.

Demirbag, M., Yilmaz, S., 2020. Preservice teachers' knowledge levels, risk perceptions and intentions to use renewable energy: a structural equation model. J. Educ. Sci. Environ. Health 6 (3), 193–206. https://doi.org/10.21891/jeseh.625409.

Destek, M.A., Sinha, A., 2020. Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: evidence from organisation for economic Co-operation and development countries. J. Clean. Prod. 242 https://doi.org/10.1016/j.jclepro.2019.118537.

Dhakal, C.P., 2017. Dealing with outliers and influential points while fitting regression. J. Inst. Sci. Technol. 22, 61–65. https://doi.org/10.3126/jist.v22i1.17741.

Djurisic, V., Smolovic, J.C., Misnic, N., Rogic, S., 2020. Analysis of public attitudes and perceptions towards renewable energy sources in Montenegro. Energy Rep. 6, 395–403. https://doi.org/10.1016/j.egyr.2020.08.059.

Dogan, E., Seker, F., 2016. Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy. Renew. Energy 94, 429–439. https://doi.org/10.1016/j.renene.2016.03.078.

Domac, J., Richards, K., Risovic, S., 2005. Socio-economic drivers in implementing bioenergy projects. In: Biomass and Bioenergy, pp. 97–106. https://doi.org/10.1016/j.biombioe.2004.08.002.

Doytch, N., Narayan, S., 2021. Does transitioning towards renewable energy accelerate economic growth? An analysis of sectoral growth for a dynamic panel of countries. Energy 235, 121290. https://doi.org/10.1016/j.energy.2021.121290.

Dumitrescu, E.I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Econ. Modell. 29, 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014.

Economou, A., 2010. Renewable energy resources and sustainable development in Mykonos (Greece). Renew. Sustain. Energy Rev. 14 (5), 1496–1501. https://doi.org/10.1016/j.rser.2009.11.008.

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T., Minx, J.C., 2014. Climate Change 2014 : Mitigation of Climate Change : Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Emmann, C.H., Arens, L., Theuvsen, L., 2013. Individual acceptance of the biogas innovation: a structural equation model. Energy Pol. 62, 372–378. https://doi.org/10.1016/j.enpol.2013.07.083.

Fan, W., Hao, Y., 2020. An empirical research on the relationship amongst renewable energy consumption, economic growth and foreign direct investment in China. Renew. Energy 146, 598–609. https://doi.org/10.1016/j.renene.2019.06.170.

Fan, X., Thompson, B., Wang, L., 1999. Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. Struct. Equ. Model. 6, 56–83. https://doi.org/10.1080/10705519909540119.

Fang, Y., 2011. Economic welfare impacts from renewable energy consumption: the China experience. Renew. Sustain. Energy Rev 15 (9), 5120–5128. https://doi.org/10.1016/j.rser.2011.07.044.

Genç, M., Akilli, M., 2019. The correlation between renewable energy knowledge and attitude: a structural equation model with future's educators. J. Baltic Sci. Educ. 18, 866–879. https://doi.org/10.33225/jbse/19.18.866.

Global Solar Atlas, 2021. Map and data downloads. https://globalsolaratlas.info/download/sri-lanka (accessed 22 May 2021).

Gonzalez-Salazar, M.A., Morini, M., Pinelli, M., Spina, P.R., Venturini, M., Finkenrath, M., Poganietz, W.R., 2014. Methodology for estimating biomass energy potential and its application to Colombia. Appl. Energy 136, 781–796. https://doi.org/10.1016/j.apenergy.2014.07.004.

Guo, X., Liu, H., Mao, X., Jin, J., Chen, D., Cheng, S., 2014. Willingness to pay for renewable electricity: a contingent valuation study in Beijing, China. Energy Pol. 68, 340–347. https://doi.org/10.1016/j.enpol.2013.11.032.

Hasan, K., 2019. Moving towards renewable and sustainable energy in Sri Lanka: an uphill battle? https://asian-power.com/regulation/commentary/moving-towards-renewable-and-sustainable-energy-in-sri-lanka-uphill-battle (accessed 30 April 2021).

Haseeb, M., Abidin, I.S.Z., Hye, Q.M.A., Hartani, N.H., 2019. The impact of renewable energy on economic well-being of Malaysia: fresh evidence from auto regressive distributed lag bound testing approach. Int. J. Energy Econ. Pol. 9, 269–275. https://doi.org/10.32479/ijeep.7229.

Heimiller, D., 2006. Sri Lanka Wind Resource Map. https://openei.org/wiki/File:Sri_Lanka_Wind_Resource_Map.pdf (accessed 30 April 2021).

Hersh, M.A., 2006. The economics and politics OF energy generation. In: IFAC Conference on Supplemental Ways for Improving International Stability through Automation ISA ′06. Elsevier, Prishtina, pp. 77–82. https://doi.org/10.1016/B978-008045406-1/50011-2.

Höök, M., Tang, X., 2013. Depletion of fossil fuels and anthropogenic climate change-A review. Energy Pol. 52, 797–809. https://doi.org/10.1016/j.enpol.2012.10.046.

Hossain, S., Saeki, C., 2012. A dynamic causality study between electricity consumption and economic growth for global panel: evidence from 76 countries. Asian Econ. Financ. Rev. 2, 1–13.

Hu, L.-T., Bentler, P.M., 1995. Evaluating model fit. In: Hoyle, R.H. (Ed.), Structural Equation Modeling: Concepts, Issues, and Applications. Sage Publications, Inc., pp. 76–99

Hu, L.T., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct. Equ. Model. 6, 1–55. https://doi.org/10.1080/10705519909540118.

IEA, 2021a. https://www.iea.org/data-and-statistics/data-tables?country=SRILANKA&energy=Electricity&year=2018 (accessed 10 April 2021).

IEA, 2021b. Data and statistics. https://www.iea.org/data-and-statistics/data-tables?country=SRILANKA&energy=Balances&year=1991 (accessed 10 April 2021).

Jöreskog, K.G., Sörbom, D., 1996. In: LISREL 8: User's Reference Guide, second ed. Scientific Software International.

Karunarathne, H.D.S.S., Walpalage, S., 2013. Applicability of pressure retarded osmosis power generation technology in Sri Lanka. Energy Proc. 34, 211–217. https://doi.org/10.1016/j.egypro.2013.06.749.

Khan, S.A.R., Zhang, Y., Kumar, A., Zavadskas, E., Streimikiene, D., 2020. Measuring the impact of renewable energy, public health expenditure, logistics, and environmental performance on sustainable economic growth. Sustain. Dev. 28, 833–843. https://doi.org/10.1002/sd.2034.

Kline, R.B., 2016. In: Principles and Practice of Structural Equation Modeling, fourth ed. The Guildford Press, New York.

Koçak, E., Şarkgüneşi, A., 2017. The renewable energy and economic growth nexus in black sea and Balkan Countries. Energy Pol. 100, 51–57. https://doi.org/10.1016/j.enpol.2016.10.007.

Kulasekara, H., Seynulabdeen, V., 2019. A review of geothermal energy for future power generation. In: Proceedings of the 2019 5th International Conference on Advances in Electrical Engineering (ICAEE). IEEE, Dhaka, pp. 223–228. https://doi.org/10.1109/ICAEE48663.2019.8975470.

Lokuliyana, R.L.K., Folley, M., Gunawardane, S.D.G.S.P., Wickramanayake, P.N., 2020. Sri Lankan wave energy resource assessment and characterisation based on IEC standards. Renew. Energy 162, 1255–1272. https://doi.org/10.1016/j.renene.2020.08.005.

Maduranga, W.L.S., Lewangamage, C.S., 2018. Development of wind loading maps for Sri Lanka for use with different wind loading codes. Engineer. J. Inst. Eng., Sri Lanka 51, 47. https://doi.org/10.4038/engineer.v51i3.7305.

Mahmoodi, M., Mahmoodi, E., 2011. Renewable energy consumption and economic growth: the case of 7 Asian developing countries. Am. J. Sci. Res. 146–152.

Moselle, B., Padilla, J., Schmalensee, R., 2010. In: Harnessing Renewable Energy in Electric Power Systems, first ed. RFF Press, New York.

Narayan, S., Doytch, N., 2017. An investigation of renewable and non-renewable energy consumption and economic growth nexus using industrial and residential energy consumption. Energy Econ. 68, 160–176. https://doi.org/10.1016/j.eneco.2017.09.005.

NASA, 2021. The Causes of Climate Change. https://climate.nasa.gov/causes/ (accessed 30 April 2021).

Ogbonnaya, C., Abeykoon, C., Damo, U.M., Turan, A., 2019a. The current and emerging renewable energy technologies for power generation in Nigeria: a review. Therm. Sci. Eng. Prog. https://doi.org/10.1016/j.tsep.2019.100390.

Ogbonnaya, C., Turan, A., Abeykoon, C., 2019b. Energy and exergy efficiencies enhancement analysis of integrated photovoltaic-based energy systems. J. Energy Storage 26. https://doi.org/10.1016/j.est.2019.101029.

Ogbonnaya, C., Turan, A., Abeykoon, C., 2019c. Numerical integration of solar, electrical and thermal exergies of photovoltaic module: a novel thermophotovoltaic model. Sol. Energy 185, 298–306. https://doi.org/10.1016/j.solener.2019.04.058.

Oikonomou, E.K., Kilias, V., Goumas, A., Rigopoulos, A., Karakatsani, E., Damasiotis, M., Papastefanakis, D., Marini, N., 2009. Renewable energy sources (RES) projects and their barriers on a regional scale: the case study of wind parks in the Dodecanese islands, Greece. Energy Pol. 37, 4874–4883. https://doi.org/10.1016/j.enpol.2009.06.050.

Ozcan, B., Ozturk, I., 2019. Renewable energy consumption-economic growth nexus in emerging countries: a bootstrap panel causality test. Renew. Sustain. Energy Rev. 104, 30–37. https://doi.org/10.1016/j.rser.2019.01.020.

Perera, A., 2016. Inception. High costs slowing Sri Lanka push toward solar energy (accessed 30 April 2021).

Power Technology, 2013. The 10 biggest hydroelectric power plants in the world. https://www.power-technology.com/features/feature-the-10-biggest-hydroelectric-power-plants-in-the-world/ (accessed 30 April 2021).

Rahman, M.M., Velayutham, E., 2020. Renewable and non-renewable energy consumption-economic growth nexus: new evidence from South Asia. Renew. Energy 147, 399–408. https://doi.org/10.1016/j.renene.2019.09.007.

Salim, R.A., Rafiq, S., 2012. Why do some emerging economies proactively accelerate the adoption of renewable energy? Energy Econ. 34, 1051–1057. https://doi.org/10.1016/j.eneco.2011.08.015.

Samarasekara, M.B.S., Wijekoon, R.B., Hapuarachchi, D.C., Fernando, M.D.V., Kaushalya, K.H.A., Pathiratne, K.A.M.N., 2019. LONG TERM GENERATION EXPANSION PLAN 2020-2039. Ceylon Electricity Board.

Scarlat, N., Dallemand, J.F., Monforti-Ferrario, F., Banja, M., Motola, V., 2015. Renewable energy policy framework and bioenergy contribution in the European union - an overview from national renewable energy action plans and progress reports. Renew. Sustain. Energy Rev. 51, 969–985. https://doi.org/10.1016/j.rser.2015.06.062.

Seetharaman Moorthy, K., Patwa, N., Saravanan Gupta, Y., 2019. Breaking barriers in deployment of renewable energy. Heliyon 5, 23. https://doi.org/10.1016/j.heliyon.2019.e01166.

Silva, E.I.L., Silva, E.N.S., 2016. Handbook on small hydropower development and environment: a case study on Sri Lanka. In: Water Resources Science and Technology (WRST), Ragama, first ed. https://doi.org/10.13140/RG.2.1.1414.8243

Singh, M., Keswani, S., Chitkara, P., Joseph, R., Singha, H., Sen, S., Mahindru, G., Rao, V., Sumanasekaran, P., Shazaad, N., 2017. 100% Percent Electricity Generation through Renewable Energy by 2050: Assessment of Sri Lanka's Power Sector. Asian Development Bank.

Sri Lanka Energy Sector Development Plan for a Knowledge-based Economy 2015-2025, 2015. Ministry of Power & Energy.

Sri Lanka Sustainable Energy Authority, 2021. Inception. https://www.energy.gov.lk/index.php/en/about-us/inception (accessed 22 May 2021).

Statistical Digest 2019, 2020. Ceylon Electricity Board.

The World Bank, 2021. Data Bank | World Development Indicators. https://databank.worldbank.org/reports.aspx?source=2&country=LKA (accessed 10 April 2021).

Tucker, L.R., Lewis, C., 1973. A reliability coefficient for maximum likelihood factor analysis. Psychometrika 38, 1–10.

West, S.G., Finch, J.F., Curran, P.J., 1995. Structural equation models with nonnormal variables: problems and remedies. In: Hoyle, R.H. (Ed.), Structural Equation Modeling: Concepts, Issues, and Applications. Sage Publications, Inc, pp. 56–75.

Withanaarachchi, A., Nanayakkara, J., Pushpakumara, C., 2014. The progress of Sri Lanka's renewable energy sector developments in mitigating the GHG emission. Energy Environ. Eng. 2, 113–119. https://doi.org/10.13189/eee.2014.020502.

Zeb, R., Salar, L., Awan, U., Zaman, K., Shahbaz, M., 2014. Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy. Renew. Energy 71, 123–132. https://doi.org/10.1016/j.renene.2014.05.012.