Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-020-12041-y

RESEARCH ARTICLE

Does tradeoff between financial and social indicators matters in environmental consideration: evidence from G7 region

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Received: 1 November 2020 / Accepted: 9 December 2020

Abstract

The study tries to discover the impact of financial and social indicators' growth towards environmental considerations to understand the drivers of economic growth and carbon dioxide emissions change in G7 countries. The DEA-like composite index has been used to examine the tradeoff between financial and social indicator matters in environmental consideration by using a multi-objective goal programming approach. The data from 2008 to 2018 is collected from G-7 countries. The results from the DEA-like composite index reveals that there is a mixed condition of environmental sustainability in G-7 countries where the USA is performing better and Japan is performing worse among the set of other countries. The further result shows that the energy and fiscal indicators help to decrease the dangerous gas emissions. Divergent to that, the human and financial index positively contributes to greenhouse gas emissions. Fostering sustainable development is essential to successfully reduce emissions, meet established objectives, and ensure steady development. The study provides valuable information for policymakers.

Keywords Energy security · Environmental sustainability · Low-carbon finance · Common weight DEA · Composite indicator

Introduction

Climate change is a huge challenge facing the world today. As a result, greenhouses gas (GHS) emission reduction has become one of the major concerns in the field of environmental scientific research. The temperature of the world is forecasted to be increased by 3 °C by 2100 compared to the world average temperature at the end of the last century (Zheng et al. 2019; LaBelle 2017). Because of the rapid growth of economy, China's GHG emissions also increased substantially. G7' GHG emissions exceeded the USA's GHG emission to be the highest GHG emitter globally. Despite the increased emission and having a fast developing economy and large population, G7 has undertaken a set of successful preventing measures to alleviate the impact of GHG emissions (Ebiringa and Anyaogu 2014). Many studies in the field analyzed carbon emission reduction and reached the conclusion that addressing emissions regionally is highly significant for realizing the objective of G7's policy for the environment (Zweifel et al. 2017). G7 contributed effectively to the governance of global climate and struggled to mitigate climate degradation by implementing various measures through government and private organizations. The impact of greenhouse gas and CO_2 on climate change is environmental issue that is greatly

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Published online: 06 January 2021

influenced by the development of the economy. The impressive development of the economic structure in China particularly in new sectors has had its property on carbon emissions (Alemzero et al. 2020b; Alemzero et al. 2020a). G7 is continuously developing in the industry that produces new energy (Hussain et al. 2019). Reducing the speed of economic development has (Wu et al. 2020; Green and Stern 2017) reduced carbon emissions since 2012 (Bhattacharyya 2018), Ahmed et al. (2020) and Shah et al. (2019).

The United Nations General Assembly on November 25, 2015, adopted the 2030 Development Agenda "Transforming our world: the 2030 Agenda for Sustainable Development". The aim of the 2030 Agenda is to build a collaborative partnership at all levels by emphasizing sustainable development for all, using the principle "leaving no one behind" (Steffen 2018; Zhan and de Jong 2018). On January 1, 2016, new goals and targets are known as the Sustainable Development Goals (SDGs) came into effect, becoming the key reference material for the development of policies which are geared towards sustainable development in all directions until 2030—social, environmental, and economic (Srivastava and Kathuria 2020; Cao and Alanne 2018). Fighting climate change through limiting the emissions of greenhouse gases (GHG), particularly through renewable energy generation and demand management, can increase efficiency and reduce environmental pollution significantly in all sectors of the economy (Piñeiro-Chousa et al. 2021; van Moerkerk and Crijns-Graus 2016).

Energy performance and sustainability assessment are considered key for the achievement of climate change and energy policies (Zhou and Li 2019; Sudmant et al. 2017). Previous studies such as Beccue et al. (2018), Millard et al. (2017), and Romero et al. (2018) have projected some level of shift in CO_2 emissions in certain areas of China. However, not much information is available on the relationship and Tran's impact between different regional emissions; this ought to be investigated to help in policy formulation. GHG emissions are influenced by the impressive development of the Chinese economy especially in new sectors that have had its impact on GHG emissions in the country. China is continuously developing its energy sector through the inclusion of new forms of energy. The primary energy consumption in China is mainly from five sources, i.e., oil, coal, nuclear, gas, and renewables that are mostly used in industry, transport, buildings, and other sectors (Khalid and Salman 2020). Since GHG emissions have a debilitating effect on the environment, it is very important to monitor and measure the environmental performance of economies with respect to the volatility of GHS emissions. Such initiatives present not only precise summary for growth evaluation but also lead countries in the setting up of environmental objectives to keep the average temperature rise below 2 °C and continue to work on limiting the rise in temperature to 1.5 °C (Chen et al. 2019).

Prior studies observed the relationship of emission levels with various factors such as efficiency of energy, the structure of energy, economic development, production, industry, technological development openness, and population by using different methodologies. CO_2 emissions may decrease by implementing a model that improves the efficiency and structure of energy and the key components. In comparison to others, we used a common weight composite indicator similar to the data envelopment analysis (DEA) model to consolidate these factors into single measures of the index. Composite indicators were developed to measure the energy economic and environmental efficiency by using multiple sets of social and financial indicators. The study is to provide the important contributions conducted by researchers, as both arithmetic mean aggregation and DEA approaches were applied so as to develop an eco-friendly G7 index of nations and to measure the mathematical aggregation. No individual partial indicator can accurately measure the composite efficiency score of an entire system.

The remaining part of the article is divided into 4 parts: Section 3 contains the data and methodology, Section 4 contains results and discussion, while Section 5 concludes the study.

Literature review

Various studies such as Bampatsou and Halkos (2019) introduced the inclusive sustainable transformation index, which takes into consideration structural change as the basis for sustained and inclusive growth. Their study looked at the extent to which a nation has developed a services-based economy or modern industry that is gender inclusive and also protects the environment at the same time (Al-Salem et al. 2017; Sueyoshi et al. 2017). Furthermore, Hall et al. (2018) and Geddes et al. (2018) developed a low-carbon finance index which has the potential to induce private and foreign direct investments into a low-carbon sector. Samaras et al. (2019) discussed the performance of sustainable development in the G7 region. The objective of their study was to assess the efficiency of these relative to the transformation of productive resources as well as technological innovation into sustainable development. Sun et al. (2020a, b, c) analyzed and calculated the energy efficiency for BRICS using the Super-SBM model. The Bootstrap was used to modify the values using DEA obtained from small sample data, and lastly, the nexus between carbon emissions and energy efficiency was measured. Also, an aggregated composite index of environmental sustainability and energy security on some of the world's highest GHG emitting countries is employed. Numerous studies discuss the issues associated with energy economic and environmental concerns such as Anser et al. (2020) and

Mohsin et al. (2019b), Mohsin et al. (2020), Iram et al. (2019), and Baloch et al. (2020).

Composite indices (CI) facilitate the evaluation of performances of countries instead of the identification of common trends among several individual indicators; this could assist in setting up of policy priorities proposing a non-compensatory multi-criteria decision analysis (MCDA) outline for the building of the CI. The non-compensatory MCDA features were used in the previous literature to incorporate the loss of information during aggregating the various indicators. Lavaca and Szirma explored the nexus between paths of structural modernization and countries' capacity to escape middle-income and poverty trap (Sun et al. 2020a, b, c, 2019a).

Moreover, the slack-based model (SBM) helped to deal with undesirable outputs. Besides, when there is an efficiency evolution problem caused by the efficiency of many decision-making units, the traditional DEA model introduced super efficiency concepts in order to calculate the efficient decision-making unit's efficiency values (Ervural et al. 2018). Some research studies are based on city-level energy efficiency. Researchers have conducted complete surveys of objective measurements of regional differences, impact issues, and urban efficiency and applied the Super-SBM approaches, which deal with undesirable outputs under the low disposal ability. In this literature, we review that in most cases, different DEA models in various fields of research were applied to measure energy efficiency with sustainable production (Mohsin et al. 2019a; Sun et al. 2019a). Previous studies have not combined the most relevant set of comprehensive indicators, nor have they used comprehensive methods like composite indicator methods to measure the recommended indicators. This article looks at the methodological framework for quantifying the compromise between financial and social indicators in environmental considerations: evidence from a multi-objective planning approach. We have developed a comprehensive indicator system that evaluates and explores the interrelationships between all indicators and combines all these indicators into a comprehensive indicator (CI) through mathematical programming methods, but the weight distribution of each sub-indicator is restricted.

Data and methodology

The Super-Data Envelop Analysis model is used with the best of knowledge to an equal measure of the financial stock market's future production functions. An empirical study is conducted on various provinces of China to measure energy efficiency in the context of better understating of energy utilization status and to improve energy utilization efficiency and (Sueyoshi et al. 2017) to analyze the transportation sector's environmental efficiency of 30 China regions using non-radial Super-DEA models.

Finally, we realized that when any inputs were reduced, Asia Pacific countries would become more effective. These factors in (Table 1) are unlikely to be affected by Asia Pacific countries because GDP and GCF rely on many of the economy's inputs and outputs. Because employee involvement may cause a decline in society's welfare and lead to conflict, this feedback will not change (United Nations 2013). As a result, Asia Pacific provides a realistic and rational forecast on reaching a significant boundary within the targets set by reducing its consumption of fossil fuels (solid fuel, natural gas, or total petroleum product) if the type of fuel whose consumption is to be decreased is observed. We, therefore, concluded that DMUs did not seek any increase in the number of staff, the GCF, or GDP; therefore, by reducing their fossil fuel intake, the G7 countries would try to reach an efficient stage. A DEA-like composite indicator model for aggregation purpose is used to remove the issues of energy and economic and environmental concerns such as:

$$\begin{aligned} bI_i &= \max \sum_{j-1}^{n} W_{ij}^{g} I_{ij} \\ s.t. \sum_{j-1}^{n} W_{ij}^{b} I_{kj} &\leq 1, k = 1, 2, \ldots., m \\ W_{ij}^{g} &\geq 0, j = 1, 2, \ldots, n \end{aligned} \tag{1}$$

Model 1 assesses the inclusive enactment scores of indicators entity i. Consequently, we will get a set of indexes $g_{i,\,1}, g_{i,\,2}, \ldots, g_{i,\,m}$ for all these entities by solving model 1 for each entity i. Model 1 has an identical objective function as the Simple Additive Weighted (SAW) aggregation method. Each entity will receive one score. If its sub-indicator dominates the alternative entity's value, the value of the other sub-indicators will be incorrect. For resolving this issue, model 1

Table 1 Indicator system

Indicators	Unit
GDP	USD per capita
FDI	Million USD
Energy supply	Million tone
Renewable energy	(KTOE)
Electricity	GWH
Air emission	Million tone
Pollution effects	1,000,000 HAB
Financial index	Consumer price index (CPI %)
R&D	R&D (% GDP)
Export	%
Energy consumption	Mtoe
Labor cost	% of GDP

can be outspread with comparable linear programming of the DEA model as follows:

$$gI_i = \min \sum_{j-1}^{n} W_{ij}^{g} I_{ij}$$
$$s.t. \sum_{j-1}^{n} W_{ij}^{g} I_{ij} \leq 1, k = 1, 2, \ldots, m \qquad (2)$$
$$W_{ij}^{g} \geq 0, j = 1, 2, \ldots, n$$

To aggregate the sub-indicators, model 2 chooses the worst set of weights by assessing the efficiency score of each entity. Additionally, model 2 is similar to the DEA input multiplier minimized with constant output. Thus, both models (1 and 2) are based on the DEA model to assess each entity's efficiency. These indexes take the most and least favorable weights of the different entities to show their overall performance scores' partial structure. Finally, the CI index constructed is as follows:

$$(CI)\lambda = \lambda \frac{gI_i - gI}{gI^* - gI} + (1-\lambda) \frac{bI_i - bI}{bI^* - bI}$$
$$\text{Where } gI^* = \max \{ gI_i, i = 1, 2, 3, \ldots, m\}, gI^- = \min \{ gI_i, i = 1, 2, 3, \ldots, m$$
$$\text{And } bI^* = \max \{ bI_i, i = 1, 2, 3, \ldots, m\}, bI^- = \min \{ bI_i, i = 1, 2, 3, \ldots, m \qquad (3)$$

In model 3, the value of parameter λ (ranged [0, 1]) can adjust with linear scaling minimum-maximum value. By linearly summing all these sub-indicators, we can find the adjusted parameters. $\lambda = 0.5$ is the neutral choice for decision-makers, where its normalized version will be g_i, while if $\lambda = 1$, its normalized version is b_i, and this is a negotiation among indexes when $\lambda = 0$. The outcomes of the abovementioned model are considered unrealistic because they lead to poor discrimination. There are no constraints placed on the weight selection of the sub-indicators in the preceding model. Theoretically speaking, a configuration item is a mathematical summary of a set of single indicators that summarize and measure multidimensional concepts. They usually do not have any universal unit of measurement. A combination of individual indicators is used in benchmarking, performance evaluation, policy-making, and public communication in the energy, economic, social, and environmental fields. CI can be used to measure energy performance and carbon emissions at the national level, so as to compare different countries and provide valuable information for decision-makers. Generally, we divide the construction of configuration items into two steps. We propose a multidimensional indicator to construct a single indicator by using a mathematical model similar to the weighted DEA.

Results and discussion

Analysis based on individual indicators

The global energy transition is underway to adopt low-carbon alternatives to fossil fuels. Following this, people are increasingly pressing for global warming to be maintained at a maximum temperature of 1.5 °C and remind us that our natural resources are limited. The energy system is a social technology system, and changes in energy technology have reshaped social practices, ethics, associations, and organizations. Considering the impact of the energy transition on humans and society plays a vital role in ensuring the effectiveness of technology adoption and policy execution. Although this transformation is of great significance, sociological viewpoints are still not well reflected in contemporary energy research.

Table 2 shows that the global energy efficiency investment in 2017 increased by 3% compared to 2016, reaching 236 billion US dollars. Similarly, since energy efficiency became a popular strategy in the 1970s, energy efficiency has also received great attention from energy policy in scientific literature. After the oil crisis despite having such a wealth of knowledge and deploying energy efficiency strategies in the world's main countries in the past four decades, global energy-related carbon dioxide emissions increased by 1.4% in 2017, attaining a historical increase of 32.5 gigatons. Social scientists criticize the dominant technological and economic methods of reducing energy consumption that are too concentrated and call for research to observe more complex social environments and practices to find solutions. In this case, people call for further separation of energy efficiency, including unsympathetically speaking about unpack and get a better understanding. The findings of the study is consistent with Ouedraogo (2017) and Pashaei Kamali et al. (2017).

Figure 1 shows the GDP of G7 countries. This implies that living standards or economic conditions seem to be important factors in the pursuit of environmental sustainability. The positive impact of living standards on environmental performance will not change environmental conditions. Similarly, the fact that trade intensity has a detrimental effect on the environmental performance of countries with low environmental performance means that there are environmentally unsustainable trade policies, or environmentally damaging trade activities, that are prioritized to fill the economic vacuum created by low trade volume. This result are complementary to the performance achieved by government integrity under the lowest quantized where environmental performance is conditionally allocated. This means that the focus of the system has shifted from pollution-intensive activities aimed at sustainable development practices (Chandio et al. 2020; Mohsin et al. 2018; Mohsin et al. 2019b).

Table 3 shows the FDI of G7 economies. Therefore, in formulating energy management policies, the direct impact of energy consumption on the development of economic factors must be considered. However, constructing meaningful measures to improve energy efficiency will help energy security and reduce CO_2 emissions. Therefore, it is necessary to

Table 2 GDP (per capita USD$)

Year	Canada	France	Germany	Italy	Japan	UK	USA
2000	29,363.64	26,104.48	27,461.25	27,082.57	26,841.23	26,422.36	36,304.60
2001	30,214.48	27,506.03	28,670.66	28,042.92	27,476.22	27,733.32	37,099.91
2002	30,963.22	28,528.16	29,504.29	28,716.20	28,170.05	28,999.26	37,979.61
2003	32,333.58	28,146.38	30,236.40	29,114.55	28,943.72	30,236.47	39,426.09
2004	33,911.26	29,038.70	31,712.92	29,446.50	30,354.46	31,920.30	41,647.84
2005	36,327.66	30,504.06	32,236.74	30,016.16	31,667.91	32,586.15	44,043.73
2006	38,106.96	32,435.70	34,624.97	32,256.67	33,094.34	34,673.37	46,230.85
2007	39,554.85	34,092.92	36,820.15	33,903.21	34,507.17	35,513.58	47,902.06
2008	40,376.33	35,102.87	38,432.45	35,274.31	34,803.66	36,634.61	48,311.22
2009	38,893.18	34,719.50	37,501.13	34,355.46	33,201.99	35,060.10	47,028.16
2010	40,113.53	35,936.04	39,703.56	34,857.27	34,994.37	36,464.71	48,395.80
2011	41,666.72	37,447.95	42,541.51	36,183.32	35,775.26	37,154.16	49,810.70
2012	42,290.88	37,684.20	43,359.54	36,002.91	37,213.84	38,296.70	51,540.97
2013	44,298.51	39,528.47	44,993.67	36,067.71	39,008.36	39,945.10	53,045.95
2014	45,753.78	40,144.06	47,011.28	36,194.92	39,183.47	41,292.49	54,993.17
2015	44,671.41	40,840.85	47,622.33	36,909.30	40,406.10	42,583.08	56,812.54
2016	46,480.50	42,851.62	50,574.37	39,922.93	39,990.05	44,121.08	57,977.39
2017	48,633.84	44,693.76	53,254.67	41,784.60	40,884.62	45,923.36	60,056.48
2018	50,077.79	46,397.96	54,652.83	42,908.65	41,363.67	46,918.23	62,949.28
2019	51,341.71	49,144.87	56,305.20	44,217.70	43,278.54	48,725.42	65,143.42

consider energy and economic and environmental efficiency in order to formulate a policy framework. Furthermore, it is important to assess the capabilities of countries in terms of energy saving and emission reduction. Moreover, the increase in major energy consumption affects the environment locally, regionally, and globally. Simultaneously, putting more efforts to generate clean energy can help improve energy efficiency. It is for this reasons that energy efficiency estimates must consider environmental and economic factors to produce fair results (Sun et al. 2019b).

Figure 2 shows the primary energy supply (Table 4). We use renewable energy (RES) by integrating renewable energy technology into the grid. The environmental benefits of RES are to reduce carbon emissions, increase the diversity of power sources, and continue to provide green energy. The increase in energy consumption leads to environmental degradation. The cycle from energy production to energy consumption involves carbon dioxide emissions, air pollution, and global warming. The USA has the highest energy supply having 2228.31 million tons while Italy has the lowest value of primary energy supply with 150.92 million tons.

Figure 3 show the renewable energy (Table 5) which helps to reduce the CO_2 and GHG emission. Results show the amount of change in carbon emission with energy consumption although this difference is intuitive, and it is because when markets with greater depth and breadth are impacted, the impact is expected to spread and the spillover effect to other markets will be greater. The UK's interaction with the USA and Canada also seems to be strong. The pairwise correlation from the UK to the USA (the USA to the UK) is equal

Fig. 1 GDP of G7 economies

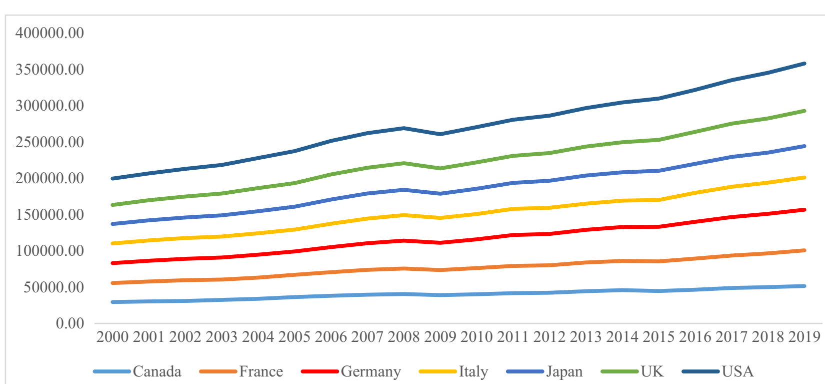


Table 3 FDI outward in million USD

Country	FDI outward(million$)
Canada	76,553.94
France	38,662.51
Germany	98,697.8
Italy	19,586.45
Japan	226,572.6
UK	41,415.23
USA	118,893

to 10.27% (10.39%). Approximately in the UK-Canada case, the same correlation figures appear, indicating that the three markets are interconnected. In addition, the European and Canadian markets are influencing each other because the connectivity values are 11.40% and 10.94%, respectively.

Figure 4 shows the electricity generation which can also be seen in Table 6. Over 90% of energy consumption in the transportation sector depends on petroleum products. As the demand for transportation energy grows, natural gas is being consumed, which is constantly increasing the CO_2 emission. A one-way causal relationship was found among the G7 countries from GDP growth to pollutant emissions. After some time, the G7 countries' declining energy intensity during the last two decades indicates that energy efficiency passes on various strategies, policies, and technologies, which are associated with overall energy consumption (Sun et al. 2020b).

Table 4 Primary energy supply (million ton)

Year	Canada	France	Germany	Italy	Japan	UK	USA
2000	253.57	251.74	336.6	171.54	518.17	222.99	2273.78
2001	249.97	260.35	346.69	172.11	509.66	223.81	2230.68
2002	250.69	261	338.91	173.32	511.15	220.66	2256.07
2003	263.9	267.6	337.07	181.62	507.68	224.52	2261.3
2004	270.5	271.48	339.53	182.88	524.2	221.81	2307.91
2005	273.48	272.66	337.59	186.37	522.25	222.85	2318.92
2006	277.9	268.25	346.87	184.67	521.91	219.11	2296.93
2007	277.13	265.31	328.57	184.08	516.63	211.17	2337.47
2008	270.68	266.49	331.51	181.65	498.36	208.83	2277.24
2009	259.66	254.97	310.4	169.62	475.42	196.36	2164.84
2010	260.05	262.86	326.36	173.74	501.37	203.67	2216.89
2011	265.78	257.06	309.87	167.97	463.89	188.83	2186.79
2012	268.62	257.08	311.21	161.34	454	193.86	2147.61
2013	273.06	258.1	317.98	155.39	454.65	191.04	2184.64
2014	280.22	248.05	306.06	146.77	439.82	179.97	2210.7
2015	281.3	251.8	308.17	152.56	432.06	181.67	2187.39
2016	281.21	247.33	310.12	150.98	427.12	179.17	2163.47
2017	289.06	247.09	311.25	153.45	432.03	175.88	2155.23
2018	299.61	245.29	298.28	150.92	426.81	176.88	2228.31

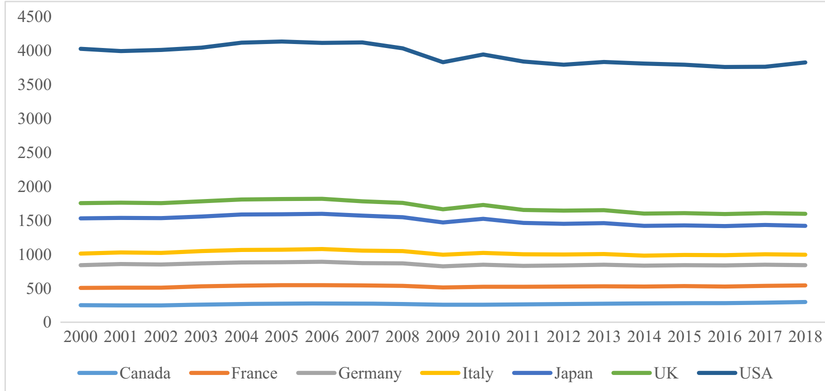
Subsequently, due to the volatility of oil and natural gas prices in the USA, efficiency increased, and short-term energy/GDP decoupling. For example, from 1965 to 2012, the number of megajoules used per USD of GDP in the world decreased from 11 to 8, which ostensibly meant decoupling. However, in these years, on average, the correlation between energy and GDP still maintains a close relationship of 99.4%. However, due to these trends, in the last two decades of the twentieth century, the rate of increase in energy intensity exceeded the historical rate. The mutation theory linking productivity and energy was discarded and replaced by other less restrictive descriptions of human economic prosperity.

Figure 5 shows the air emission of G7 regions (Table 7). The world average absolute emissions in terms of CO_2 emissions were 28,086.13 from 2000 to 2014. During the period on average non-OECD total was ranked as the 1st highest regarding average CO_2 emissions 14,659.53 more than 50% of the world's CO_2 emissions. The second highest CO_2 emissions during the period were observed in OECD total 12,409.6. Asia (including China) is the only region that CO_2 emissions value increases more than double during the period. If we compare the results with Brazil, the CO_2 emissions by different sectors in Brazil can be seen. During the period from 2000 to 2014, the agriculture sector was ranked as the 1st highest regarding average CO_2 emissions 409.840 followed by the energy sector 375.268. The industrial processes produce minimum CO_2 emissions during the period.

Economic growth and a sustainable environment are the most concerned topics in the world today. The current era requires productive and stable GDP growth. In order to stand with modern society, especially in the emerging economic zone, economic prosperity is essential. If we compare the G7 situation with the "Silk Road Economic Belt," the "Silk Road Economic Belt" is about 50 million km^2, with a total population of about 3 billion. It has abundant capital and is unique in terms of potential markets. It has an east-west road to the Asia Pacific economic circle and a Western link to the European economy. The road and belt countries have strong economic ties and have great potential in winning partnerships to win growth in the transportation, finance, and energy sectors. It is the longest economic corridor in the world with the greatest development potential. It has an important geological location and a stable location advantage.

Figure 6 shows the pollution effects in the G7 region (Table 8). Our results show that an environmental data without explicitly setting environmental goals for their entrepreneurship. Therefore, our model does control other types of green knowledge to a certain extent, rather than green knowledge quantified by patent data.

Fig. 2 Primary energy supply



Interestingly, the entry of biofuels and grid technology start-ups is highly dependent on existing infrastructure and not on the creation of new environmental knowledge. The second main focus of our research is to reveal the relationship between environmental policy and the entry of brown start-ups and the entry of green start-ups and financing results (see Table 10 for a summary of the results). However, we found that once fossil fuel companies were established, they will benefit from a stricter emission standard system by strengthening regional funding channels. This indicates that new brown companies still have opportunities, which may help existing fossil fuel companies improve emission efficiency.

Analysis based on overall composite index score performance

Energy consumption, GDP, and CO_2 emission level of the G7 countries are almost identical to the OECD region, as statistics show 55 bate of energy consumed by the OECD member nations, with a real gross domestic product, i.e., GDP of $39 trillion. This accounts for about 75% real world's gross domestic product, i.e., GDP, and 42.0% of the world's total energy. In 2010, primary energy derived from oil and coal contributed around but 13 CO_2 release, i.e., emissions than global releases of 2010 in total was 40.0%). China's advancing economy demands 18.0% of energy consumption globally. The core source of energy

Table 5 Renewable energy (KTOE)

Year	Canada	France	Germany	Italy	Japan	UK	USA
2000	44,581.92	15,738.74	8983.305	10,112.83	15,854.55	2263.767	101,974.2
2001	41,478.11	16,586.38	9636.373	10,341.08	15,140.6	2274.764	89,223.75
2002	44,148.28	15,014.52	10,782.73	10,889.38	15,970.76	2524.301	91,337.1
2003	42,822.64	15,457.91	13,761.99	12,909.27	17,421.08	2705.232	97,264.43
2004	44,200.06	15,716.45	16,008.24	12,963.45	17,639.72	3241.906	101,409.2
2005	45,647.05	15,730.06	18,560.66	14,106.77	17,209.67	3904.695	105,196.5
2006	44,348.13	15,377.13	22,650.93	15,326.51	18,319.3	4202.764	109,624.8
2007	46,019.53	16,650.62	26,187.22	16,945.88	17,706.33	4529.933	109,094.1
2008	46,065.34	18,729.53	27,203.45	19,707.15	17,223.78	5851.735	115,485.4
2009	45,140.38	18,894.65	27,084.59	21,026.53	17,039.7	6566.166	117,736.4
2010	44,111.98	20,997.42	30,757.03	21,864.34	18,783.36	7347.153	125,874.5
2011	46,571.62	18,062.83	31,852.18	21,025.84	18,903.08	8115.468	135,225.1
2012	47,242.33	21,176.98	35,785.39	23,884.75	18,185.12	8787.444	138,130.7
2013	49,509.22	23,478.85	36,881.43	26,370.66	19,592.26	10,646.89	148,137.4
2014	49,441.97	21,944.77	36,625.4	26,512.23	20,756.22	12,349.48	152,531.7
2015	49,672.67	22,579.87	39,025.49	26,268.7	22,388.95	14,621.87	149,656.4
2016	49,097.35	24,231.37	38,853.08	26,017.93	21,903.97	15,211.65	155,087.4
2017	50,572.53	23,697.1	41,446.85	26,170.7	24,010.94	16,843.28	162,450
2018	49,849.57	25,597.54	41,885.04	26,685.56	25,060.51	18,979.89	172,385.1
2019	49,455.39	25,787.3	44,019.09	26,916.59	26,186.21	21,408.05	174,468.2

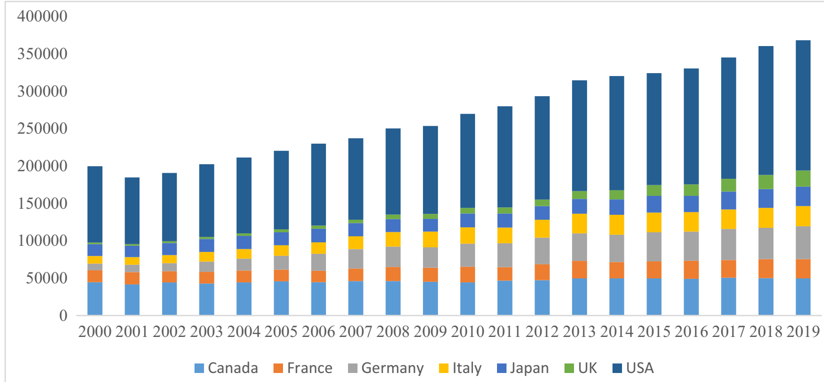


Fig. 3 Renewable energy (KTOE)

remained oil with its 33.0% share, even though its percentage as witnessed reduced over time. The comparison of G7 with OECD countries shows that they meet high political pressure globally to decrease their emissions,that is considered a main source of global warming.

Results from Table 9 shows that vertical analysis reveals that the USA ranked top in terms of overall index number while Japan has the lowest rank having the lowest score of 0.19. The USA has the highest score of 1 in 2008 while the lowest score of 0.75 in 2018. Contrary to that, Japan has the highest score of 0.40 in 2014, whereas 0.08 in 2010. Germany ranked second followed by the USA. In the past few decades, the attractiveness of ethical, environmental, and socially responsible investments can be in sharp contrast to the unobstructed investment portfolio of modern finance, which is considered the best choice for investors who wish to allocate funds. Environmentally and socially accountable investments have been a help to some extent global sustainable investment. The global socially responsible investment has increased by more than 34%, which proves the remarkable growth of environmental, social, and governance. According to data from the European Sustainable Investment Fund, the past two decades have shown clear signs that environmental, social, and governance have become indispensable for sustainable environmental integration.

Figure 7 shows the overall composite index score in G7 countries. As it is argued that the consumption of renewable energy led to decreasing CO_2 emission levels, the countries consuming a reduced quantity of renewable energy in their

Table 6 Electricity generation (GWH)

Year	Canada	France	Germany	Italy	Japan	UK	USA
2000	586,662	516,109	538,489	263,305.2	1,027,338	360,765	3,816,731
2001	570,523	525,950.8	548,166	265,981.3	1,010,241	367,392	3,736,858
2002	582,106	534,837.3	549,288	270,798.5	1,027,805	370,121	3,892,170
2003	570,542	542,213.3	569,713	280,202.7	1,018,859	380,072	3,919,132
2004	580,517	549,322	578,577	290,046.7	1,047,316	376,904	4,006,188
2005	601,167	550,034.9	582,874	290,634.9	1,065,925	380,483	4,087,961
2006	590,622	549,179.5	598,995	301,258.7	1,070,420	378,779	4,097,795
2007	608,360	544,361.6	600,683	301,299.3	1,098,983	379,136	4,190,552
2008	613,812	548,443.5	601,150	307,064.6	1,066,176	372,551	4,152,093
2009	590,537	512,284.7	558,760	281,106.3	1,049,564	360,147	3,978,760
2010	584,585	544,298.9	594,414	290,746.2	1,128,526	365,946	4,158,959
2011	614,408	548,252.8	576,247	291,442.1	1,072,883	351,530	4,136,136
2012	613,532	548,012.8	591,431	287,803.4	1,058,173	345,889	4,077,151
2013	638,562	557,770.9	600,926	278,833.4	1,066,870	340,434	4,093,401
2014	639,348	548,506	590,874	269,147.9	1,042,272	321,617	4,123,552
2015	638,494	555,126.8	610,292	272,428.4	1,027,691	327,447.2	4,109,219
2016	644,437	540,340.7	614,332	279,702.6	1,030,815	323,811	4,119,445
2017	644,141	538,092.9	619,053	285,265.6	1,040,145	322,700.3	4,086,003
2018	635,812	558,087.3	609,190	279,844.6	1,026,697	317,467	4,236,927

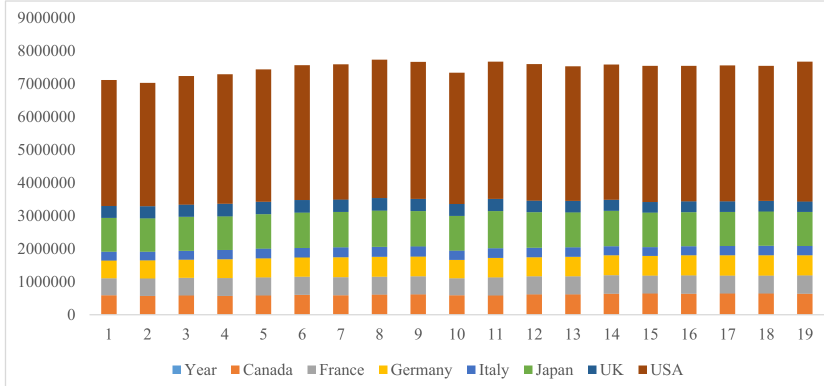


Fig. 4 Electricity generation (GWH)

nationwide demand for energy are majorly responsible for higher GHG emissions. Not surprisingly, the nation's having greater GHG releases, i.e. emissions per capita, have a lesser amount of renewable utilization and vice versa, For example, Australia's GHG emission per capita is 24.61, whereas its renewable energy consumption in the national energy mix is about 9%. Figure 4 shows the renewable energy score of G7 countries. The increasing concern and urgency of society to respond to climate change have prompted many global participants to seek solutions to environmental problems. Previously entrepreneurs have used business models, technology, finance, and social innovation to solve our most pressing social challenges. The basic mechanism promotes the emergence of new technologies in the energy sector. However, the impact of the institutional environment on emerging industries may be highly different, because it can not only encourage the establishment of new enterprises through market design incentives, for example, but also hinder the establishment of newly established companies through excessively regulated and/or restrictive regulations.

Robustness analysis

Energy and environmental indexes are derived by applying models based on linear programming, whereas the programming is based on linear modeling; its solution may be affected by obtainable entities score, which is the measurement of the true frontier, although its sample disparity and ambiguity are measured through the construction of the metrics of environmental performance. As a result, sensitivity analysis (Table 10) of data uncertainty was carried out using the non-parametric frontier method. An

Table 7 Air emission (million tons)

Time	Canada	France	Germany	Italy	Japan	UK	USA
2000	516.2592	364.67	364.6748	812.3116	420.4366	1135.607	5729.875
2001	508.5786	368.20	368.2053	831.4792	420.1814	1125.665	5702.169
2002	514.4452	362.52	362.5242	817.9019	427.1831	1165.261	5545.478
2003	534.2623	368.28	368.2827	820.7324	445.2578	1174.41	5610.75
2004	526.181	369.08	369.0813	804.6729	454.9948	1166.071	5688.778
2005	540.4315	371.89	371.8929	786.6643	456.4318	1166.814	5703.22
2006	531.1386	362.61	362.611	799.1027	449.1845	1144.715	5602.45
2007	561.8938	353.75	353.7517	766.7215	441.4611	1186.362	5686.716
2008	541.8741	349.49	349.4955	775.1868	428.8545	1122.344	5512.513
2009	514.4154	336.07	336.0744	720.2054	383.7171	1070.343	5120.69
2010	528.6186	340.21	340.2181	758.8026	391.9923	1127.152	5352.12
2011	541.1608	322.27	322.2734	731.2247	384.1074	1183.494	5128.178
2012	539.7405	325.31	325.3182	744.6742	366.6772	1225.86	4903.01
2013	549.6408	325.27	325.2773	763.7692	337.5757	1234.045	5038.524
2014	555.4694	293.18	293.1842	723.1771	319.1553	1194.052	5046.565
2015	557.6607	299.64	299.6406	729.6841	329.6623	1155.667	4928.611
2016	548.0953	301.69	301.6959	734.4871	325.6572	1146.888	4838.476
2017	547.7986	306.12	306.1235	718.7941	321.4812	1132.435	4761.302

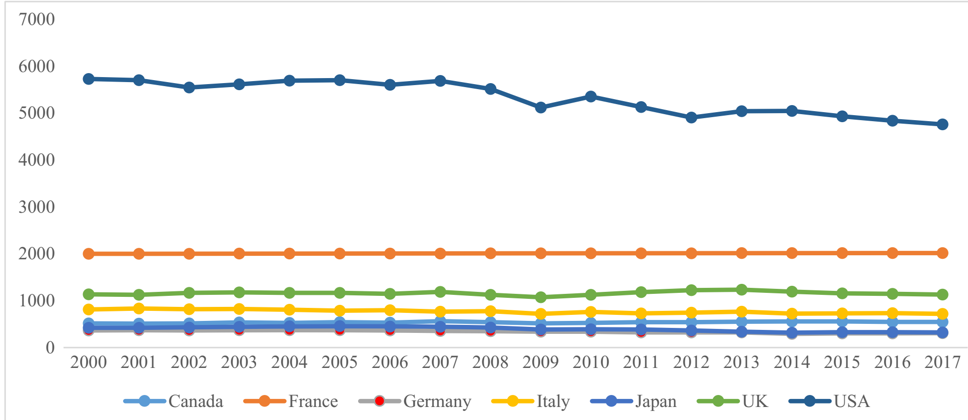


Fig. 5 Air emission (million tons)

assumption within ± 10% was used as observations for data errors. To obtain the energy and environmental efficiency for G7 countries, 15 datasets were produced through engendered and within the range of interval [− 10%, 10%] using random numbers. Additionally to the equivalent standard derivations through these 20 sets, the average value was calculated.

The values considerably fluctuate after the uncertainty within which the data accuracy was considered, while the comparison between the values produced by the original dataset and newly developed dataset for the sensitivity analysis were also provided. Few titular changes can be seen in Fig. 8), where the median and ranges of the values could be the point of insensitivity to the insecurity in data correctness with a relatively large size of the sample.

Discussion

Due to different driving factors, carbon dioxide emissions vary from region to region; therefore, suitable solutions must be employed for different scenarios. We provide new ideas for interregional cooperation. Regions should benefit from the experience of other regions with similar conditions but less emissions of CO_2 to enhance their development models. The implications of the study include. The decarbonization economy and the combination of modern and clean energy are vital for reducing carbon emissions and improving environmental quality. This pursuit of policies has always been a core of energy security, energy efficiency, and environmental sustainability goals. Policies should promote investment and research in renewable energy, which are essential for accomplishing a

Table 8 Pollution Effects (1,000,000 HAB)

Time	Canada	France	Germany	Italy	Japan	UK	USA
2000	260.846	324.095	510.9	481.412	307.511	522.841	362.279
2001	260.434	323.081	498.576	477.599	307.582	502.346	361.324
2002	261.737	324.316	497.617	477.954	309.15	496.889	359.622
2003	261.866	323.179	493.615	487.604	317.842	487.617	355.178
2004	255.999	303.716	471.518	458.052	321.716	458.557	342.345
2005	251.862	304.451	464.637	455.218	333.479	441.578	340.543
2006	247.718	300.151	457.479	452.2	334.352	430.74	333.913
2007	249.034	298.219	458.267	454.012	339.734	415.611	325.974
2008	247.089	301.566	464.963	456.795	344.162	408.015	322.742
2009	239.514	305.073	475.749	458.921	345.811	389.447	315.519
2010	229.879	301.999	479.28	448.508	353.12	379.129	306.293
2011	230.249	302.048	469.848	469.525	363.857	379.113	316.746
2012	220.521	291.377	449.521	453.59	347.96	357.442	298.242
2013	209.496	285.276	453.718	443.78	353.854	356.295	291.055
2014	205.924	263.166	436.504	439.65	341.008	335.172	277.725
2015	201.792	273.147	457.702	461.389	343.369	341.194	276.34
2016	182.572	260.384	452.778	433.194	334.002	335.749	259.243
2017	180.705	263.182	450.025	436.249	346.338	336.862	263.227

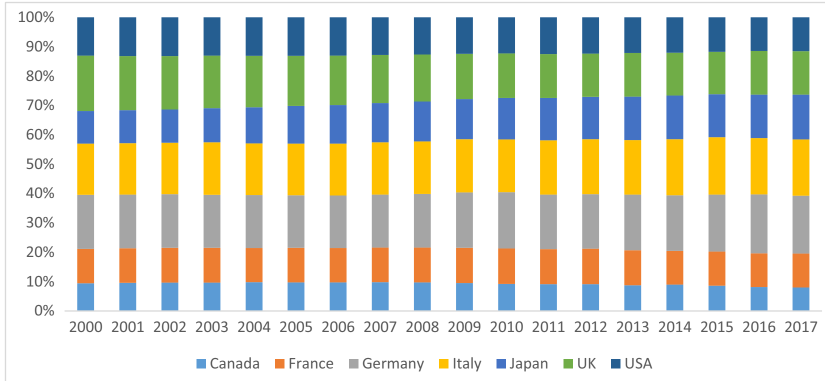


Fig. 6 Pollution effects (1,000,000 HAB)

clean and sustainable development. Besides, strict rules and regulations, like polluter fines, carbon taxes, and emission credits, are critical to reducing the rise in carbon emissions. In the long run, trade policy can be used as a means to improve the quality of the environment, although in the short run, it will worsen the environment (Song et al. 2020; Ríos and Olaya 2018).

Decarbonization is the main strategy to deal with having energy economic and environmental problems brought about by climate change. Achieving the reduction of carbon dioxide emissions and financial development is the common goal of the low-carbon development path of global communities. Considering the abovementioned importance of selecting indicators, we will appropriately consider this issue when constructing energy and economic and environmental indicators. According to the prediction of the Asian Development Bank (ADB), the temperature in the region will rise by 6 °C by 2100, which is unstoppable. It is worth mentioning that the sustainability index refers to environmental sustainability indicators, which are selected based on various indicators such as per capita carbon dioxide emissions, per capita carbon emissions, carbon dioxide emissions from power generation, forest area ratio, and public proportion. Therefore, in each scatter chart, the thicker circles indicate countries with higher government credibility, and the thinner plots indicate countries with lower government credibility. Some outliers can be observed in the graph, which may bias the value of the estimated coefficient of the traditional mean-based estimator, so it is necessary to use the quantile regression technique (Shahbaz et al. 2017). These figures represent bivariate cross-sectional relationships, so the influence of other variables in the model cannot be controlled. The positive correlation between per capita trade volumes can prove this point.

If the global economy continues to grow at an annual rate of about 3.0%, then in the next 30 years, we will consume as much energy and materials as we have accumulated in the past 10,000 years. In this context, what kind of future economic system is feasible now? What kind of choreography will enable them to achieve? As far as the human generation is concerned, in the broadest sense, the relationship between ecosystems and economic systems can hardly be seen as a hint to our collective future. Ecological economics is in a leading position in recognizing the fundamental importance of natural services and the biophysical basis of the human economy. Before formulating a prescription, we first need to make a comprehensive diagnosis of the patient. In 2019, we no longer just list the problems sporadically (Gathala et al. 2020). A coherent description of the global economy requires a systematic view, describing each part, each process, how each part and each process interact, and the implications of these interactions for future possibilities.

In this modern era, energy participation in GDP growth is of great significance. Environmental hazards cannot be ignored. Well, energy is measured in two parts such as RE and NRE. Emerging countries are relying on NRE resources, such as fossil fuel energy and crude oil. For economic reasons, the

Table 9 Overall composite index score

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Canada	0.89	0.72	0.86	0.79	0.77	0.81	0.82	0.78	0.67	0.63	0.72
France	0.51	0.43	0.30	0.37	0.48	0.53	0.50	0.52	0.30	0.52	0.36
Germany	0.83	0.85	0.94	0.94	0.93	0.87	0.73	0.94	0.74	0.94	0.77
Italy	0.38	0.33	0.65	0.26	0.35	0.49	0.47	0.14	0.17	0.38	0.57
Japan	0.19	0.22	0.08	0.16	0.13	0.31	0.40	0.33	0.24	0.26	0.33
UK	0.27	0.32	0.52	0.41	0.50	0.19	0.45	0.39	0.24	0.18	0.36
USA	1.00	0.95	0.99	0.98	0.92	0.92	0.88	0.90	0.86	0.85	0.75

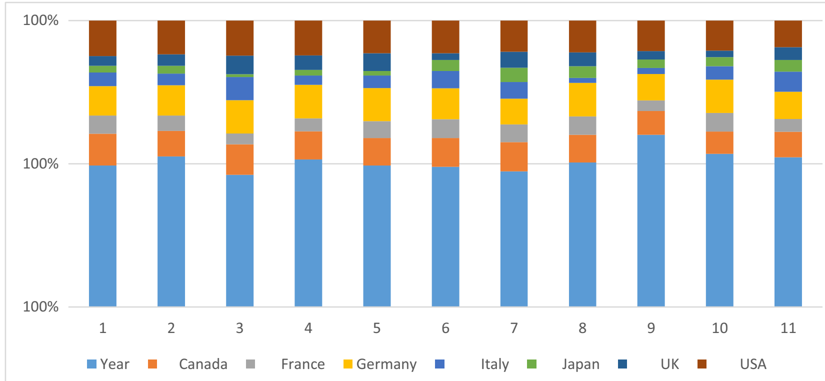


Fig. 7 Overall composite index score

NRE resources of these third world economies are relatively cheap and easy to obtain. Due to the high dependence on NRE resources, greenhouse gas and CO_2 outflows have increased, especially in emerging countries (Lin and Xu 2018; Mudakkar et al. 2013; Hanif et al. 2019). The massive emission of greenhouse gases is the main cause of climate change, global warming, and environmental degradation. Some countries have a high degree of confidence in NRE resources (such as the use of fossil fuels). Because of this belief, a large amount of CO_2 emissions have been found in these countries. In the past decade, the average value of NRE energy consumption and CO_2 emissions in emerging countries has been staggeringly high (Raza et al. 2019). In Southeast Asia, Malaysia uses 96.77% of NRE, and Malaysia's per capita carbon dioxide emissions are 7.38 tons, the highest in the region. In South Asia, India consumes 70.19% of NRE resources, and per capita carbon dioxide emissions are about 1.39 metric tons. In Central Asia, Kazakhstan is highly dependent on NRE, about 98.93%, and its per capita carbon dioxide emissions are 14.18 metric tons. In the Middle East, Iran ranks among the countries that consume the most NRE with emissions of 99.18, with recorded per capita carbon dioxide emissions of 7.57 metric tons (World Bank 2017). Although stable GDP growth and a sustainable environment are requirements for every emerging society to obtain a developed social status, therefore the main focus of this study is to measure GDP growth, renewable energy, and the impact of renewable energy on carbon dioxide emissions.

Conclusion and policy implication

The assessment of the financial and social indicators considered for CO_2 emissions in G7 countries, from 2008 to 2018, took place when the emissions growth rate declined due to the decrease of the economic growth. The DEA-like composite index, environmental performance, and social and financial indicators in the G-7 countries show that the USA performs better for sustainability by mediating the role of other financial, human, fiscal, and energy-related indicators. Economies such as Canada and Germany show an acceptable condition of environmental sustainability after the USA. Nevertheless, Japan, UK, and Italy are suffering from environmental problems. Consequently, more efforts are needed to find a sustainable environment in their corresponding regions. Principally, the escalation of CO_2 emissions in G7 was driven by the fast and monotonic economic growth which surpassed the evaluation of the CO_2 emissions. However, this driver has gradually led to a reduction of the emissions growth rate. By the new normal stage, the economic development fell from 39 to 19.7% in the first three stages. From this standpoint, the growth rate drop-off could be considered one of the factors that might have led the G7 economy to shift from a growing high-quantity pattern to a high-quality pattern with inclusive and sustainable improvements.

The optimization of energy consumption requires vigorous inclusion of non-fossil energy, hydropower development, safe nuclear power application, wind and solar power, as well as

Table 10 Sensitivity analysis

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Canada	0.86	0.77	0.86	0.74	0.77	0.81	0.82	0.78	0.69	0.67	0.71
France	0.53	0.43	0.3	0.37	0.48	0.53	0.5	0.52	0.3	0.52	0.41
Germany	0.84	0.85	0.94	0.94	0.93	0.85	0.73	0.94	0.74	0.94	0.81
Italy	0.41	0.33	0.65	0.26	0.35	0.49	0.47	0.21	0.21	0.38	0.62
Japan	0.21	0.22	0.15	0.16	0.13	0.31	0.31	0.33	0.24	0.26	0.41
UK	0.31	0.32	0.52	0.41	0.5	0.19	0.45	0.39	0.24	0.29	0.33
USA	0.98	0.96	0.99	0.97	0.92	0.91	0.88	0.86	0.86	0.85	0.78

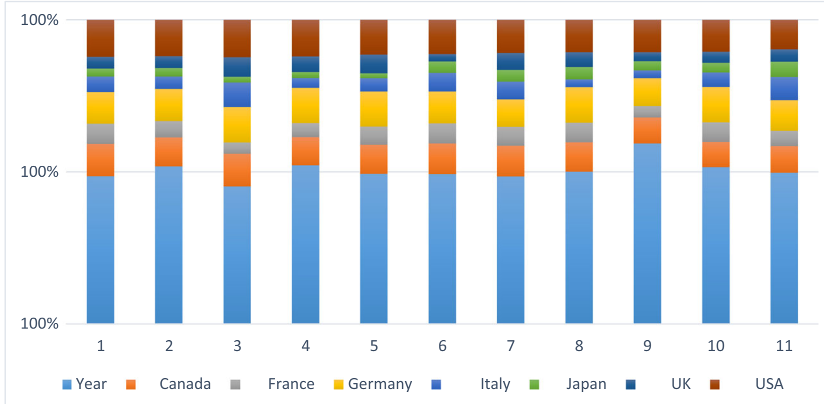


Fig. 8 Sensitivity analysis

solid advancements of geothermal and biomass energy. Therefore, clean energy has a powerful effect on the energy structure adjustments and the entire economic redeployment. Energy industries are growing fast; G7 can successfully save energy and reduce its consumption through a series of policies that include transforming the modes of energy development, increasing the proportion of green-environmentally-friendly energy as well as its consumption, and continuously optimizing the energy consumption structure. Another surprising finding is that the G7 energy consumption growth rate has decreased to 2.3% despite the population growth that previously caused CO_2 emission increase. The emission intensity remained almost stable at about 6% throughout the entire period, with slight fluctuations only.

This means that the world is the least carbon safe and most environmentally fragile, even though the G7 nations have higher economic growth. Therefore, the study proposes the following policy framework: strong policies and mechanisms should be put in place to expand supplies of adequate renewable and inexpensive energy to maintain a healthy climate without limiting economic growth and development. At the corporate level, the corporations should adopt social responsibility policies and strategies in which the safety of the environment would be given a priority. Such CSR activities may include awareness of zero-emission operations during production, establishing green parks, and footpath development. Furthermore, through encouraging and implementing energy efficiency strategies, the state should concentrate on decreasing pollutant emissions and electricity conservation under the Paris Agreement. The government should control enormous energy demand as there is a need for cooperation between energy markets to reach climate change targets. The creation of industry standards and sustainable industry strategy may produce higher pollution barriers with environmental concerns to gain economic benefits. Contemporary and growing concerns on sustainable development and global warming should be advocated globally by energy policymakers.

Authors' contributions Nguyen Van Song: Conceptualization, data curation, methodology, writing—original draft

Nguyen Thi Minh Phuong: Data curation, visualization

Thai Thi Kim Oanh: Visualization, supervision, editing

Do Huy Chien: Review and editing

Vu Quang Phuc: Writing—review and editing and software

Muhammad Mohsin: Editing, reviewing

Funding This research did not receive any specific funding from public, commercial, or non-profit sector funding agencies.

Data availability The data that support the findings of this study are openly available on request.

Compliance with ethical standards

Competing interests We declare that there is no conflict of interest.

Ethical approval and consent to participate The authors declare that they have no known competing financial interests or personal relationships that seem to affect the work reported in this article. We declare that we have no human participants, human data, or human tissues.

Consent for publication We do not have any individual person's data in any form.

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