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Impact of energy efficiency and sharing economy on the achievement of sustainable economic development: New evidences from China

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ABSTRACT

Recently, energy efficiency and the sharing economy have become significant factors for sustainable economic development (SED), which require the attention of researchers and policymakers. Thus, the present research investigates the impact of energy efficiency and the sharing economy on SED in China. Secondary data is used covering the period from 1991 to 2020. The study runs the augmented Dickey-Fuller (ADF) test to check the unit root and the quantile autoregressive distributed lag (QARDL) model to investigate the linkages amongst the variables. The results indicate that efficient energy use, sharing economy users, sharing economy values, population growth, urbanization and industrialization have positive linkages with SED in China. This study guides policymakers developing policies related to the achievement of SED using efficient energy and a valuable sharing economy.

Introduction

Sustainable economic development refers to economic development in which the primary goal is to safeguard the environment and ensure human wellbeing. It is a form of human development in which resources are used in a way that meets human needs with little impact or damage to the environment, with the goal of meeting the current needs of people and those of future generations (Abad-Segura & Gonzalez-Zamar, 2021). Economic activity, such as running plants, machines or appliances, building infrastructure, logistics, and the use of resources for production and operational purposes, leave an impact on the environment and cause harm (Oyedepo, 2012). When a country's economy grows rapidly, these activities have negative consequences for the environment, such as hazardous waste emissions, greenhouse gas (GHG) emissions, smoke, climate change, land pollution, and water pollution (Shahsavari & Akbari, 2018). These environmental difficulties harm natural resources and living species, including animals, birds, and fish, as well as the health of those who live in the area (Bejinaru et al., 2022; Gryshova et al., 2020; Odei & Novak, 2022; Pilinkienė et al., 2021). Natural resources, including living things, offer operational resources and raw materials to fulfil basic human requirements (Chand et al., 2022). So, if natural resources are used up completely as a result of economic activity, sooner or later social welfare and the rate of development of the economy will come to a halt, making it tough for the country to survive. Therefore, it is necessary to incorporate environmental protection into economic development, which is referred to as sustainable economic development (Bejinaru et al., 2022; Candan & Cengiz Toklu, 2022; Du et al., 2020; Akmal, Laeeque, Ahsan & Fatima, 2020; Sharma & Das, 2021; Wang & Lei, 2022).

Energy consumption is a necessary component of both life and the economy, since it facilitates a variety of social and economic activities. These activities include lighting, heating, cooling, building, transport (goods and people moving from one location to another), household appliances, machines, plants, and technologies used in manufacturing, production, construction, and services (Aljohani et al., 2022; Clauss et al., 2021; Mondal et al., 2018; Akmal, Laeeque, Ahsan & Fatima, 2020; Sharma & Das, 2021; Wang & Lei, 2022). It is an undeniable fact that energy sources which are available naturally are few in number and limited in amount. If people continue to use

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them, they will soon become depleted. Secondly, the use of energy sources such as fossil fuels, produces hazardous gases, including GHGs, and toxic waste, which are destructive to the environment and upset its equilibrium. It is difficult to build consistency into a country's development and economic growth with climate change and damaged natural resources (Bartkiewicz, 2020; Felis & Golebiowski, 2021; Malinauskaite et al., 2019). Through energy efficiency, the use of energy can be reduced, naturally occurring energy sources can be preserved and the negative environmental impacts of economic activities can be lessened (Hassan et al., 2022). By maintaining the environment and its elements, such as natural resources, living species, and healthy individuals, energy efficiency ensures energy for the future while simultaneously ensuring resources and a labour force. As a result, energy efficiency helps promote sustainable economic development (Radchenko et al., 2020; Tronchin, Manfren & Nastasi, 2018; Ward, 2020; Wawrzyniak & Doryń, 2020).

In the sharing economy, individuals or businesses exchange physical, technological, financial, information, and human resources. The sharing economy has numerous benefits, such as reduction of costs, increased access to resources, equal rights to use various types of resources, and alleviated financial suffering (Alawajee & Almutairi, 2022; Ma et al., 2019; Zelenović et al., 2022). The effective implementation of the sharing economy inside a country is beneficial for promoting optimal use of resources, reducing energy consumption, and improving sustainable economic development. Thus, it improves the environmental quality and social welfare (Cheng, 2016). The efficient resource utilization, lower energy consumption, simple access to resources, cost reduction, and smart financial management that comes with an increase in the number of sharing economy users or improvement in the value of the sharing economy, contribute to economic sustainability (Chen, Feng & Zhou, 2022b; Geissinger et al., 2019; Hussain et al., 2022; Jamil et al., 2022).

The current study explores the impacts of energy efficiency, sharing economy users, and sharing economy value along with population growth, urbanization, and industrialization on sustainable economic development in the Chinese economy. China has an upper-middle-income economy. It has a large population of 1411,787,241 people, as of 2020, and in 2022 it is set to achieve a GDP of $19.91 trillion. It is a great credit to China that it is paying attention to the achievement of sustainability in economic development at a time when the country's GDP is hardly more than a third of the developed economies of the world. Although China, a relatively poor country, is making rapid economic growth, it has started to turn its focus from quantitative development to qualitative economic development (Haibo et al., 2020; Hoa et al., 2022; Nasution, 2021). China is the biggest emitter of GHGs, which is why, for the achievement of sustainable development, the country makes efforts to reduce of the use of energy, become more ecological friendly in terms of transportation, and implement energy transition, and a sharing economy. China is the largest energy consumer in the world. For this reason, China's sharing economy and energy efficiency are crucial to global energy and environmental issues (Jia et al., 2018; Oladele & Nubong, 2022; Seriwatana, 2022).

As of 2018, China had 22% of global energy consumption and 29% of global GHG emissions from the combustion of non-renewable energy such as fossil fuels (Yang & Li, 2017). In recent years, China has made progress in energy efficiency and the sharing economy, especially in terms of technology. The country has achieved almost no gains in energy efficiency or the sharing economy since 2010, and consumes 25% more energy than in 2018 (Fig. 1). China's economy has transitioned from energy-intensive firms, primarily large industries, to service-orientated enterprises, resulting in structural changes and reduced energy needs. The majority of energy efficiency struggles occur in the industrial sector (ALSoud et al., 2021; Vo & Ngo, 2021; Zhu et al., 2019). For sustainable economic development, schemes such as digital labelling of the nature of energy, and

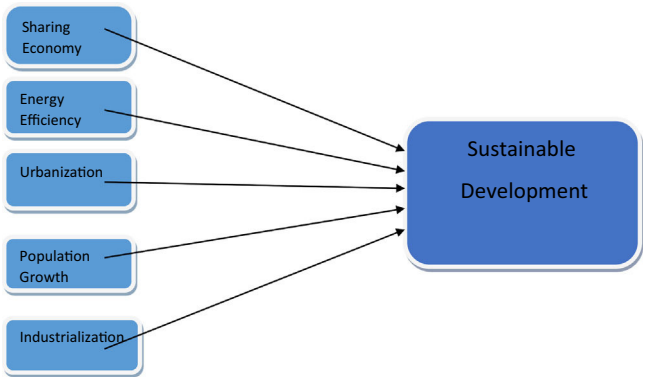

Fig. 2. Conceptual Framework.

reinforcement of the TOP 10,000 plan in the industrial sector are appreciated. These are major pieces of legislation that put China's energy efficiency programmes far ahead of the global average. China has advanced technology, a rapidly expanding industrialized economy, a large population, and a vast transportation system. As a result, energy consumption in this country is higher than in other economies, and this high energy consumption, particularly from fossil fuel combustion, releases a significant quantity of GHGs (Draper & Schellenberg, 2022; Duke & Osim, 2020; Wu et al., 2019). The resulting environmental degradation makes it impossible for the country to achieve sustainable economic progress. The economy still requires measures to achieve sustainable economic development, and this study addresses this issue. The objective of the study is to explore the influences of efficient use of energy, sharing economy users, and sharing economy value along with population growth, urbanization, and industrialization on sustainable economic development (He, Leng & Pan, 2021; Malakauskas & Lakštutienė, 2021; Sytsma, 2021; Zhang et al., 2021).

Over recent years, sustainable economic development has become a popular topic of discussion. The present study makes many contributions to the literature. Firstly, in the previous literature, either studies address the role of energy efficiency or the sharing economy in sustainable economic development. The present study sheds light on both energy efficiency and the sharing economy as it analyses sustainable economic development, adding to the previous literature. Secondly, in previous research, the sharing economy's role in sustainable economic development is analysed as a whole. There are hardly any literary articles which discuss the dimensions of a sharing economy, such as sharing economy users or sharing economy value, to determine sustainable economic development. In this study, this literary gap is filled. Thirdly, China has long been the biggest emitter of GHGs, but studies simply discuss this as a hurdle to achieving sustainable economic development. The present study contributes to the literature by highlighting measures such as energy efficiency and the sharing economy for sustainable economic development (Paraschiv et al., 2021; Tiberius, Schwarzer & Roig-Dobón, 2021).

The paper is structured as follows. The next section is a review of the past literature on the relationships amongst the study factors. Then the methodology, processes applied for data collection and analysis, and results are described. The results of the study are supported by previous studies, and this discussion is followed by the conclusions and limitations.

Literature review and theoretical underpinnings

Consideration of the conditions that lead to the formation of a sharing economy and how they align with the tenets of sustainable development is necessary to comprehend the relationship between the sharing economy and sustainable development. A sharing

economy is characterized by complex economic, technological, environmental and social changes. The following list, based on the work of (Gold, 2003; Lyaskovskaya, 2021; Zhu & Liu, 2021), indicates the prerequisites necessary for the emergence of a sharing economy.

The present notion of a sharing economy, which represents a significant shift in the technological and technical aspects of consumption and production is, in the opinion of the majority of researchers, brought about by the digitalization of many spheres of life. Digitalization and a new phase of industrialization are widely acknowledged as the most important aspects of the shift to a digital world, including big data, augmented production, robotization, cloud computing, 3D printing, storage of data etc. Digitalization has a greater influence on consumption techniques, which affect millions of families worldwide, than how goods and services are created. New sharing economy business models emerge as a result of these shifts, demonstrating a new level of socially and ecologically conscious behaviour engrained in sustainable purchasing. The new models of business in a sharing economy including responsible and sustainable consumption coincide with the socially conscious, economic and ecological objectives of sustainable purchasing and are made possible by analysis of the conditions that lead to the birth of a sharing economy (Lyaskovskaya & Khudyakova, 2021). The sharing economy is presented in various studies as an economic benefit that facilitates more environmentally friendly consumption of shared goods and acts as a stepping stone to a strong and sustainable society (Boar, Bastida & Marimon, 2020; Curtis & Lehner, 2019). The connections between the sharing economy and the long-term health and growth of national economies, as well as the implications for the attainment of sustainable development goals, are highlighted by these arguments (Curtis & Mont, 2020; Mi & Coffman, 2019).

Sustainable economic development is the act of building an economy with the goal of not only achieving economic or financial objectives but also protecting the natural environment and ensuring the social welfare of the population. It is a process of development in which resources are used in such a way that they meet not only current economic requirements, but also future needs. Increasing use of energy resources, economic practices such as manufacturing, building infrastructure, transportation, and technology may obstruct future generations' progress by destroying the environment and natural resources (Ndubisi, Zhai & Lai, 2021; Serra et al., 2021). Energy efficiency is a significant step to sustainable economic development. Energy efficiency is a way of undertaking social and economic activities in which energy consumption is decreased, and negative environmental repercussions minimized. When energy efficiency is applied effectively, it can help create a secure environment and abundant high-quality natural resources. The sharing economy is a concept that carries a number of social benefits, including maximizing resource utilization, providing access to, or the right to use, resources, enhancing equality, lowering expenses, and assisting with financial management. The adoption of a sharing economy at a larger scale opens a path to sustainable economic development (Ma et al., 2018). The current article analyses the impacts of efficient use of energy, sharing economy users, and sharing economy value along with population growth, urbanization, and industrialization on sustainable economic development in the light of previous literature.

Using empirical research, (Rebelatto et al., 2019) examine energy efficiency initiatives' contribution to sustainable development. The analysis is based on data regarding energy sources and information about energy efficiency initiatives taken by the University of Passo Fundo, an institution of higher education in Brazil. The study implies that initiatives for energy efficiency with a focus on photovoltaic solar power generation and utilization, and free energy marketing increase people's access to modern energy, encourage renewable generation and consumption, increase the productive capacity of energy sources, and encourage clean energy, all of which are essential to sustainable economic development. So, energy efficiency has a positive link to sustainable economic development. (Nurunnabi et al., 2020) posit that environmental pollution is mostly caused by energy production, such as nuclear power, as well as energy consumption. Energy efficiency uses the smallest amount of energy, mostly renewable energy, without disrupting economic processes, and therefore allows pollution to be reduced and economic growth to be sustainable. (Ziolo et al., 2020) analyse the influences of energy efficiency on sustainable economic and financial development in OECD countries over the period 2000 to 2018, using data envelopment analysis and regression analysis. The study implies that climate change is caused by GHG emissions, and poses challenges to emerging economies. The increasing use of energy and machinery is a major cause of environmental concerns. The question is whether it is likely to achieve sustainable economic and financial development without damaging the environment. The integration of energy efficiency in business policies answers this question by making it possible to achieve sustainable economic and financial development with the least impact on the environment (Genc, 2021; Sigalat-Signes et al., 2020; Wang et al., 2020).

(Leung, Xue & Wen, 2019) investigate the influence of sharing economy users on sustainable eco-systems and sustainable economic development, using news media discourse. The data on sharing economy users, sustainable eco-systems and sustainable economic development come from 341 online news articles published in 13 US news outlets between 2011 and 2017. The findings show that sharing economy users have a positive association with sustainable economic development for assuring a sustainable eco-system. An increase in sharing economy users develops resilience in nature and, with a sustainable eco-system, sustainability can be created in economic development. (Curtis & Lehner, 2019) identify the relationship between sharing economy users and sustainable economic development. The study posits that the many people who lack access to resources, professional knowledge, training, and the opportunity to avail themselves of technology are unable to participate in economic activity. But the distinction between access to technology, human capital, and other resources is reduced when the number of sharing economy users grows. When more people participate in economic activities or continue such activities, the economy develops sustainably. (Pouri & Hilty, 2018) analyse sharing economy users' role in sustainable economic development, arguing that, as the number of sharing economy users grows, increasing environmentally friendly economic activity, firms should have less negative impact on the environment. Consequently, the sustainability of environmental quality and protection of natural resources develop sustainability in economic performance. So, the number of sharing economic users has a positive association with sustainable economic development.

(Govindan, Shankar & Kannan, 2020) identify the contribution of sharing economy value to sustainable economic development. The authors investigate the hurdles to sharing economy execution in small and medium firms functioning in the Indian economy, to determine the relationship between sharing economy value and sustainable development. Previous literature is used to determine hurdles to sharing economy value, and, thus, the sharing economy value's contribution to sustainable economic development. According to the report, if these hurdles to sharing economy implementation are addressed, and it is implemented properly, any sort of economic resources can be preserved for future consumption while addressing the demands of the current generation. In this sense, the sharing economy contributes to sustainable economic growth. (Shih, 2019) takes the view that, as the value of the sharing economy rises, commercial enterprises are able to obtain environmentally friendly technology with fewer resources and use them to reduce the negative environmental effects of their operations. Environmental deterioration is reduced, and natural resources are protected, ensuring sustainable economic development. (Sung, Kim & Lee, 2018) also examine the sharing economy's impact on sustainable economic

development. During the business journey, organizations may cause environmental concerns such as air pollution, GHG emissions, filthy water, and soil pollution. With an increase in the value of the informational, physical, and technological resources under a sharing economy, organizations can overcome these environmental problems. This provides environmental purity, abundant resources, and a skilled and active workforce which offer high sustainability in economic development.

The study conducted by Rehman et al. (2022) examines population growth and its contribution to sustainable economic development. A society's labour force is determined by its population, and a growing population needs massive production of products and services. The increased human resources and the demand for goods and services result in enhanced economic productivity, as well as natural and manufactured resources, allowing for sustainable economic development. Kurniawan and Managi (2018) shed light on the association between population growth and sustainable economic development, arguing that humans are in charge of and undertake all economic activity. When a country's population grows rapidly, there is a need for economic expansion and a significant number of administrators and labour. This ensures economic development's sustainable viability.

Deep research by Fang et al. (2019) sheds light on urbanization's role in sustainable economic development. The study suggests that urban areas are where economic activities take place and all economic resources are readily available. In metropolitan locations, technological advancement and human capital growth are conceivable. When the population shifts from rural to urban regions, economic development is more likely to be sustainable. So, urbanization positively contributes to sustainable economic development. (Zhang et al., 2019) also consider the role of urbanization in sustainable economic development, and are of the view that, in urban areas, better health facilities are available, human capital is high, there are technological advancements and effective communication systems, and efforts to attain sustainable economic development can be fruitful. The findings show a positive association between urbanization and sustainable economic development. (Zhang et al., 2022) show the relationship between urbanization and sustainable economic development, suggesting that urbanization enhances economic activity in all sectors, capital formation, and human capital development in the wider country.

Through empirical research, (Opoku & Boachie, 2020) identify the relationship between industrialization and sustainable economic development. Information is acquired from 37 African countries using a survey spanning 1980 to 2014, and the generalized method of moment technique is applied for the analysis. Firstly, the study confirms that industrialization boosts economic growth. Secondly, it reveals that, when trade openness is at its peak, it improves industrialization's contribution to economic growth and makes the economic development sustainable. (Candan & Cengiz Toklu, 2022) examine sustainability in industrialized performance and the resultant sustainable economic development. Data are collected from EU member states, and sustainable economic development is analysed under three criteria, environmental, social, and economic, with 16 sub-criteria. The research finds that industrialization determines people's living standards and the development of human capital, both of which are necessary for economic fluency. As a result, there is no doubt that countries can achieve long-term economic growth.

This review of earlier studies, reveals the relation between the efficient use of energy, sharing economy users, sharing economy value, population growth, urbanization, industrialization, and sustainable economic development. However, while these studies focus on various countries and areas, China has never been the focus of research. In previous literature, the role of energy efficiency and the sharing economy in sustainable economic development are analysed, but in separate articles. The present study amalgamates energy efficiency, the sharing economy and sustainable economic development. Moreover, throughout the previous literature, the sharing economy, as a determinant of sustainable economic development, is examined without its dimensions. This study examines two measurements of a sharing economy, sharing economy users and sharing economy value, and their effect on sustainable economic development. The selection of China, as the biggest emitter of GHGs, to analyse these relationships is another literary contribution. Therefore, this study fills a research gap and analyses the impacts of efficient use of energy, sharing economy users, and sharing economy value, along with population growth, urbanization, and industrialization, on sustainable economic development in China.

The following hypothesis are formed on the basis of previous studies:

H1: Sharing economy affects sustainable development significantly and positively.
H2: Energy efficiency affects sustainable development significantly and positively.

Research methods

Conceptual framework

The conceptual framework of this study is presented in Fig. 2, below. It shows how the study investigates the impact of efficient energy use, sharing economy users, sharing economy values, population growth, urbanization, and industrialization on sustainable economic development in China.

The secondary data for the study are extracted from Statista, WDI and Sustainable Development Solution Network databases from 1991 to 2020. The study establishes the equation:

$$SED_t = \alpha_0 + \beta_1 EEU_t + \beta_2 SEU_t + \beta_3 SEV_t + \beta_4 POPG_t + \beta_5 URB_t + \beta_6 IND_{it} + e_i \quad (1)$$

where:

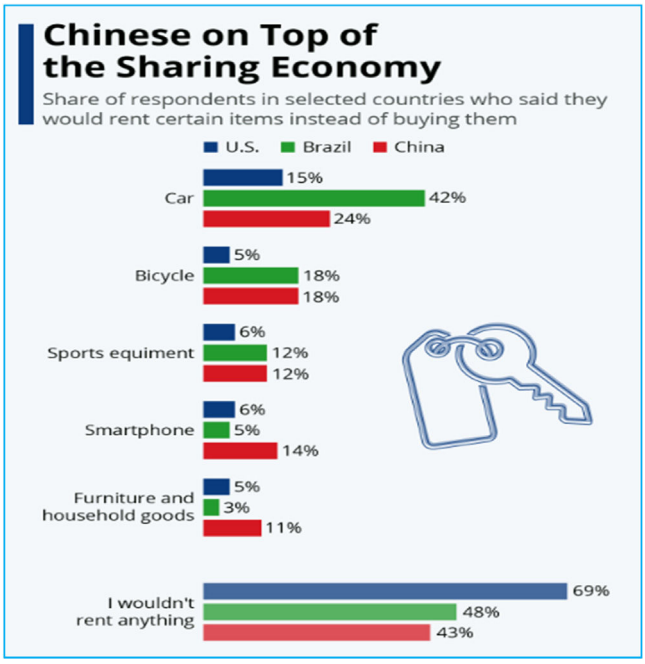

Fig. 1. China's Sharing Economy Source: Statista (2020).

Table 1
Measurements of variables.

S#	Variable	Measurement	Source	Expected sign	Reference
01	Sustainable Economic Development	Sustainable development index	Sustainable Development Solution Network		
02	Efficient Energy Use	Energy use (kg of oil equivalent per capita)	WDI	Positive	(Rebelatto et al., 2019), (Nurunnabi et al., 2020)
03	Sharing Economy	Sharing economy users (in millions) Sharing economy values (in billions of US dollars)	Statista	Positive	(Pouri & Hilty, 2018) (Govindan et al., 2020), (Shih, 2019)
04	Population Growth	Population growth (annual%)	WDI	Positive	(Rehman et al., 2022), Kurniawan and Managi (2018)
05	Urbanization	Urban population (% of total population)	WDI	Positive	(Zhang et al., 2022)), (Fang et al., 2019)
06	Industrialization	Industry value added (% of GDP)	WDI	Positive	(Opoku & Boachie, 2020), (Candan & Cengiz Toklu, 2022)

SED = sustainable economic development
t = time period
EEU = efficient energy use
SEU = sharing economy users
SEV = sharing economy value
POPG = population growth
URB = urbanization
IND = industrialization

The article takes SED as the predictive variable, measured by the sustainable development index. The article has two predictors, EEU measured as the energy use (kg of oil equivalent per capita) and sharing economy, measured as SEU (in millions) and SEV (in billions of US dollars), following (Leung et al., 2019), (Curtis & Lehner, 2019), and (Shih, 2019). Finally, the article takes three control variables, POPG measured as population growth (annual%), URB measured as the urban population (% of the total population), and IND measured as the industry value added (% of GDP), in line with (Jiang et al., 2022; Lipińska, 2021; Mohammad & Pan, 2021; Nilakantan, 2021; Ramos et al., 2021). Table 1 shows the variables and their measurements.

This research article employs descriptive statistics to provide details of variables such as mean, minimum, and maximum values and standard deviations. The article also employs a matrix of correlation to provide the directional associations amongst the variables. In order to apply the autoregressive distributed lag (ARDL) model, the augmented Dickey-Fuller (ADF) test is used to find the unit root. The equation is:

$$d(Y_t) = \alpha_0 + \beta t + \gamma Y_{t-1} + d(Y_t(-1)) + \varepsilon_t \quad (2)$$

The ADF unit root test has the features of checking the unit root of the variables individually, and the individual equations are given below.

Sustainable economic development:

$$d(SED_t) = \alpha_0 + \beta t + \gamma SED_{t-1} + d(SED_t(-1)) + \varepsilon_t \quad (3)$$

Efficient energy use:

$$d(EEU_t) = \alpha_0 + \beta t + \gamma EEU_{t-1} + d(EEU_t(-1)) + \varepsilon_t \quad (4)$$

Sharing economy users:

$$d(SEU_t) = \alpha_0 + \beta t + \gamma SEU_{t-1} + d(SEU_t(-1)) + \varepsilon_t \quad (5)$$

Sharing economy value:

$$d(SEV_t) = \alpha_0 + \beta t + \gamma SEV_{t-1} + d(SEV_t(-1)) + \varepsilon_t \quad (6)$$

Population growth:

$$d(POPG_t) = \alpha_0 + \beta t + \gamma POPG_{t-1} + d(POPG_t(-1)) + \varepsilon_t \quad (7)$$

Urbanization:

$$d(URB_t) = \alpha_0 + \beta t + \gamma URB_{t-1} + d(URB_t(-1)) + \varepsilon_t \quad (8)$$

Industrialization:

$$d(IND_t) = \alpha_0 + \beta t + \gamma IND_{t-1} + d(IND_t(-1)) + \varepsilon_t \quad (9)$$

Following (Suki et al., 2020), (Godil et al., 2021), (Chang et al., 2020; Godil et al., 2020), the research uses the quantile autoregressive distributed lag (QARDL) model to examine the nexus amongst the variables, as proposed by Cho, Kim and Shin (2015), which shows quantile asymmetries in the long and short run adjustments between dependant and independent variables. The QARDL model outperforms the linear ARDL technique by permitting possible asymmetries in the response of sustainable development to variations in energy efficiency, sharing economy, population growth, urbanization and industrialization across the quantile range. The major feature of the ARDL model is that it is suitable when the stationarity results show that some constructs that have unit root at I(0) and some at I(1). This approach is also appropriate when researchers have small sample sizes (Sharif et al., 2020) such as the current study with only 30 observations. It also has the ability to provide the short and the long-run nexus amongst the variables. The study develops the panel ARDL model:

$$\begin{aligned}\Delta SED_{it} = {} & \alpha_0 + \sum \delta_1 \Delta SED_{it-1} + \sum \delta_2 \Delta EEU_{it-1} + \sum \delta_3 \Delta SEU_{it-1} \\ & + \sum \delta_4 \Delta SEV_{it-1} + \sum \delta_5 \Delta POPG_{it-1} + \sum \delta_6 \Delta URB_{it-1} + \sum \delta_7 \Delta IND_{it-1} \\ & + \varphi_1 SED_{it-1} + \varphi_2 EEU_{it-1} + \varphi_3 SEU_{it-1} + \varphi_4 SEV_{it-1} \\ & + \varphi_5 POPG_{it-1} + \varphi_6 URB_{it-1} + \varphi_7 IND_{it-1} + \varepsilon_{it}\end{aligned} \quad (10)$$

where δ_1, δ_2, δ_3, δ_4, and δ_5 represent the short-term association coefficients, and φ_1, φ_2, φ_3, φ_4, φ_5, and ε_1 represent the long-term association coefficients. The QARDL model is:

$$\begin{aligned}Q_{SEDt} = {} & \alpha(\tau)_0 + \sum_{i=1}^{n1} b_i(\tau) SED_{t-i} + \sum_{i=0}^{n2} c_i(\tau) EEU_{t-i} + \sum_{i=0}^{n3} d_i(\tau) SEU_{t-i} \\ & + \sum_{i=0}^{n4} e_i(\tau) SEV_{t-i} \\ & + \sum_{i=0}^{n5} f_i(\tau) POPG_{t-i} + \sum_{i=0}^{n6} g_i(\tau) URB_{t-i} + \sum_{i=0}^{n7} h_i(\tau) IND_{t-i} \\ & + \varphi_1 SED_{t-1} + \varphi_2(\tau) EEU_{t-1} + \varphi_3(\tau) SEU_{t-1} + \varphi_4(\tau) SEV_{t-1} + \varphi_5(\tau) POPG_{t-1} \\ & + \varphi_6(\tau) URB_{t-1} + \varphi_7(\tau) IND_{t-1} + \varepsilon_t\end{aligned} \quad (11)$$

The quantiles used are $\tau = (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9)$. The stability of the model is examined using the CUSUM and CUSUMQ tests, while the model's goodness of fit is examined using adjusted r squared.

Research findings

The research employs descriptive statistics to provide details of the variables such as mean, minimum, and maximum values and

Table 2
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
SED	30	54.453	3.892	51.029	80.882
EEU	30	1390.829	74.092	903.875	27.810
SEU	30	41.928	2.891	29.810	50.122
SEV	30	215.902	7.010	194.998	239.014
POPG	30	0.653	0.281	0.372	0.902
URB	30	14.901	2.871	5.902	27.928
IND	30	9.092	1.892	5.018	19.626

Table 3
Matrix of correlations.

Variable	SED	EEU	SEU	SEV	POPG	URB	IND
SED	1.000						
EEU	0.661	1.000					
SEU	0.765	0.673	1.000				
SEV	0.497	0.362	0.463	1.000			
POPG	0.746	0.894	−0.661	0.473	1.000		
URB	0.554	0.343	0.996	0.535	0.524	0.434	
IND	0.537	0.437	0.456	0.581	0.388	1.000	1.000

standard deviations. The findings reveal that the mean value of SED is 54.453%, while the average value of EEU is 1390.829 kg of oil. The mean value of SEU is 41.928 million people, while the average value of SEV is 215.902 billion dollars. The mean value of POPG is 0.653%, while the average value of URB is 14.901% and the average value of IND is 9.092%. Table 2 shows the descriptive statistics.

The research employs a matrix of correlation to provide the directional associations amongst the variables. The results indicate that efficient energy use, sharing economy users, sharing economy values, population growth, urbanization and industrialization have a positive link with SED in China. Table 3 shows the correlation matrix.

To apply the ARDL, the article tests the unit roots of the variables using the ADF test. The results indicate that EEU, POPG, and URB are stationary at level, while SED, SEU, SEV, and IND are stationary at first difference. Table 4 shows the results of the unit root test.

The results indicate that efficient energy use, sharing economy users, sharing economy values, population growth, urbanization and industrialization have positive linkages with SED in China. The results also indicate that the EEU has a significant nexus with SED in quantiles 1 to 7 in the short run and quantiles 1 to 8 in the long run. SEU has a significant nexus with SED in quantiles 1 to 8 in the short run and quantiles 1 to 8 in the long run. SEV has a significant nexus with SED in quantiles 1 to 4 and 6 to 7 in the short run and quantiles 1 to 5 and 7 in the long run. POPG has a significant nexus with SED in quantiles 1 to 6 and 9 in the short run and quantiles 1 to 6 and 8 in the long run. URB has a significant nexus with SED in quantiles 1 to 8 in the short run and quantiles 1 to 7 and 9 in the long run. Finally, IND has a significant nexus with SED in quantiles 1 to 4, 6, and 9 in the short run and quantiles 1 to 6 and 8 in the long run. Table 5 shows the QARDL results.

Table 4
Unit root test.

Variable	Level	t-statistic	p-value
SED	I(1)	−7.102	0.000
EEU	I(0)	−2.981	0.032
SEU	I(1)	−6.092	0.000
SEV	I(1)	−3.762	0.004
POPG	I(0)	−2.376	0.041
URB	I(0)	−2.332	0.045
IND	I(1)	−5.762	0.000

Table 5
Panel QARDL.

	EEU	SEU	SEV	POPG	URB	IND
Panel A: Short-run Coefficients						
Q0.1	0.543*	0.546*	0.749*	0.748**	0.645**	0.763*
Q0.2	0.672*	0.356*	0.392*	0.377*	0.728*	0.263*
Q0.3	0.664*	0.527*	0.390*	0.319*	0.546*	0.873**
Q0.4	0.182*	0.763**	0.363**	0.356*	0.983***	0.463*
Q0.5	0.362*	0.388*	0.105	0.983***	0.736*	0.192
Q0.6	0.873***	0.726*	0.473*	0.54*	0.716**	0.675**
Q0.7	0.323*	0.629*	0.317*	0.29	0.377*	0.172
Q0.8	0.134	0.267*	0.052	0.10	0.174*	0.241
Q0.9	0.027	0.103	0.232	0.271*	0.028	0.637*
Panel B: Long-run Coefficients						
Q0.1	0.765*	0.564**	0.574**	0.382*	0.102**	0.473**
Q0.2	0.638**	0.874*	0.538*	0.765*	0.473*	0.764***
Q0.3	0.272*	0.453*	0.374*	0.578*	0.930***	0.182*
Q0.4	0.894***	0.675*	0.567*	0.302*	0.453*	0.536*
Q0.5	0.373*	0.282*	0.877***	0.299**	0.647**	0.473*
Q0.6	0.783*	0.373*	0.092	0.549*	0.273**	0.182*
Q0.7	0.352**	0.657***	0.745**	0.181	0.073	0.064
Q0.8	0.473*	0.384*	0.103	0.473*	0.053	0.463*
Q0.9	0.103	0.103	0.087	0.092	0.763**	0.027
Panel C: Diagnostics						
Ad. R square	0.759					
CUSUM	S					
CUCUMQ	S					

Note: * represents 1% level of significance.

Fig. 3, below, shows the stability of the model using the CUSUM and CUSUM square graphs. On both graphs, the CUSUM and CUSUMSQ lines lie under the critical boundaries at 5%, supporting the fitness and stability of the model.

Discussion

The results reported in Table 5 reveal that energy efficiency has a positive association with sustainable economic development. For sustainability of the country's economic development, it is compulsory to ensure a clean working environment, clean and abundant natural resources, and healthy social and economic actors. This is all possible if the country makes efficient use of energy. These results agree with Mahi et al. (2021), who examine energy efficiency's role in economic development. The study implies that energy production, such as nuclear power, as well as energy consumption, are major sources of environmental pollution. Energy efficiency means the minimum amount of energy is used without disturbing economic practice, and environmental pollution can be controlled, making economic development sustainable. These results are supported by Chen et al. (2022a), who highlight the performance of economic activity, and the need for enough energy. When businesses apply energy efficiency, the optimal use of energy and energy transition help save resources for future use and achieve sustainable economic development (Jin & Chen, 2022; Lei et al., 2022).

The results reveal that sharing economy users have a positive association with sustainable economic development. The study implies that, when a large number of people are encouraged to share various resources, the resources are likely to be fully utilized without wastage. Hence, financial resources can be saved, and by the sharing of environmentally friendly resources, environmental quality can be sustained. As a result, sustainability can be created in economic development. These results are supported by Asian, Hafezalkotob and John (2019), who explain that an increase in sharing economy users helps firms involved in natural resource production gain access to technologies with fewer financial resources and increase production. Increased natural resource production adds to sustainable economic development. These results are in line with Laukkanen and Tura (2020), who show that, with an increase in sharing economy users, the number of technologies and amount of energy used are

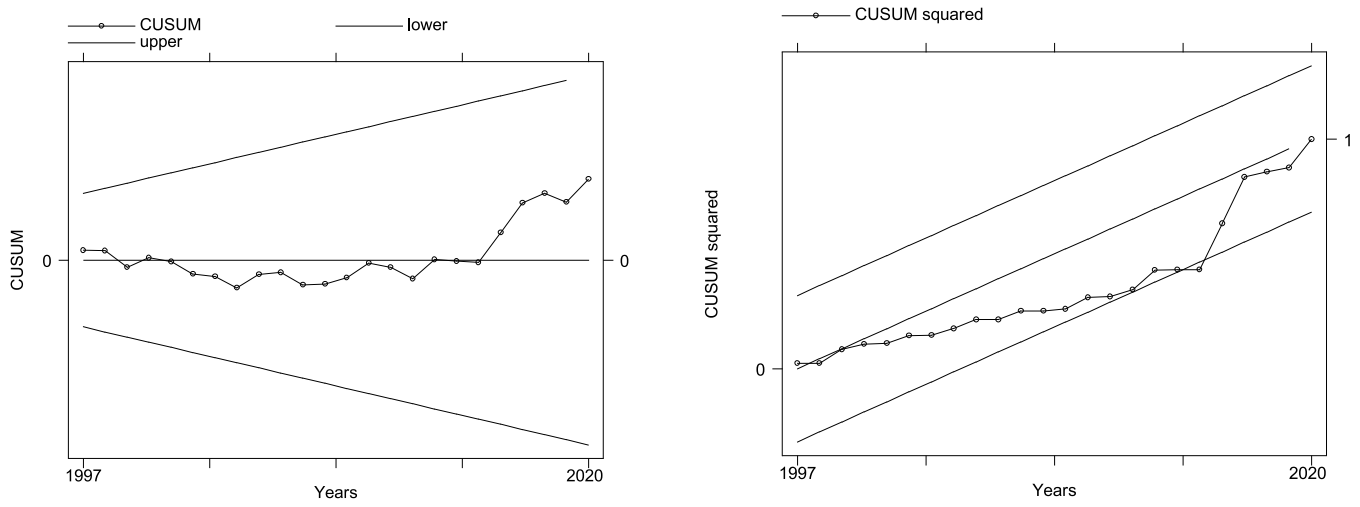

Fig. 3. CUSUM and CUSUM Square.

reduced. The improved environmental quality which results helps attain sustainable development.

The results reveal that sharing economy values have a positive association with sustainable economic development. When there is an increase in the value of the sharing economy, that is, financial resources are saved, there is a reduction in the costs incurred directly buying resources, of any nature, and an increase in earnings from resources rented out. These economic benefits help socially and environmentally friendly activities, so there is a high level of sustainable economic development. These results are supported by Mi and Coffman (2019), who show that an increase in sharing economy value increases the capacity of firms to acquire ecologically friendly technologies with minimum resources, and employ them in reducing the negative environmental impacts of business practice. The reduced environmental degradation and protection of naturally occurring resources assure sustainable economic development. These results are in line with Plewnia and Guenther (2018), who indicate that, as the sharing economy helps businesses acquire resources which they can rent at any time, they develop consistency in implementing their business plans. This assures sustainable development.

The results reveal that population growth has a positive association with sustainable economic development. Economic activities are all managed and performed by human beings. When a country sees large population growth, there is a need for expansion of economic activity, as well as the availability of a large number of administrators and a labour force. This assures the sustainability of economic development. These results are in line with Avtar et al. (2020), who shed light on population growth and its role in sustainable economic development. The study posits that, with an increase in population, the human capital within a country also increases. The improved human capital increases sustainability in economic development. These results are in line with Khan et al. (2019), who show that, when a country has a large population and the government pays attention to improving human capital over time, the skilled, active, and talented human resources available for economic activities help attain sustainable economic development.

The results reveal that urbanization has a positive association with sustainable economic development. This is supported by Arshad et al. (2020), who state that economic activities are mostly performed in urban areas. All economic resources are readily available in urban areas, making technological advancement and human capital development possible. When there is a tendency for the population to shift from rural areas to urban areas, it is likely to create sustainability in economic development. These results are supported by Yang, Zeng and Yang (2020), who show that better health facilities, human capital development, technological innovation, and social connections are all more available in urban areas, and the struggle for sustainable economic development is more likely to succeed. The results reveal that industrialization has a positive association with sustainable economic development. This is in line with Rivera-Quiñones (2022), who reveals that industrialization is the source of production of numerous products and services used as resources in economic practices. Increased industrialization assures sustainability in economic development. These results also agree with Rehman, Ma and Ozturk (2021), who state that industrialization determines people's living standards and human capital development, which are essential for fluency in economic activity.

Implications

The present study has theoretical importance for its contribution to sustainability literature. The study examines the role of efficient use of energy, sharing economy users, and sharing economy value, along with population growth, urbanization, and industrialization, in sustainable economic development. In previous literature, the roles of energy efficiency and the sharing economy in sustainable economic development are analysed, but in separate articles. The present study amalgamates energy efficiency and the sharing economy and their effect on sustainable economic development. Moreover, throughout previous literature, the sharing economy is examined as a determinant of sustainable economic development, without its dimensions. The present study examines the two measurements of sharing economy, sharing economy users and sharing economy value. The selection of China, as the biggest emitter of GHGs, for analysing the relationships between the factors is also a literary contribution. This article has great significance for counties where there is an expansion of economic activity and an increase in energy consumption, but where there is a threat to sustainable economic development. The study provides suitable guidelines for economists and governments on how sustainability can be created in economic development. This study guides policymakers developing policies related to the achievement of sustainable economic development using efficient energy and a sharing economy. Governments and economic regulatory authorities must encourage the efficient use of energy and a sharing economy, both in terms of users and value, for the achievement of sustainable economic development. The results suggest they develop human capital from increased population and encourage urbanization and industrialization, while reducing the negative effects, so that sustainability can be created for economic development.

Conclusions

This study has been conducted to explore the influences of energy efficiency, sharing economy users, and sharing economy value on sustainable economic development, and to test the roles of population growth, urbanization, and industrialization in sustainable economic development over the period 1991 to 2020. A quantitative research method is applied, and data on the energy efficiency, sharing economy users, and sharing economy value, along with population growth, urbanization, and industrialization, and their impacts on sustainable economic development are collected from the Chinese economy. The results denote positive relationships between energy efficiency, sharing economy users, and sharing economy value, along with population growth, urbanization, industrialization, and sustainable economic development. The results show that the efficient use of energy reduces overall energy consumption, encourages energy transition from non-renewable to renewable sources, and enhances the productivity of technologies and energy sources. It assures a clean working environment, good quality natural resources, abundant energy, and improved production, leading to sustainable economic development. The results show that an increase in sharing economy users and value encourages the optimal use of factors of production, reduces energy consumption, reduces costs, and enhances access to resources. Thus, an economy can see sustainable development. The results reveal that, when a country has high population growth, there is large human capital, fluency in economic activities, and increased natural resources, so there is sustainable economic development. Increased urbanization and industrialization also bring improvements in human capital, capital formation, and economic performance, helping to achieve sustainable economic development.

Limitations and future recommendations

Although this study is of great significance, there are still some limitations. The study has no focus on administrative factors such as corporate social responsibility, or financial factors such as green securities, green investment, green loans, and financial risk management. In future studies, these administrative and financial factors should be taken into account. The present study considers the Chinese economy in order to judge the role of efficient use of energy, sharing economy users, and sharing economy value, along with population growth, urbanization, and industrialization, in sustainable economic development. The selection of a single economy for analysis makes the study limited, and future authors are expected to seek evidence from multiple economies.

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