



# Evaluating energy financing considerations and sustainable energy innovation with the role of financial development and energy development

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## Abstract

The purpose of the study is to test the role of energy development in energy financing considerations for sustainable energy innovation and financial development. To achieve the study objective, a fuzzy decision-making modeling technique is applied. The results revealed that bank loans are now the main source of financing for innovation and creativity in Chinese business entities. Project-based financing might be replaced with collaborative and sustainable energy innovation (CSI), warranting energy development. Moreover, green financing loan schemes invest both public and private funds in sustainable energy innovation to capitalize on financial development through sustainable energy innovation. The consideration and application of financial consideration for sustainable energy innovation-financing projects or companies are limitless. Providing for screening energy development cooperation proposals with small financial payback hurdle rates might have large opportunity costs. There may be a case for governments to increase industrial growth, improve resource efficiency, and increase factor productivity while tackling climate change. Economic growth in China may have an even greater influence on environmental sustainability than in other countries. On such points, there is a need to pay the attention. If the suggested policy suggestions are implemented successfully, they would help to enhance the scope of financing considerations for sustainable energy innovation to uplift financial development through energy development mechanisms at the corporate level.

**Keywords** Energy financing considerations · Financial development · Sustainable energy innovation · Energy development · Bank loans · Fuzzy AHP-TOPSIS

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## Introduction

In today's business environment, there is a vigorous discussion over international green practices (Alemzero et al. 2021). Considering municipalities are where the majority of the global total resides and are forecast to continue to do so in the next decades, they are seen as especially crucial forums for sustainability challenges (Li et al. 2021). There are several environmental and social obstacles that cities confront, such as air pollution and crowding, overcrowding, noise, safety concerns, as well as a growing gap between the urban middle class and the rest of the population based on educational and financial status (Iqbal et al. 2021a, b). Ecological preservation, economic viability, and social well-being are all three indicators (Li et al. 2021). Numerous and varied meanings are found in prior literature. The World Commission on Environment and Development (WCED) defined sustainable development in 1987 as "filling today's requirements without jeopardizing tomorrow's abilities to fulfil their own." Achieving a wide range of global environmental objectives will require innovation. There has been a great deal of discussion among politicians and academia over effective techniques and innovative ways to achieve sustainability (Anh Tu et al. 2021).

Cities, for example, are progressively creating living laboratories, which are both physical and virtual spaces in which many partners work together to find solutions to problems via cooperation and collaborative brainstorming (Iqbal et al. 2021a, b). It is thus important to investigate the role of collaboration in sustainable cities via the lens of collaborative innovation (CI). "The actor's engagement and founder with multiple parties, including but not limited to, suppliers, consumers, rivals, and research organizations for the aim of generating new products and services" is how we define CI in our study (Ahmad et al. 2021a, b). Based on prior research, this study examines the function of several "CI models" in social interaction and open innovation, where consumers and other players collaborate for sustainable energy innovation (Iqbal and Bilal 2021a, b). Several CI models are available, but very little research has been done to compare or analyze the quality of these approaches (Zhang et al. 2021). Past research on CI focused on the dyadic contact between two actors, but complex networks in terms of regional, industry, or research cooperation that allow enterprises to develop and commercialize discoveries are becoming increasingly widespread nowadays, according to Iqbal and Bilal (2021a, b). As a particular example, floating labs are becoming more popular in research efforts. Numerous living lab initiatives concentrate on urban sustainability and low-carbon concerns (Tiep et al. 2021). Anecdotal

evidence suggests that in urban planning programs that prioritize ecological sustainability, living laboratories may boost innovation and hence improve people's everyday experiences. As a result, this article acknowledges the significance of living labs and provides a definition for them (Agyekum et al. 2021).

The process of economic growth would not be possible without financial development (De Gregorio and Gudotti 1995). Excessive financial expansion, however, has been shown to have a detrimental effect on economic growth (Marjanovic 1999). After reaching the financial development threshold point, the importance of growth accounting diminishes and has a negative effect on economic growth. Fiscal policy and innovative activities have not yet been properly studied in connection with each other (Abdullah et al. 2005). The link between these two factors is now being studied in two distinct ways in the finance–innovation literature. First and foremost, it is recommended that financial growth be encouraged. Capital systems would enhance information accessibility, therefore minimizing the risk of unknown creative initiatives, which in turn encourages investors to participate in young, successful companies (Yasseri and Kertesz 2013). Second, financial deepening has a detrimental influence on innovation because it encourages industry monopolization, which discourages development (Van Der Walt et al. 2009).

Literature on multi-actor networks that allow companies to develop and market organizations through regional, industrial, or research partnerships is rare in the CI field (Ahmad et al. 2021a, b). Scholars stress the importance of understanding how CI models are organized and implemented. Research on comparing various CI models that concentrate on ecology is uncommon, despite the fact that cooperation for creation is varied (Bommert 2010). Furthermore, we currently lack information on how various CI models aimed at achieving sustainable development in cities operate. This study seeks to fill in some of the knowledge gaps on CI's role in environmental regeneration by examining and conceptualizing the many CI models and then examine the impact of CI archetypes on urban sustainability. Specifically, our goals are as follows: It uses a two-step research strategy, which includes the formulation of a conceptual framework and the verification of that framework using a qualitative technique (Swink 2006). The environmental and CI literature benefit from the research in several ways. In the first place, it provides a conceptual foundation for CI models in urban situations. Second, it presents and evaluates the relationships between four CI archetypes. Third, it emphasizes the importance of urban environments in CI models for sustainability by advancing the ideas of "space" and "place." CI's role in sustainable urban has also been highlighted (Shahbaz et al. 2018).

Several empirical studies have demonstrated that firms with more intellectual capital perform better in the UK and Turkey. While EU regulations are crucial to multilateral cooperation, English law is the major emphasis for the UK. As a result, Turkey's personal property laws are now being revised in order to meet EU and worldwide standards for protectionism (Zaidi et al. 2019). As a result, intellectual property rights (IPRs) are critical to wealth creation in industrialized nations. However, the role of institutions in limiting monetary investment and creativity in order to attract capital must be acknowledged.

In recent studies on constant development, there is a lack of support for the involvement of the credit market in a company's creativity. As a result, this conclusion is only partially correct.

1. Due to the critical importance of the financial middlemen's position in a lending company's product lifecycle, it is improper to minimize their contribution. In poorer nations, where equity markets are less established, this function is especially important.
2. Credit market growth may also favor monopolization, which can stifle competition since brokers want to safeguard their present clientele. From the viewpoint of a developed nation (the UK), these studies investigated the function of funding in various sectors.
3. There is evidence to suggest that enterprises in the high-tech industry that are heavily indebted have benefitted from a rise in market value and reduced volatility since the economic meltdown. Extending the evidences of study is another contribution of the study.

This article presents a fresh perspective by highlighting the importance and effect of ESG elements on the development of sustainable business models by organizations. Environmental, social, and governance (ESG) are the novel techniques commonly used in the region. ESG elements and business models have not yet been studied in depth, nor has any effort been made to identify which environmental, social, or management concerns are most relevant. Even while innovation has long been acknowledged in the context of business models, the originality of this piece is its emphasis on the relevance of innovation in the context of sustainable models. Some limitation and obstacles arise since there are not any similar variables available for the study's subject.

The ramming paper is as follows: the "Literature review" section describes the literature review, the "Data and methodology" section explains the data and methodology, the "Empirical results and discussion" section describes the results and discussion, while the "Conclusion and implications" section concludes the study.

## Literature review

According to past research on this topic, there is little doubt that equity markets play a significant role in a country's development (Oganisjana 2015). In high-tech businesses, where there is a high degree of unpredictability and more performance, this function is especially important, resulting in higher stock values when a breakthrough idea is introduced (Cormican and O'Sullivan 2003). Thus, the growth of the stock market stimulates companies to participate in innovative activities. The pecking order idea, on the other hand, limits this point of view. A corporate control market that absorbs underperforming enterprises in order to limit competitive may also be encouraged by the growth of the stock market, which might discourage creativity in the long run (Nasir et al. 2019; Ahmad et al. 2019; Zhang et al. 2021).

This view emphasizes the importance of a high profit and capital level in order to offer a concentrated market with an inventive environment. According to Chiu and Lee (2020), market concentration does not encourage innovation, since absolute control over the market discourages businesses from engaging in venture creation. If there was no competition in the market, monopoly enterprises would be compelled to innovate. Competitiveness, on the other hand, would encourage a company to come up with new ideas. According to earlier research, removing the monopoly would encourage market research and development (R & D). However, more markets would lead to a decrease in research and development (Destek and Sarkodie 2019). The financial systems have been extensively studied in relation to innovation and competition. However, does this impact the amount of competitiveness that ultimately decides a country's innovation? Developing financial markets would help new creative businesses get the capital they need, which would in turn promote innovation (Hipp 2010). It would therefore drive incumbent companies to innovate as a result of their own active invention, resulting in an innovation atmosphere that fosters innovation (Fan et al. 2020). However, if financial development goes any farther, creativity will be stifled. Market competition and innovation would be hindered if banking institutions acted in a way that protected their clients' interests and acquisitions (Romero and Molina 2011). As a result, this research tries to determine whether the latter stages of financial development, which result in economic concentration, are influenced (Santoro et al. 2020).

At least two camps have emerged in theories on the role of finance in encouraging innovation. Companies that have a good possibility of generating new items and manufacturing methods are identified via credit market

improvement (Duin et al. 2008). Financial institutions must have access to more reliable information in order to identify the most promising innovation initiatives (Chi et al. 2018). While economic inclusion has been shown to have a negative effect on economic growth, a sign reversal was observed when threshold-type effects were taken into account. This research suggests that the relationship between money and growth may be changing (Araujo et al. 2012). According to a second theory of debt market expansion, higher innovation improves information availability and discourages financial intermediaries from funding innovative companies. This strategy encourages the financial sector to lend money to well-established companies with a good reputation, thus halting Schumpeter's theory of radical innovation.

It also supports economic monopolization, since banking institutions block off competitors for their current consumers, preventing competition and market innovation (Acheampong et al. 2020; Ullah et al. 2021). It is also revealed that the financial sector's rise may have a negative effect on production, which in turn might harm economic growth. Greater levels of financial development seem to have a less or negligible impact on innovation (Jalil and Feridun 2011). Increasing financial expansion has a diminishing influence on the incremental impact of innovation on the economy (Anton and Nucu 2020). Another factor that influences financial intermediary performance is availability, bank auditing efficacy, and adherence to a rule-of-law that minimizes discrimination or moral hazard (Yang et al. 2018). Equitable utilization of funds in the stock market also necessitates the presence of solid organizations. In the next part, we examine the function of market institutions in regulating the link between finance and entrepreneurship (Serrano and Fischer 2007). Focusing on governmental structures for financial growth has been widely discussed in academic writing. Previous research has shown that a robust intellectual regime fosters creativity since the return of the funder is assured. However, the strength of a government's infrastructure is not the only factor in investors' choice to fund risky technological ventures (Baldwin and Von Hippel 2011). Additionally, relying on institutions that can make information accessible, avoid market distortion, safeguard property rights, and share responsibilities in the event of a surprise, among other things, although FDI synergies are largely horizontal, nations with greater IP rights and a "business climate" tend to better manage both horizontal and vertical FDI-related spillovers when institutional variables are taken into account (Flores et al. 2009; Cinelli et al. 2019).

As the stock market grows, something that is between lenders and borrowers may be minimized, which has less of an influence when enterprises or finance companies exhibit monopolistic behavior. If capital systems

continued to expand, competition and innovation would be hampered. Our hypothesis is that bond and stock markets have a unique, nonlinear connection with innovation by merging the two existing perspectives on the finance–innovation nexus. According to this hypothesis, bond and stock innovations interact in an inverted U form. Financial development, according to this concept, might lead to innovation in the early stages of capital formation. Innovation would be stifled by market monopolization if the capital institutions were further developed. However, if such a nonlinear finance–innovation nexus is not there, Schumpeter and Nichol (1934) thesis will be supported. If you want to know the actual effect of economic markets on development, this is a critical piece of evidence to have on hand.

Using the four categories of capital markets proposed by Rodrik (2005), this research examines whether numerous market organizations have distinct consequences for the finance–innovation mechanism. Financial development helps to protect the business environment and is enforced by economic institutions, but their disappearance raises the danger of contractual rejection. In each of these respects, these organizations are critical to the innovation industry. It is possible to defend inventors' interests by ensuring that property rights are well protected. Financial firms are more likely to fund hazardous innovation initiatives if they know that their contracts will be upheld. Market-creating institutions are expected to have a favorable effect on the finance–innovation link since assuring potential income is essential for any company to participate in innovation. Planning for monetary and fiscal policy, reducing volatility in the market, and neutralizing market shocks are all functions of market stabilizing institutions (MSIs). Fiscal and monetary policy are two examples of this. Increasing investor trust and encouraging financial intermediaries to fund riskier ventures are two ways a stable financial system may promote innovation.

Increasing attention has been paid to sustainable business models (SBM) as a means of achieving both environmental and commercial objectives. Mixed results are reported in the literature on the link between social and environmental performance as well as financial performance. Some researchers believe that there is a beneficial association, while others believe that there is a negative one. Only a meta-analysis that analyzed the financial advantages of corporate social and environmental responsibility was able to come to an unequivocal result. Sustainable business models are being researched, and organizations are changing their business models to be more sustainable because of the beneficial association between sustainability and financial success. There is also a lot of demand from capital investors and financial institutions to include ESG issues in the decision-making process.

As a result of the wide range of studies dedicated to business models, it is difficult to create a theory around these studies, which are defined and conceptualized differently depending on the study objective and theoretical approach used by researchers. There are certain broad trends in business model research. However, these trends are not standardized, and the research techniques reported in the published papers are not comparable. Research on SBM innovations covers a wide range of topics, including the connection between environmental and social sustainability, business models, and sustainable energy innovation models, as well as the triple bottom line approach or the Triple Layered Business Model Canvas. Changes in the competitive environment, new information and communication technologies, and the need to adapt to the needs of external stakeholders are all factors that drive sustainable business models. Non-financial elements (ESG) have yet to be investigated in depth from a sustainability perspective by researchers (Li et al. 2021).

According to most writers, a sustainable business model is essential to satisfy the needs of a changing environment and society. Regardless of the model approach selected, eco-design and eco-efficiency gains are not adequate to counteract the rising resource usage and environmental effects of a growing global population, according to Owusu and Asumadu-Sarkodie (2016). Several studies have found that credit risk management should include environmental and sustainability factors in addition to credit risk. According to Weber et al. (2010), sustainable criteria may be used to anticipate the financial performance of a debtor and increase the predictive validity of the credit rating process. Their conclusion was that sustainability has an impact on a company's creditworthiness, which is part of its financial performance. In the absence of collateral, lenders are more attentive to CSR concerns, according to Goss and Roberts (2011). Lending institutions in 15 EU nations were surveyed to find out how sustainable performance affects a company's finances. According to the study, debt costs are lower for companies with better ESG performance. Egede and Lee (2007) found that the financial industry may affect the environmental and sustainability implications of their customers, such as projects or borrowers and their investors.

## Data and methodology

### Theoretical framework

The analytical hierarchy process (AHP) technique is an organized MCDM method used to organize and assess complex decision-making processes. AHP has been developed by Saaty in 1977 (Saaty 1977). Both qualitative and non-qualitative data is needed to measure the techniques

used by AHP for decision-making based on a various criteria (Xu et al. 2019). The method excerpts the significances of alternatives criteria from pairwise comparisons. AHP is being used as a basis for various MCDM methodologies, and it can be combined with other theories such as fuzzy set theory (Sharma et al. 2022). There were four major categories of papers found in the literature on CI for sustainability, according to this analysis. In order to make sense of the content, we divided it into four categories based on two factors: the importance of the innovation setting, as well as the total number of partners. In this research, fuzzy set methodology has been used to develop optimal decision support for energy financing, sustainable energy innovation, and financial development for collecting the decision-makers, prioritizing and ranking the alternatives options. All the selected decision-makers are responding to the criteria inducing the human error, while collecting the decision-maker's estimations have been aggregated across the weight function of the individual factors of this analysis. Various aspects, such as the location and structure of an inventive setting, are critical to understanding the space and place.

### Fuzzy set theory

For a classical set  $A$ ,  $x \in A$  or  $x \notin A$  ( $\forall x \in R^n$ ), this feature can be expressed as the following function:

$$\chi_A(x) = \begin{cases} 1, & x \in A \\ 0, & x \notin A \end{cases}$$

ordering—where  $\chi_A(x)$  is the characteristic function of  $A$ , which is extended to the fuzzy set? In the classical set, the characteristic function is extended to the fuzzy set as an interval  $[0, 1]$ . Because there is no absolute subordinate relation between points and sets, fuzzy sets no longer have the characteristic of “either or”, and their operations can only be determined by the relation between membership functions.

**Definition 1** Let  $X$  denote a universal set and then  $\tilde{A}$  be a fuzzy set in  $X$ , which reflects the relationship between  $X$  and  $[0, 1]$ . Its membership function is as follows:

$$\tilde{A} : X \rightarrow [0, 1], x \rightarrow \tilde{A}(x)$$

where  $x \in R$ ,  $\tilde{A}(x)$  is the membership function of  $\tilde{A}$  or the membership degree of  $x$  to  $\tilde{A}$ . The fuzzy set  $\tilde{A}$  can be determined by the function  $\tilde{A}(x)$ . The fuzzy set of  $\tilde{A}$  is denoted by  $A = \left\{ \left( x, \tilde{A}(x) \right) \mid x \in X \right\}$ .

**Definition 2** Let  $X$  denote a universal set. Then  $\tilde{A}, \tilde{B}, \tilde{C}$  are fuzzy sets in  $X$ ,

(1) If  $\forall x \in X$ , there is  $\tilde{A}(x) \leq \tilde{B}(x)$ , and then  $\tilde{A} \subseteq \tilde{B}$ .

- (2) If  $\forall x \in X$ , there is  $\tilde{A}(x) = \tilde{B}(x)$ , and then  $\tilde{A} = \tilde{B}$ .
- (3) If  $\forall x \in X$ , there is  $\tilde{C}(x) = \max\{\tilde{A}(x), \tilde{B}(x)\}$ , and then  $\tilde{C} = \tilde{A} \cup \tilde{B}$ .
- (4) If  $\forall x \in X$ , there is  $\tilde{C}(x) = \min\{\tilde{A}(x), \tilde{B}(x)\}$ , and then  $\tilde{C} = \tilde{A} \cap \tilde{B}$ .
- (5) If  $\forall x \in X$ , there are  $\tilde{A}^C(x) = 1 - \tilde{A}(x)$ ,  $\tilde{B}^C(x) = 1 - \tilde{B}(x)$ , then  $\tilde{A}^C(x)$  is the complementary set of  $\tilde{A}(x)$ , and  $\tilde{B}^C(x)$  is the complementary set of  $\tilde{B}(x)$ . The above operations of fuzzy set are a generalization of the operations of ordinary set, which has similar properties to ordinary set operation.

**Definition 3** Let  $\tilde{A}$  be a fuzzy set with membership function  $\tilde{A}(x)$ . Then the set:

$$\tilde{A}_\alpha = \{x \in X | \tilde{A}(x) \geq \alpha\}$$

is called the  $\alpha$ -level of  $\tilde{A}$ ,  $\alpha$  is called the confidence level. Especially, the set  $\{x \in X | \tilde{A}(x) > 0\}$  is called the support of  $\tilde{A}$ .  $\alpha$ -level is an important concept to transform fuzzy sets into ordinary sets.

**Definition 4** Fuzzy numbers are special cases of fuzzy sets, described by given intervals of crisp numbers. Let  $N$  a trapezoidal fuzzy number, denoted by  $N = (a, b, c, d)$ , whose membership functions is defined as:

$$N(x) = \begin{cases} \frac{x-a}{b-a}, & \text{if } a \leq x \leq b \\ 1, & \text{if } b \leq x \leq c \\ \frac{c-x}{c-d}, & \text{if } c \leq x \leq d \\ 0, & \text{if else.} \end{cases}$$

Interval fuzzy numbers and triangular fuzzy numbers can be regarded as special cases of trapezoidal fuzzy numbers, such as  $N$  is a triangular fuzzy number when  $b = c$  and  $N$  is an interval fuzzy number when  $a = b$  and  $c = d$ . In particular,  $E$  is a crisp number when  $a = b = c = d$ , and crisp numbers can also be considered a special case of fuzzy numbers.

## Evaluation system of indicators

The collaborative innovation, an innovative model, guides various cooperating entities to carry out in-depth cooperation, integrates with financial development and energy development of the organizations, and turns knowledge to the driving force of sustainable social and economic development. Through multi-agent cooperation, the complementarity and the update of knowledge can be achieved, and a long-term and effective collaborative innovation power for collaborative governance can be provided for social development. Through the contributions of these two aspects, the

collaborative innovation in the china-based companies has become an important measure for the sustainable development of society, which give full play to the advantages in talents, resources, and funds of various subjects and optimize the allocation of innovative resources. It will contribute to the formation of energy development, and financial development, so as to promote regional sustainable economic development. Sustainable exploration innovation and sustainable exploitation innovation are important supports for regional economy development.

Five levels of linguistic variables are used to describe the correlation measures between performance index (CRs) and influential factor indicators (TAs), which are none, weak, moderate, strong, and very strong. A corresponding triangular fuzzy weight set is predefined as  $\{U1, U2, U3, U4, U5\}$ , expressing five linguistic variables, where  $U1 = (0,0,0.3)$ ,  $U2 = (0,0.25,0.5)$ ,  $U3 = (0.3, 0.5, 0.7)$ ,  $U4 = (0.5, 0.75, 1)$ , and  $U5 = (0.7, 1, 1)$ . The process of evaluating the factors influencing the collaborative innovation in universities is a group decision-making process, which needs to consider the authority ( $C_k$ ) of different evaluators. The degree of authority is mainly determined according to the judgment basis and familiarity of the evaluator's evaluation of the factors affecting the collaborative innovation in universities. The formula for determining  $C_k$  is as shown in Eq. (1).

$$C_k = (C_{ak} + C_{sk})/2 \quad (1)$$

where  $C_{ak}$  represents the judgment basis of the  $k^{th}$  evaluator and contains four cases: theoretical analysis, practical experience, domestic and foreign understanding, and intuition, which are respectively assigned as 0.3, 0.3, 0.3, and 0.1. The evaluator's familiarity with the collaborative innovation in universities is divided into six levels: very unfamiliar, unfamiliar, general, little familiar, familiar, and very familiar, with the value as 0, 0.2, 0.4, 0.6, 0.8, and 1, respectively.

## Data processing

According to the results of the questionnaire survey, the fuzzy preference degree of each evaluator's four indexes of the collaborative innovation in universities and the fuzzy correlation between these four performance indexes and 17 influence factor indicators are obtained. Then the opinions of different evaluators are calculated, and the formula is calculated in Eq. (2) as follows:

$$W_i = \sum_{k=1}^n C_k W_i^k / \sum_{k=1}^n C_k, D_{ij} = \sum_{k=1}^n C_k D_{ij}^k / \sum_{k=1}^n C_k \quad (2)$$

In Eq. (2),  $W_i$  is the weight of the collaborative innovation in universities index ( $CR_i$ ), and  $D_{ij}$  is the fuzzy correlation degree of the performance index ( $CR_i$ ) and the influencing factor indicator ( $TA_j$ ).  $W_i^k$  is the degree of fuzzy preference of the evaluator  $k$  to the performance indexes, and  $D_{ij}^k$  is the

fuzzy correlation evaluation value between the performance index and the influencing factor indicator by the evaluator  $k$ .  $C_k$  is the authority of the evaluator  $k$ .  $W_i^k$  and  $D_{ij}^k$  ( $i = 1, 2, 3, 4; j = 1, 2, \dots, 17$ ) are predefined triangular fuzzy set. The number of evaluators is denoted by  $n$ .

**Calculation of fuzzy importance about study indicators**

The fuzzy importance of influence factor indicator  $\tilde{Z}_j$ , which is the influence factor indicator of the collaborative innovation in universities, is calculated by Eq. (3).

$$Z_j = \sum_{i=1}^4 W_i D_{ij} / \sum_{i=1}^4 W_i \tag{3}$$

$Z_j$  is a triangular fuzzy number, which cannot be directly measured to rank the importance of the influencing factor indicators. In this study, the  $h$ -cut set fuzzy-weighted linear programming method is used to represent the value of  $Z_j$ . The  $h$ -cut sets of  $W_i^k$  and  $D_{ij}^k$  are defined as  $(W_i)_h$  and  $(D_{ij})_h$  respectively, as shown in Eq. (4).

$$\{(W_i)_h = \{w_i \in W_i | \mu_{W_i}(w_i) \geq h, 0 \leq h \leq 1\} (D_{ij})_h = \{d_{ij} \in D_{ij} | \mu_{D_{ij}}(d_{ij}) \geq h, 0 \leq h \leq 1\} \tag{4}$$

According to the definition, the upper and lower limits of the  $Z_j$   $h$ -cut set are  $(Z_j)_h^U$  and  $(Z_j)_h^L$ , respectively, and they are also the maximum and minimum values of  $Z_j = \sum_{i=1}^4 w_i d_{ij} / \sum_{i=1}^4 w_i$ , where  $w_i \in (W_i)_h, d_{ij} \in (D_{ij})_h$ .

By using the integrating fuzzy-weighted average method, the fuzzy expected value operator  $E(Z_j)$ , which is the importance degree of the influence factor indicator, is obtained.

**Empirical results and discussion**

**Data processing and pre-processing**

Based on previous experience, 5–7 experts are sufficient to meet the effectiveness requirement of group decision-making. This study requires evaluators to be familiar with the development status and operation mode of the collaborative innovation in China-based companies. Therefore, 10 experts were selected to conduct interviews on the evaluation of the factors affecting the collaborative innovation in universities. Through the interview, this information is checked: the authority of the experts, the weights of the performance indexes, and the fuzzy correlation between the performance indexes and the influencing factor indicators. According to Eqs. (1) and (2), the authority of the expert  $C_k$ , the weight of the energy development  $W_i$ , and the fuzzy correlation between the sustainable energy innovation indicators and the influencing factor indicator of financial development  $D_{ij}$  can be obtained, respectively.

Based on data collected, the  $C_k$  value can be summarized as follows:  $C_1 = 0.95, C_2 = 0.7, C_3 = 0.75, C_4 = 0.55, C_5 = 0.7, C_6 = 0.75, C_7 = 0.65, C_8 = 0.85, C_9 = 0.8$ , and  $C_{10} = 0.7$ . The values of the weight of the energy development  $W_i$  are as follows:  $W_1 = (0.765, 0.965, 1), W_2 = (0.622, 0.817, 0.953), W_3 = (0.733, 0.928, 0.98)$ , and  $W_4 = (0.586, 0.77, 0.916)$ . The  $D_{ij}$  value, which is the fuzzy correlation between the financial development and the influencing factor indicator, is summarized in Table 1.

When it comes to a company’s ability to expand, we found that financial development, defined by the number of financial service providers per population, has a favorable impact on firm growth. In addition, in provinces with a competitive business climate, the influence of local financial development on company expansion is larger. In contrast, in counties where the financial industry is much more established, gains in provincial competitiveness have a greater impact on business expansion. A few caveats apply, but in broad sense, our findings are unaffected by accounting for the interaction between financial development and corruption or by using various methods of local financial advancement like private credit volume relative to total output or the number of financial suppliers per square kilometer Using a new method of identification, we found that income at the provincial level had a considerable impact on company growth. A competing business climate, on the other hand, has a beneficial impact on company growth. Business world features such as cheap costs of entry and availability to land have a greater impact on the growth of a company than local financial development.

There are three elements to capital formation: availability, depth, and effectiveness of financial markets and institutions (Iqbal et al. 2021a, b). There is unfortunately no data on the efficiency of the financial industry after 2009 in VES. Data sets may be used to assess economic progress by assessing both availability and depth. The number of financial service providers in a province is an indicator of how accessible financial institutions are in that area. We use this figure as a proxy for two different province-level features when assessing the finance sector’s ease of access. Six as a starting point, we look at the number of financial service providers per population. Every region had an average of 2.5 financial services for every 100,000 residents from 2009 to 2012. A second FD variable is the number of economic suppliers in a specific location, given that a small business’s ability to receive external financing may be influenced by the distance between the firm and the financial providers. Another way to gauge financial strength is to use the ratio of private credit to output (O’Toole and Newman 2017), which is calculated as the number of personal business liabilities divided by the total output of all enterprises in a certain province’s value added tax (VET).

**Table 1** The fuzzy correlation between the study indicator

	$CR_1$	$CR_2$	$CR_3$	$CR_4$
$TA_1$	(0.619, 0.889, 0.968)	(0.499, 0.728, 0.909)	(0.558, 0.808, 0.937)	(0.462, 0.693, 0.850)
$TA_2$	(0.455, 0.666, 0.902)	(0.477, 0.696, 0.909)	(0.514, 0.730, 0.970)	(0.437, 0.650, 0.876)
$TA_3$	(0.537, 0.774, 0.941)	(0.537, 0.774, 0.941)	(0.538, 0.767, 0.970)	(0.418, 0.627, 0.848)
$TA_4$	(0.507, 0.732, 0.933)	(0.464, 0.677, 0.950)	(0.568, 0.833, 0.949)	(0.532, 0.778, 0.949)
$TA_5$	(0.514, 0.758, 0.926)	(0.528, 0.783, 0.917)	(0.428, 0.652, 0.860)	(0.342, 0.570, 0.753)
$TA_6$	(0.568, 0.833, 0.949)	(0.494, 0.758, 0.876)	(0.591, 0.867, 0.949)	(0.495, 0.731, 0.927)
$TA_7$	(0.587, 0.861, 0.949)	(0.463, 0.715, 0.868)	(0.490, 0.736, 0.887)	(0.440, 0.666, 0.872)
$TA_8$	(0.531, 0.769, 0.933)	(0.507, 0.737, 0.919)	(0.569, 0.821, 0.947)	(0.660, 0.949, 0.970)
$TA_9$	(0.413, 0.627, 0.861)	(0.269, 0.461, 0.707)	(0.471, 0.698, 0.915)	(0.578, 0.847, 0.949)
$TA_{10}$	(0.623, 0.895, 0.968)	(0.464, 0.696, 0.891)	(0.493, 0.730, 0.917)	(0.475, 0.711, 0.895)
$TA_{11}$	(0.535, 0.762, 0.972)	(0.603, 0.862, 0.978)	(0.578, 0.828, 0.970)	(0.430, 0.652, 0.828)
$TA_{12}$	(0.518, 0.737, 0.968)	(0.541, 0.779, 0.945)	(0.604, 0.866, 0.970)	(0.422, 0.647, 0.845)
$TA_{13}$	(0.549, 0.793, 0.939)	(0.535, 0.802, 0.890)	(0.601, 0.873, 0.937)	(0.553, 0.806, 0.919)
$TA_{14}$	(0.497, 0.728, 0.905)	(0.531, 0.775, 0.915)	(0.550, 0.794, 0.943)	(0.542, 0.782, 0.943)
$TA_{15}$	(0.371, 0.594, 0.817)	(0.412, 0.617, 0.893)	(0.493, 0.729, 0.921)	(0.553, 0.811, 0.949)
$TA_{16}$	(0.297, 0.507, 0.747)	(0.285, 0.490, 0.705)	(0.299, 0.509, 0.749)	(0.434, 0.643, 0.874)
$TA_{17}$	(0.324, 0.547, 0.767)	(0.209, 0.431, 0.673)	(0.291, 0.517, 0.747)	(0.420, 0.659, 0.857)

The average number of financial service providers per 100 square kilometers is 2.5. For every 100,000 inhabitants, there are just 0.1 financial markets in the provinces with the lowest and highest populations, respectively. Furthermore, there are around 0.1 and 43 finance houses per 100 square kilometers in the provinces with the lowest and largest concentrations of financial institutions. From 4 to 95% of the total production is financed by private borrowing. The number of financial service providers per 1000 residents is our primary local FD indicator. The coefficient of correlation between the 2 factors of openness is larger than 0.8, as predicted. Our primary financial development indicator, corporate credit to production, has a somewhat positive connection with this measure (correlation coefficient of 0.52). The results of our robustness tests reveal that the statistical evidence presented in this study is consistent with different metrics of capital formation, such as the variety of financial providers per square kilometer and the ratio of private credit to production.

### Calculation of fuzzy importance of influencing factor indicators

With MATLAB software, the fuzzy importance of the influence factor indicators affecting the collaborative innovation in universities under different h cut-off levels is calculated, as shown in Table 2.

Using Eq. (4), we can calculate the importance degree and ranking of seventeen indicators in six dimensions of influencing factor indicators of the collaborative

innovation in universities, as shown in Table 3. China-based companies have 8.77 individuals on their board of directors, with a 17 percent female and 37 percent non-executive director ratio. NEV board members have an average academic qualification of 4.08, meaning they have a master's degree. Nearly half of these board members have failed to get a bachelor's degree (median = 2.9). As Fig. 1 illustrates, the complete sample of board members has a reasonably wide range of educational attainment. According to Fig. 2, the majority of directors in China's National Electric Vehicle (NEV) companies are between the ages of 35 and 65. Twenty of the 70 NEV companies have CEOs that serve in both capacities. In addition, from 2013 to 2018, the number of board meetings conducted by Chinese NEV enterprises varied greatly, ranging from 6 to 37. Table 2 shows that GS and CGI have a statistically significant correlation, suggesting the importance of these two factors. It is also worth noting that there is an obvious association between the size of a company and the amount of financial development it receives through financial consideration for sustainable energy innovation and energy development.

This indicates a U-shaped association between GS and CGI since the coefficients of linear and non-linear components are  $-5.254$  and  $5.539$ , respectively,  $p < 0.01$ . Diagnostic checks are conducted in order to confirm this favorable relation. According to Sasabuchi's findings, the inclination of something like the lower limit is considerably negative, whereas the slope of the theoretical limit is notably favorable in Table 3.



**Table 2** Fuzzy importance degree of influencing factor indicators under different *h* level

	Indicators	<i>h</i> level										
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
$TA_1$	L	0.529	0.555	0.580	0.606	0.631	0.657	0.683	0.709	0.735	0.760	0.786
	U	0.925	0.912	0.898	0.884	0.871	0.857	0.843	0.829	0.815	0.801	0.786
$TA_2$	L	0.467	0.489	0.511	0.533	0.555	0.576	0.598	0.620	0.642	0.664	0.686
	U	0.921	0.897	0.874	0.850	0.826	0.803	0.779	0.756	0.733	0.709	0.686
$TA_3$	L	0.501	0.525	0.549	0.572	0.596	0.620	0.644	0.668	0.692	0.716	0.740
	U	0.934	0.914	0.895	0.876	0.857	0.837	0.818	0.798	0.779	0.759	0.740
$TA_4$	L	0.513	0.537	0.561	0.585	0.609	0.634	0.658	0.683	0.707	0.732	0.756
	U	0.946	0.927	0.909	0.890	0.872	0.853	0.834	0.815	0.795	0.776	0.756
$TA_5$	L	0.443	0.468	0.493	0.518	0.543	0.568	0.593	0.618	0.643	0.669	0.694
	U	0.878	0.860	0.841	0.823	0.805	0.787	0.768	0.750	0.731	0.713	0.694
$TA_6$	L	0.532	0.559	0.586	0.613	0.640	0.667	0.694	0.721	0.748	0.775	0.802
	U	0.931	0.918	0.906	0.893	0.880	0.867	0.854	0.841	0.828	0.815	0.802
$TA_7$	L	0.491	0.516	0.542	0.568	0.594	0.620	0.646	0.672	0.698	0.724	0.750
	U	0.901	0.886	0.872	0.857	0.842	0.827	0.811	0.796	0.781	0.766	0.750
$TA_8$	L	0.555	0.581	0.607	0.633	0.659	0.685	0.711	0.737	0.763	0.789	0.815
	U	0.945	0.933	0.921	0.908	0.895	0.883	0.869	0.856	0.843	0.829	0.815
$TA_9$	L	0.413	0.437	0.461	0.486	0.510	0.534	0.558	0.583	0.607	0.631	0.656
	U	0.872	0.852	0.830	0.809	0.788	0.766	0.744	0.722	0.700	0.678	0.656
$TA_{10}$	L	0.508	0.534	0.559	0.584	0.610	0.635	0.661	0.686	0.712	0.738	0.764
	U	0.924	0.909	0.893	0.877	0.861	0.845	0.829	0.813	0.797	0.780	0.764
$TA_{11}$	L	0.528	0.553	0.578	0.603	0.628	0.653	0.678	0.703	0.728	0.753	0.779
	U	0.949	0.932	0.915	0.898	0.881	0.864	0.847	0.830	0.813	0.796	0.779
$TA_{12}$	L	0.514	0.539	0.564	0.588	0.613	0.638	0.662	0.687	0.712	0.737	0.761
	U	0.942	0.924	0.906	0.888	0.870	0.852	0.834	0.816	0.798	0.780	0.761
$TA_{13}$	L	0.557	0.583	0.609	0.635	0.662	0.688	0.714	0.740	0.767	0.793	0.819
	U	0.925	0.915	0.904	0.893	0.883	0.872	0.862	0.851	0.841	0.830	0.819
$TA_{14}$	L	0.526	0.551	0.575	0.599	0.623	0.647	0.672	0.696	0.720	0.744	0.768
	U	0.929	0.913	0.897	0.881	0.865	0.849	0.833	0.817	0.801	0.785	0.768
$TA_{15}$	L	0.443	0.466	0.490	0.514	0.538	0.562	0.586	0.610	0.635	0.659	0.683
	U	0.899	0.878	0.857	0.836	0.815	0.793	0.771	0.749	0.727	0.705	0.683
$TA_{16}$	L	0.317	0.339	0.360	0.382	0.404	0.425	0.447	0.469	0.490	0.512	0.534
	U	0.777	0.753	0.728	0.704	0.679	0.655	0.631	0.606	0.582	0.558	0.534
$TA_{17}$	L	0.298	0.322	0.346	0.370	0.393	0.417	0.441	0.465	0.489	0.513	0.536
	U	0.770	0.747	0.723	0.700	0.677	0.654	0.630	0.607	0.583	0.560	0.536

**Empirical results**

Despite of Fieller’s estimate (Fieller 1954), the inflection point of GS (18.994) is inside its own region, suggesting that a full U-shaped curve may be seen. Empirical estimation has a good deal of support. Findings demonstrate that a 1 percent increase in GS would reduce CGI by 5.254 percent, while a quadratic GS term that is favorable at high levels of subsidies in China’s NEV sector supports the relationship between GS and CGI. When GS reaches its inflection point, the research shows that CGI declines in an inadequate stage but then begins to rise again. According to this study, the association among GS and conventional is comparable to that seen in prior research.

Between 0.005 and 0.014 of a per capita gain in capital formation is associated with an increase in the administration measure (GOV). It is easy to see how this conclusion is in line with market theory. Expenditure in role of institutions grow as business investment rises, and the dependence on informal channels reduces. Small and local economies, as Anh Tu et al. (2021) point out, benefit greatly from the ability to maintain cooperation via interpersonal links and recurrent contacts. But when economic growth happens, the sophistication and scope of commerce may impair the efficacy of formalized organizational processes (Dixit 2003; Greif 1994), producing larger incentives for public investments in governance institutions. As a result, poor countries generally find it difficult to implement

**Table 3** The importance degree of the impact factor indicators and their ranking

Influence factor	Technical attributes	Importance degree	Ranking
Sustainable energy innovation (CI)	TA1	0.757	5
	TA2	0.690	12
	TA3	0.729	10
	TA4	0.743	8
	TA5	0.677	14
	TA6	0.767	3
	TA7	0.723	11
Energy development (CGI)	TA8	0.783	1
	TA9	0.650	15
	TA10	0.740	9
	TA11	0.759	4
	TA12	0.745	7
Financial development (FD)	TA13	0.780	2
	TA14	0.748	6
	TA15	0.677	13
	TA16	0.540	16
	TA17	0.535	17

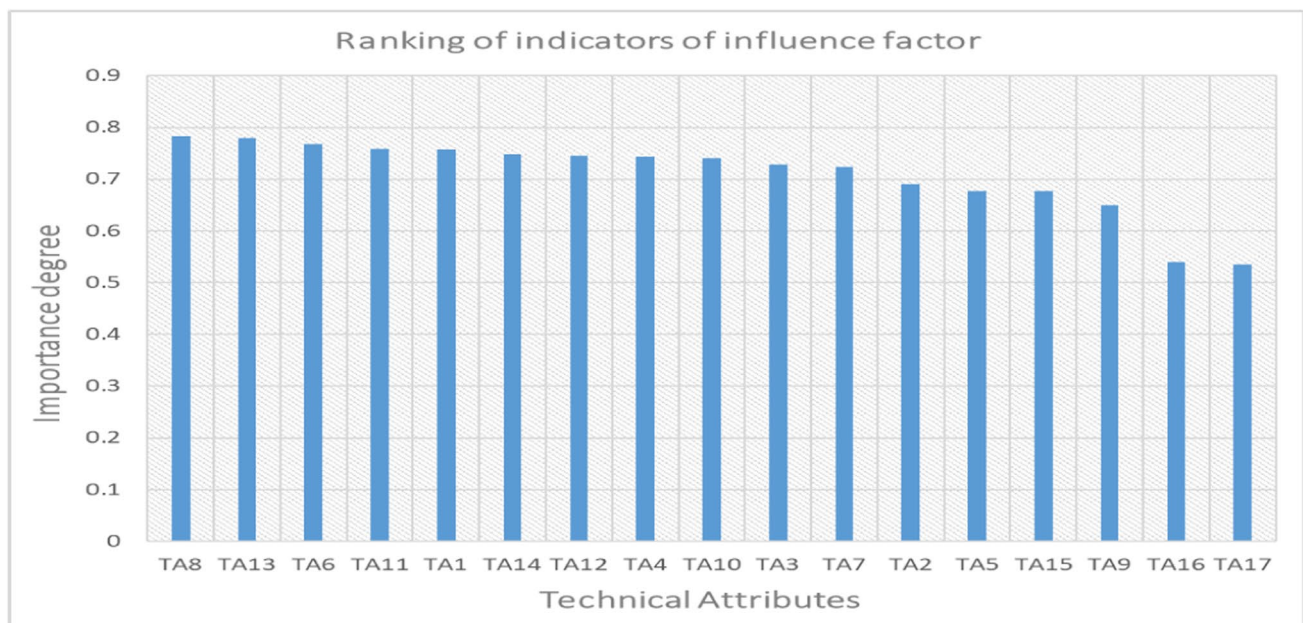
significant reform measures caused by a lack of organizational experience and financial resources. Public spending and other operations will benefit from a greater GDP per capita. Governments may benefit from advantages of scale and influence as a result of this, allowing them to operate more effectively. Likewise, the importance degree ranking

of indicators of influence factor sort result is shown in Fig. 1 as below.

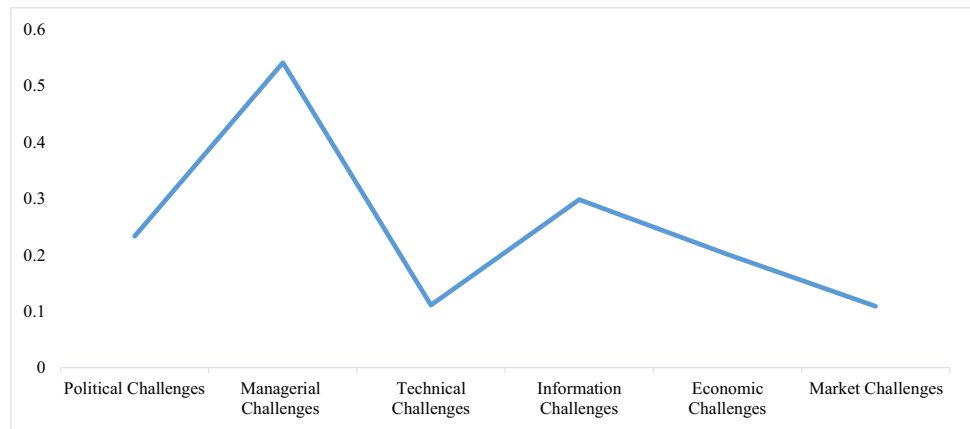
According to the calculation results in Table 4, financial development and governance have a direct correlation with a nation's economic degree of development, according to the study's findings. In nations with a greater wealth, financial growth means better governance. Developing countries have a critical role to play in promoting better governance. Baltic states will not have the financial means to sustain and strengthen their governing institutions. Since most operations are still handled via relationships and repeated purchases, the need for effective governance is likely to be lower at lower stages of growth.

Table 5 shows that the voting public study also supports these. Low-income nations' median voters are more interested in making decent living than they are with the effectiveness of their government. At increasing levels of growth, the voting population is financially off and is therefore more interested in the quality of institutions and governance. At lower levels of economic development, increased income disparity may be blamed with affecting government, whereas at higher stages of economic development, it can be blamed for improving it. As a result, it seems that better financial development has a favorable impact on governance quality only at more advanced phases of wealth creation.

Table 6 shows the FTOPSIS estimations, whereas Table 7 shows indicator-wise comparison of financial comparison. Parallel to the sustainability innovation findings, which aims to connect with the energy development and

**Fig. 1** Ranking of indicators of influence factor. Source: Author's findings

**Fig. 2** Ranking of challenges to financial consideration. Source: Author’s findings



**Table 4** Challenges of energy financing considerations for sustainable energy innovation

Barrier	Weights
Political challenges	0.233
Managerial challenges	0.541
Technical challenges	0.111
Information challenges	0.298
Economic challenges	0.201
Market challenges	0.109

**Table 5** Key drivers for energy financing considerations to pursue for sustainable energy innovation

	UIN	UIM	PIN	PIM	W
UNI	0.50	0.18	0.35	0.34	0.48
UIM	0.49	0.44	0.41	0.67	0.39
PIN	0.33	0.90	0.83	0.51	0.41
PIM	0.29	0.28	0.19	0.22	0.49

**Table 6** FTOPSIS estimate outputs

	FC	CI	CGI	FD
Within firm acceptance	0.44	0.28	0.19	0.44
Within the market acceptance	0.78	0.29	0.30	0.35
Within country acceptance	0.31	0.10	0.34	0.80
Weights	0.76	0.10	0.16	0.49

financial development, is revealed as significant by 40% role of multiple energy financing considerations by 2030. It is expected that energy financing considerations for sustainable energy innovations with the intervening role of energy development would provide this structure a boost

**Table 7** Indicator-wise and scope-wise comparison of energy financing considerations for sustainable energy innovation and energy development

Region	FCFI	CGI	FD
Within the firm	118	39	202
Out of the firm	544	47	189
Within the market	130	78	309
Out of the market	105	31	51
Within the country	254	88	91
Out of the country	189	92	296
Currency	Energy financing considerations Contribution		
UDS	39%		
EUR	48%		
Other	28%		

of roughly 60% until 2040. Figure 2 shows the ranking of challenges of financial consideration.

**Robustness analysis**

A unique strategy is used in our technique by reducing the number of potential interactions using a least absolute shrinkage and selection algorithm. A logistic model may be used to detect both simple patterns in the data and more complicated relationships between them. In addition to this, we are able to examine not only particular correlations but the aggregate likelihood of model correct predictions.

The findings showing financial performance may strengthen the administration are bolstered by this new evidence. It is also clear from the results in Table 8 that energy financing considerations have a positive influence on sustainable energy innovation, energy development indicators, and financial development correspondingly. This is only at high levels of affluence and globalization. If a society is increasingly linked to the global economy, it is more susceptible to direct investment owing to poor governance. As a result,

**Table 8** Sensitivity analysis

	FC	CI	CGI	FD
Within firm acceptance	0.46	0.11	0.35	0.90
Within the market acceptance	0.88	0.19	0.10	0.70
Within country acceptance	0.40	0.87	0.77	0.31
Weights	0.13	0.91	0.78	0.24

more globalization may serve as a stimulus for existing governance changes in response to growing capital formation.

Figure 3 shows the financial consideration to pursue for sustainable energy innovation. It is conceivable that these changes might be achieved via the spread of ideas, knowledge, and technology, as well as an increase in people's wealth as the government actually integrates with the international economy. A larger degree of globalization necessitates the harmonization of economic policies and institutional improvements across states. We additionally explore the sensitivity of our findings by using two widely accepted growth accounting metrics.

## Discussion

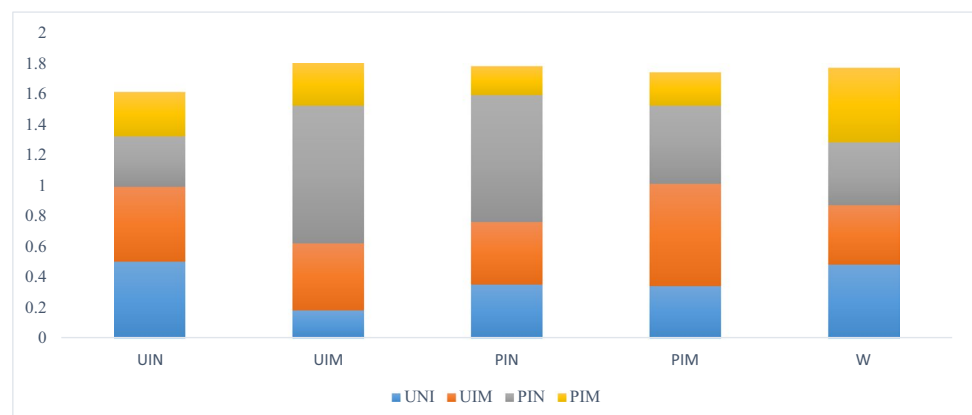
Several nations' financial sectors were weakened as a consequence of the 2007 subprime loan crisis in China that became a worldwide financial crisis as a result of globalization. This sparked a discussion over the impact of financial globalization on the growth of the financial sector. There has been an ongoing quest by academics and politicians alike to discover the ways in which financial globalization affects local economic growth. Despite the enormous advantages of financial globalization, this is not enough to convince me. Prominent economic experts argue that its alleged advantages are unconvincing and that it might entail enormous hazards. According to Stiglitz (2002), an economy is at danger of collapse when its capital inflows are unregulated. An important lecture by Mishkin (2007) points out the dangers of ignoring the need

of managing the globalization of financial markets in order to avoid financial crises. As a result of the greater capital mobility brought on by financial globalization, financial institutions, particularly banks, often take on excessive risk. As Reinhart and Rogoff (2008) write in their 2008 paper, "periods of high international capital mobility, not just famously as they did in the 1990," have "historically" led to international financial crises "not only famously as they did in the 1990s." Stulz (2005) contends that all investors risk expropriation owing to financial globalization and highlights that when the danger of expropriation is considerable, international risk sharing, financial growth, and the influence of financial globalization are restricted. There are few examples of financial globalization's benefits to be found in nations that have risen at such a rapid pace. Economic globalization, economic progress, and technical innovation have all had an effect on China's consumption-based emissions as well as territory-based emissions, which we have studied in depth. Many major developments are covered in this inquiry.

The results reveal that financial development has a significant influence on environmental pollution because of the positive impact it has on the economy. It is impossible to escape the contradiction that China relies on foreign supplies to fulfill local demand, yet the severity of foreign emissions jeopardizes environmental protection. What we can conclude is that economic and environmental changes are both important factors that affect the growth and development of any nation. The results, on the other hand, refute the theory that long-term increases in CO<sub>2</sub> emissions are linked to decreased financial growth. It is still a good idea for the country's government to carefully regulate their relationship and put an emphasis on reducing emissions, because fast growth might jeopardize the long-term sustainability aim and raise pollution control costs.

If the government wants to reduce emissions in both consumption and territory-based contexts, it should pay close attention to domestic credit to the private sector (the private sector's total deposits/private loans/stock

**Fig. 3** Financial consideration to pursue for sustainable energy innovation and financial development. Source: Author's findings



exchanged/turnover/total deposits bank concentration) and the securities market. For the sake of environmental sustainability, China should try to increase its liquid and deposit liabilities, foreign direct investment inflows, stock market capitalization, foreign assets and liabilities, and capital account solvency. This study recommends that China strengthen current natural resource rules in order to avoid the abuse of fossil fuels, based on the findings. As a further incentive for green investment, sustainable and ecologically sound resource rules should be implemented. Fossil fuels account for 64% of China's electrical production (Unwin 2019). Power generation in China is mostly based on fossil fuels, which are expensive owing to oil imports, a huge pressure on the fiscal budget, and a source of pollution. Despite China's enormous sustainable energy potential, the country is still falling behind. Natural resources abound in China, making it possible to generate significant amounts of low-cost green energy, a boon to China's efforts to build a more environmentally sound society. Public education and regulatory measures should be implemented in China to promote green energy and environmental protection. Due to the fact that stock market development in the majority of nations is still far below the point at which equity market development starts to have a negative impact on innovation, this conclusion may explain why prior studies have shown a positive impact of equity market development.

## Conclusion and implications

This research examines the relationship between financial development under different financial consideration and energy development in the current time by using fuzzy TOPSIS technique. Researchers found that emerging economy like China, sustainable energy innovation may be reduced through financial consideration, such as government subsidies and tax rebates. The study also gave political ramifications, suggesting that green fiscal policies be adopted effectively in reducing the carbon emissions more efficiently and making climate change beneficial to individuals for the long term. Based on prior study, three gaps may be found in ongoing study. Investigation is the first topic that comes to mind here. There has been some prior study on the link between environmental funding and carbon intensity, but few studies have looked at the mix of the two.  $C_k$  values are  $C_1 = 0.95$ ,  $C_2 = 0.7$ ,  $C_3 = 0.75$ ,  $C_4 = 0.55$ ,  $C_5 = 0.7$ ,  $C_6 = 0.75$ ,  $C_7 = 0.65$ ,  $C_8 = 0.85$ ,  $C_9 = 0.8$ , and  $C_{10} = 0.7$ , and the values of the weight of the energy development are  $W_1 = (0.765, 0.965, 1)$ ,  $W_2 = (0.622, 0.817, 0.953)$ ,  $W_3 = (0.733, 0.928, 0.98)$ ,

and  $W_4 = (0.586, 0.77, 0.916)$ , whereas the number of financial service providers per population shows an average of 2.5 financial services for every 100,000 residents from 2009 to 2012. Another way to measure financial strength is to use the ratio of private credit to output that shows enterprises in a certain province's value added tax (VET).

The study resulted and shown the significant links between sustainable energy innovation, energy development, and energy financing considerations that has become critical in the recent months and years. Public spending and other operations will benefit from a greater GDP per capita. Governments may benefit from advantages of scale and influence as a result of this, allowing them to operate more effectively. Additionally, this study takes into account the amount of energy used. The large distinction in index construction is similarly important. Financial consideration for innovation, which is becoming increasingly popular, has received limited attention in earlier studies on financial development and its impact on external changes. A financial development index is built utilizing data from reputable sources, as shown above.

On these findings, the study provides the following policy implications:

1. The study proposes this big gap to fill big gap in current research in the way the study was conducted. In order to improve the financial efficacy of the carbon market, a fair and constant allocation price is required. This new derivative is separate from the traditional economy or the financial market.
2. There is a need to look into the social and economic realities of sustainable energy innovation. Economic and social progress may be enhanced by its complex processes and a wider range of factors. Due to the significant volatility of permission pricing, wealth management will be more difficult.
3. To put it another way, this undermines firms' willingness to engage in carbon trading, which ultimately harms long-term efforts to reduce emissions. As a result, present carbon taxes are not conducive to global efforts to enhance financial sustainability.
4. We also propose to consider the influence of sustainability innovations varies according to national, market, industry, and business characteristics. It is debatable if these criteria can be generalized across research since each business is unique and works in unique environments. We propose to research both the existing moderating and mediating effects as well as novel elements that may impact this connection. The recent study has found that external and mediating variables (e.g., in the national, market, and industrial settings) are understudied.

**Author contribution** Conceptualization was done by Sergey Evgenievich Barykin and Sergey Mikhailovich Sergeev. Methodology, Angela Bahauovna Mottaeva; software, Elena De La Poza Plaza; validation, Natalya Vladimirovna Baydukova; formal analysis and investigation, Alexander Viktorovich Gubenko. All authors have read and agreed to the published version of the manuscript.

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

## Declarations

**Ethical approval and consent to participate** 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.

**Competing interest** The authors declare no competing interests.

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