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DOES INCOME INEQUALITY AFFECT GREEN INNOVATION? A NON-LINEAR EVIDENCE

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Abstract. It is crucial for the advancement of political economics and innovation economics to examine the relationship between income inequality and green innovation (GI). Using the panel fixed effect model, this study investigates the influence of income inequality on GI across 97 countries from 1991 to 2018 and demonstrates a significant non-linear association between the two. The empirical data exhibit an inverted U-shape relationship, suggesting that there is an optimal degree of income inequality that optimizes GI output, and the inflection point of our overall sample is at a Gini coefficient of 0.366. Additionally, we choose a set of robustness tests to validate the results by substituting explained variables, adding omitted variables, and employing the difference and system generalized method of moments (GMM) estimations. Moreover, heterogeneity analysis reveals that the non-linear patterns vary among samples, with the U-shape relationship being more significant in countries with lower income, higher corruption, and weaker government effectiveness. Our findings provide government decision-makers with a crucial reference for maximizing the importance of income distribution in fostering GI and achieving sustainable development.

Keywords: income inequality, green innovation (GI), panel fixed effect model.

JEL Classification: D63, O15, Q55.

Introduction

With resource depletion, environmental pollution, and persistent ecosystem deterioration becoming increasingly serious, environmental challenges have emerged as a fundamental barrier to sustainable economic development (Warner et al., 2010; Wei et al., 2015; Chen et al., 2021a). Human-induced climate change, especially temperature warming, has caused massive

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harm and lasting losses in terrestrial, freshwater, coastal, and pelagic marine ecosystems, according to the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report. Under the current environmental crisis, it is critical to reduce carbon emissions on both the production and consumption sides. (Zhao et al., 2023; Zheng et al., 2023a, 2023b; Wang et al., 2022; Yang et al., 2022; Long et al., 2022; Zou et al., 2023; Yin et al., 2022a).

Green innovation (GI) refers to any improvement made to an existing product, process, service, or management that aims to add value to customers and organizations while significantly decreasing negative environmental impacts (Hojnik & Ruzzier, 2016; Zheng et al., 2021; Chai et al., 2022; Hao et al., 2023; Luo et al., 2022; Ren et al., 2023; Xue et al., 2022). According to the World Intellectual Property Organization (WIPO), the widest scope of GI includes technologies connected to the disposal of environmentally relevant contaminants as well as those linked to climate change mitigation. Stakeholders have widely recognized GI as a significant method for attaining the goals of energy conservation and environmentally friendly development (Huang & Li, 2017; Fernando et al., 2019). In contrast to traditional technological innovation, which seeks only economic benefits at the expense of the environment and resources, GI seeks to strike a balance between more efficient resource utilization, fewer pollutant emissions, and better economic performance (Wang & Li, 2019; Yin et al., 2023; Li et al., 2023a, 2023b; Mgomezulu et al., 2023; Raihan, 2023; Zhongzheng, 2023). Therefore, it is imperative to study further what external environmental factors influence a country's GI capacity.

Existing studies have identified a set of factors, such as government governance, natural disasters, ideology, and stakeholders, as the primary determinants of GI (Fu et al., 2023; Peng et al., 2023). For instance, empirical research demonstrates that the impact of environmental regulation on GI differs according to the kind of environmental regulation (Song et al., 2020; Luo et al., 2021). There is also a favorable relationship between governmental efficiency and the production of GI, as well as a significant threshold impact between corruption and innovative activities (Wen et al., 2020a, 2021). Chen et al. (2021b) and Zhao et al. (2022) argue that natural disasters have a devastating effect on technological progress. According to Wang et al. (2019), government ideology affects innovation significantly, and right-wing ruling parties promote the emergence of innovative technologies. Moreover, by employing a panel GMM estimation, Wang et al. (2021) demonstrate strong evidence that democracy has a beneficial influence on innovation performance. There is a favorable link from companies' social responsibility and environmental ethics to their capacity for GI (Chang, 2011; Kraus et al., 2020; Shahzad et al., 2020). Furthermore, research shows that stakeholder legitimacy pressure can promote GI in general, whereas the impacts of suppliers, consumers, and competitors are multifaceted (Lin et al., 2014; Li et al., 2017). The aforementioned research has investigated the influencing factors from various aspects of environmental regulation, governmental efficiency, natural disaster, etc., but few have focused on income inequality, which is also an important influencing factor (Vona & Patriarca, 2011; Zecca & Nicolli, 2021). Our research addresses this vacuum in the literature on the topic.

There are two theoretical hypotheses concerning the sources of innovation in previous research. One is the "technology-push" hypothesis, which suggests that innovation is determined by technological and cost factors influencing supply (Dosi, 1998). The other is the “demand-pull” hypothesis, which argues that countries’ per capita income level and the demand size and payment capacity of the middle and upper-income classes are the most fundamental factors influencing firm innovation decisions (Schmookler, 1966). GI, as a part of innovation, is also driven by these sources. However, because of the long-standing assumption of homothetic preference, income distribution’s effects on innovation and GI have not been further explored.

The assumption of homothetic preference is too idealistic, because the preferences of people with different characteristics are bound to be different, and so the hypothesis of hierarchic preferences is proposed. Earlier studies of income inequality on innovation start with Murphy et al. (1989), who claim that the adoption of advanced technologies requires a relatively large product market size, and wealth concentration can be a barrier to the widespread adoption of cutting-edge technologies. After categorizing consumers as poor or rich, Zweimüller (2000) explores the ways through which income inequality influences the structure of product prices and consequently innovation. Foellmi and Zweimüller (2006) further extend the research by examining the price effect and scale effect. They declare that as the population share of the rich increases relative to the poor, it is beneficial for innovative firms to charge high prices and that the price effect is positive; however, it impedes the market scale of new products, and the scale effect is negative. The consumption structure effect is another channel via which income inequality can impede innovation. As Croix and Doepke (2004) note, increasing income inequality can concentrate social wealth towards a few high-income groups while decreasing the share of middle-income groups, thus discouraging innovation capacity. The ways that income inequality influences GI are shown in Figure 1. To conclude, the ultimate direction of the impact of income distribution on GI is determined by the combination of the three effects, and there is evidence that income inequality has a non-linear correlation with GI (Vona & Patriarca, 2011; Bai et al., 2020).

This study offers the following contributions. Using multi-national data from 1991 to 2018, this research establishes a non-linear relationship between income inequality and GI, thus contributing to the literature on income inequality, political economics, and innovation economics. In addition, the panel fixed effect model is used as the benchmark model, and the difference and system GMM estimations are employed to address any endogenous issues. The U-shaped link between income inequality and GI persists following robustness and endogeneity analyses. Moreover, this research analyzes how income inequality affects GI in various countries. The regression results indicate that the non-linear patterns differ between samples with the U-shaped relationship being more significant in countries with

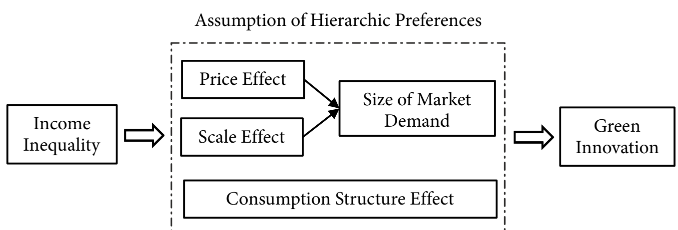

Figure 1. The mechanisms by which income inequality affects green innovation

lower income, higher corruption, and weaker government effectiveness. Finally, we compute the model inflection point values for the entire sample and each subsample. The findings suggest that the inflection point values of the Gini coefficient vary between samples, and as a result, we make specific policy recommendations.

The remaining portion of this work is presented here. Section 1 is the literature review and hypotheses. In Section 2, variable definitions and empirical methodologies are given. Section 3 contains the regression results, robustness tests, and analysis of heterogeneity. There are a conclusion and policy implications at the end.

1. Literature review and hypotheses

Many scholars have employed a range of techniques to further the scientific investigation of the connection between income inequality and residents' health, social stability, economic development, and environmental pollution (Lee et al., 2020; Soava et al., 2020). Some early research reports that income inequality plays a significant role in worsening health and well-being, including physical, mental, and public health issues (Pickett & Wilkinson, 2015; Niessen et al., 2018). Dickman et al. (2017) investigate the correlation between inequality and the healthcare system in the United States, claiming that the difference in life expectancy between the wealthy and the poor is growing. Furthermore, insufficient insurance coverage leaves many poor people uninsured, and widespread medical debt frequently leads to bankruptcy. Patel et al. (2018) claim that there is a convincing quantitative connection between income inequality and depression, implying that mental health professionals should advocate for a fairer and more equitable allocation of wealth. According to Owens et al. (2016), increased income inequality may lead to unequal access to educational resources for students, affecting academic performance. Additionally, Berg et al. (2018) argue that redistribution promotes growth, with lower income inequality strongly associated with faster and more sustained growth achieved through human capital accumulation and fertility channels. Employing a novel non-linear autoregressive distributed lag (ARDL) approach, Zhao et al. (2021) propose that rising income inequality in BRICS economies promotes carbon emissions and undermines environmental sustainability. As stated by Jorgenson et al. (2017), the wealthy prefer to pollute more, and there is a positive link between the top 10% income share and state-level emissions.

Although income inequality has been examined extensively for many years, the literature on how income inequality influences GI in the context of the prevalence of sustainable development theory is still relatively limited and no consensus results have been reached. Recently, several distinct perspectives on the impact of income inequality on GI have been presented. The first viewpoint claims that economic inequality and GI are positively related. Using the European Community Household Panel Dataset from 1995 to 2000, Tselios (2011) argues at the current level of income inequality in the European Union that increasing income inequality in a region is favorable to GI. Furthermore, geographic space and location are recognized as important aspects in determining the heterogeneity of this relationship, since knowledge spillovers are intra-regional in scope. The second viewpoint believes that rising income inequality hinders GI. Zecca and Nicolli (2021) empirically test the correlation between income inequality and green technological change through a counting regression model, discovering that reducing inequality can stimulate GI in rich and democratic countries. The last viewpoint demonstrates a non-linear correlation between income inequality and GI. Vona and Patriarca (2011) construct a dynamic model to investigate the role of income inequality in the diffusion of environmental technologies, concluding that inequality hinders innovation diffusion in rich regions while per capita income is the most influential factor in poorer regions. The findings are contradictory, with varying conclusions for diverse country groups, time periods, and modeling approaches. This is not surprising given that income inequality can influence GI through a variety of channels, with the outcomes depending on the interaction of multiple effects such as, but not limited to, price effects, scale effects, and consumption structure effects.

From the viewpoint of effective demand, income inequality has a substantial effect on market demand size and consumption structure, which further influences GI behavior (Foellmi & Zweimüller, 2017). According to Schmookler (1966), market demand determines the direction and quantity of innovative activities. When there is sufficient and effective market demand, firms' research and development (R&D) investments can be transformed into innovation revenues through the market, stimulating their incentives to innovate and improving the country's GI capacity.

The impact of income inequality on the size of market demand for innovative green products is determined by the "price effect" and "scale effect". On the one side, the widening income gap leads to a greater concentration of wealthy individuals prepared to pay higher prices for innovative items due to the higher marginal utility of innovative products for them, expanding market demand for green products and stimulating firm innovation (Foellmi et al., 2014). On the other side, as income inequality grows, most low- and middle-income people will be excluded from purchasing new products, narrowing the market scale for green products and discouraging GI (Edler & Georghiou, 2007; Chu et al., 2016; Ahuja et al., 2023; Yang & Chen, 2023; Awan & Yaqoob, 2023; Yolcan, 2023). Therefore, whether income inequality promotes or inhibits GI through the size of market demand is highly dependent on the relationship between the price effect and the scale effect: if the price effect dominates, then widening the income gap will facilitate GI; however, if the scale effect dominates, then increasing income inequality will impede GI. Moreover, income inequality has a "consumption structure effect", which may weaken the role of effective demand in increasing innovation capacity, undermining the development of GI activities. As income inequality rises, social wealth becomes more concentrated in a few high-income groups, while the share of middle-income groups falls (Croix & Doepke, 2004). However, the low-income class cannot afford non-essential goods, whereas the high-income class prefers customized products. Only the middle-income class consumes the majority of standardized industrial innovation products. Thus, rising income inequality has an adverse influence on the upgrading of the consumption structure, inhibits the consumption-ability of the middle-income class, and is detrimental to the country's GI capacity (Greewood & Mukoyama, 2001).

As the prior research has demonstrated, the influence of income inequality on GI is extensive and dependent on a complicated interaction between three effects: the price effect, the scale effect, and the consumption structure effect. Yet, there is limited consensus on the correlation between income inequality and GI (Bernardino & Araújot, 2013; Bai et al., 2020; Zecca & Nicolli, 2021). With the ongoing deterioration of the global environment and the widening of global income disparity[1], the significance of income inequality in achieving a low-carbon economy through GI warrants additional research and analysis. The following is our study's hypothesis:

Hypothesis: Income inequality has a big influence on GI. When the income gap is small, the price effect dominates, and income inequality can promote GI; as the income gap increases, the scale effect and consumption structure effect will inhibit GI.

2. Data and methodology

2.1. Data and variables

(1) Dependent variable

Patent: Grilliches (1990) points out that patent statistics can be a good proxy of innovation performance since patents can directly reveal the outputs of R&D and innovation activities. Some academics argue that openly available patent databases can provide a real-time reflection of the dynamics of the innovation system, and that patent applications can be used to quantify the intermediate products of the innovation process (Acs et al., 2002; Jalles, 2010). Thus, in this study, we chose to use the number of green patent applications as our GI indicator (Zheng et al., 2020; Wen et al., 2022). Specifically, we use the Green List of International Patent Classification compiled by the World Intellectual Property Organization to choose our green patents. In accordance with He et al. (2020), we compute the natural logarithm of the number of green patent applications in a country to determine its GI (proxied by *Patent*).

(2) Independent variable

Gini: This study's explanatory variable is income inequality, and the Gini coefficient is the most popular international indicator of income inequality. The bigger the Gini coefficient, the more unequal the income, and the threshold for a country's income inequality are typically set at 0.4. We obtain the Gini coefficient (proxied by *Gini*) from the UNU-WIDER World Income Inequality Database (WIID), which compiles sufficient income inequality statistics (Zecca & Nicolli, 2021). We also incorporate the square term of the Gini coefficient (proxied by *Gini2*) into the model to examine the non-linear influence of income inequality on GI.

(3) Control variables

Aside from income inequality, Gross Domestic Product (GDP) per capita, population size, R&D investments, urbanization, literacy, and monetary policy all affect the GI of countries (Yin et al., 2022b; Qin et al., 2023; Wen et al., 2023a, 2023b). To strengthen the validity of the regression model, our research includes a number of these variables as control variables.

[1] Inequality in wealth and income distribution has been steadily increasing over the last few decades, reaching alarming proportions in recent years. According to the World Inequality Database, the top 10% of the world's population accounts for 52% of global income, while the bottom 50% of the population earns only 8% of global income, indicating that income and wealth inequality are massive in the current era.

GDP: There is a strong tie between economic growth and innovation performance, since a higher level of economic development tends to generate greater financial resources for R&D and innovation activities (Kogan et al., 2017). This study employs GDP per capita to assess economic progress (proxied by *GDP*) (Arin et al., 2011).

Pop: Some researchers believe that population growth has a non-linear influence on technological innovation (Dong et al., 2016), however, other studies demonstrate that as a population grows, the likelihood of applying new ideas increases, hence promoting the development and widespread use of innovative technologies (Kremer, 1993). This analysis accounts for the effect of population size on GI using the total population (proxied by *Pop*).

R&D: As noted by Pradhan et al. (2018), more expenditures are likely to result in more trademark and patent applications, and the amount of innovation is highly correlated with expenditures on research and development. In this paper, we choose R&D spending to reflect a country's commitment to innovation (proxied by *R&D*).

Urban: Urbanization promotes the generation of GI (Cheng, 2010; Chen et al., 2020). First, urbanization generates an agglomeration effect and promotes the concentration of components and economic activities. Second, urbanization hastens the diffusion and spillover of technological innovation, since regions with a high level of urbanization have more frequent mobility of people and more convenient information exchange. The ratio of urban residents to the overall population is used in this study to express the level of urbanization (proxied by *Urban*).

Literacy: General education, according to Roper et al. (2017), can facilitate technical growth. On the one side, higher levels of education raise public concern for the environment to a degree (Brasington & Hite, 2005). On the other side, higher literacy rates imply higher levels of information acquisition and higher environmental quality standards. This paper uses literacy to assess national educational attainment (proxied by *Literacy*).

M2: Moran and Queralto (2018) claim that monetary policy can influence a firm's innovation and total factor productivity. The broad money supply and the borrowing rate are the primary intermediate objectives of monetary policy, and in this study, the broad money supply will stand in for monetary policy (proxied by *M2*).

(4) Data description

The data statistics utilized in the investigation are obtained from the UNU-WIDER World Income Inequality Database (WIID) (2021), the World Development Indicators (World Bank, 2020), the OECD environmental statistics database, the World Intellectual Property Organization (WDI), and the Worldwide Government Indicator (WGI). After combining all variables, we compile multi-national data from 1991 to 2018 for 97 countries[2]. Table 1 contains the variables' definitions, symbols, and data sources.

Table 2 displays the model's major variables' descriptive statistics and correlation matrix. The average value of *Gini* is 4.005[3], which has already exceeded the international alert value

[2] Due to data availability constraints, several countries' green patent applications and Gini coefficients are only available until 2018.

[3] The actual Gini coefficient value = *Gini*/10, as a result of data processing, indicating that the mean value has exceeded 0.4.

Table 1. Variable definitions and data sources

Variable	Symbol	Definition	Data source
Green patent applications	*Patent*	Total number of green patent applications	OECD environmental statistics database
Gini coefficient	*Gini*	Gini coefficient	World Income Inequality Database (WIID)
Square term of Gini coefficient	*Gini2*	(Gini coefficient)^2	World Income Inequality Database (WIID)
Per capita GDP	*GDP*	GDP divided by population	World Intellectual Property Organization (WDI)
Population size	*Pop*	Total population	World Intellectual Property Organization (WDI)
R&D expenditure	*R&D*	Research and development expenditure (% of GDP)	World Intellectual Property Organization (WDI)
Urbanization	*Urban*	Urban population (% of total population)	World Intellectual Property Organization (WDI)
Literacy rate	*Literacy*	Literacy rate, adult total (% of people ages 15 and above)	World Intellectual Property Organization (WDI)
Monetary policy	*M2*	Broad money (% of GDP)	World Intellectual Property Organization (WDI)

Table 2. Data descriptive statistics and correlation matrix

Panel A: Data descriptive statistics

Variable	Mean	Std. Dev.	Min	Median	Max
Patent	2.719	2.145	0.157	2.048	9.244
Gini	4.005	0.961	1.518	3.797	7.429
GDP	1.980	2.493	0.016	0.865	19.606
Pop	4.140	12.301	0.002	0.997	135.264
R&D	1.066	0.953	0.015	0.712	4.953
Urban	6.469	2.096	0.918	6.719	10.000
Literacy	8.810	1.616	2.573	9.438	9.999
M2	6.067	3.957	0.682	5.147	26.006

Panel B: Correlation matrix

	GDP	*Pop*	*R&D*	*Urban*	*Literacy*	*M2*	VIF	Tolerance
GDP	1						2.76	0.362
Pop	–0.089	1					1.43	0.699
R&D	0.719	0.034	1				2.66	0.376
Urban	0.603	–0.290	0.516	1			2.12	0.472
Literacy	0.192	–0.398	0.099	0.349	1		1.58	0.631
M2	0.464	0.095	0.525	0.291	–0.058	1	1.48	0.676

Notes: The table reports the data descriptive statistics and correlation matrix. Patent is the natural log of the total number of green patent applications. Tolerance value greater than 0.1 and VIF value less than 5 indicate no multicollinearity.

for the income distribution gap, indicating that income inequality is widespread. Furthermore, the standard deviation of *Gini* is 0.961, suggesting that income inequality varies greatly between countries. According to the World Inequality Report 2022 (Chancel et al., 2022), inequality differs markedly between the world's most egalitarian area (Europe) and the world's most unequal region (the Middle East and North Africa, or MENA)[4]. Similarly, the *Patent's* value ranges from a low of 0.157 to a high of 9.244, illustrating the wide variation in GI that exists across both countries and time periods.

To assess potential multicollinearity issues in the primary variables, Panel B of Table 2 offers correlation coefficients and variance inflating factors (VIF) for important control variables. The VIF value must be less than 5 and the tolerance value must be larger than 0.1, as stated by Craney and Surles (2002), for a system to be considered independent. Panel B's findings lend support to our contention that there is no major multicollinearity problem with our model because all variables are truly independent and do not significantly correlate with one another (Abban et al., 2020).

2.2. Estimation method

To investigate how income inequality influences GI, we use a panel model with two-way fixed effects in this research. This method helps us deal with endogeneity difficulties caused by missing data, controls for unobservable effects that vary by country and year, and reduces the likelihood of multicollinearity (Wen et al., 2016; Fu et al., 2020; Wen et al., 2020b).

The following is a description of our standard model:

$$\ln(Patent+1)_{it} = \alpha Gini_{it} + \beta Gini_{it}^2 + \gamma X_{it} + \mu_i + u_t + \varepsilon_{it}, \tag{1}$$

where, $Patent_{it}$ denotes green innovation,[5] $Gini_{it}$ is the Gini coefficient, $Gini_{it}^2$ is the square term of the Gini coefficient, X_{it} denotes other control variables, μ_i stands for country-specific effects, u_t stands for year-specific effects, and ε_{it} is a random disturbance term.

3. Empirical results

3.1. Baseline results

Table 3 shows the estimated effects of how income inequality influences GI capacity in 97 countries from 1991 to 2018. To investigate the non-linear relationship, the Gini coefficient (proxied by *Gini*) and the square term of the Gini coefficient (proxied by *Gini2*) are introduced into the model first. When we include per capita GDP and monetary policy in column (1), the *Gini's* coefficient is found to be 0.850 at a 10% level of significance. Column (2) extends column (1) by introducing a country's population size, and the estimated effects of *Gini* and *Gini2* both become significant at the level of 10%. Additionally, we add R&D investments and urbanization in column (3) and include literacy in column (4). The *Gini*

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[4] The richest 10% of earners account for about 36% of total European income, but 58% of all MENA earnings.

[5] We utilize the natural logarithm of the variables to maintain the series stationary and reduce the probability of covariance and heteroscedasticity. Moreover, we add one to the patents before taking the logarithm, since the number of patent applications in a particular year may be zero in certain countries.

Table 3. Baseline results

Variable	(1)	(2)	(3)	(4)
Gini	0.850* (1.75)	0.902* (1.91)	0.934** (2.04)	0.929** (2.00)
Gini2	−0.091 (−1.29)	−0.112* (−1.73)	−0.128** (−2.10)	−0.127** (−2.06)
GDP	0.010 (0.07)	0.096 (0.61)	0.213 (1.16)	0.217 (1.15)
M2	0.025 (1.07)	0.030 (1.30)	−0.012 (−0.56)	−0.013 (−0.58)
Pop		0.089*** (12.14)	0.086*** (11.74)	0.086*** (8.49)
R&D			0.571*** (4.69)	0.573*** (4.63)
Urban			−0.029 (−0.13)	−0.032 (−0.14)
Literacy				0.013 (0.10)
Constant	−0.642 (−0.78)	−1.005 (−1.18)	−0.585 (−0.34)	−0.682 (−0.33)
Country	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
R^2	0.525	0.582	0.596	0.596
F	7.913	72.731	98.364	100.226

Notes: Values in parentheses indicate t-statistics. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

and *Gini2* coefficients, respectively, are 0.929 and −0.127 at the significant level of 5% when all control variables are included. Therefore, we conclude that the correlation between the Gini coefficient and green patent applications follows an inverted U-shape and that countries' GI capacity shows an upward and then downward trend as income inequality increases. Additionally, the empirical results show that the model's inflection point is 3.66[6], implying that the Gini coefficient is 0.366. In other words, when the Gini coefficient is less than 0.366, the price effect dominates, and an increase in income inequality significantly contributes to a rise in GI level, but this promotion effect will gradually weaken; when the Gini coefficient exceeds 0.366, the scale and consumption structure effects dominate, and a rise in income inequality inhibits GI, and this inhibiting effect will gradually increase. This result supports our previous hypothesis.

The potential causes of these regression outcomes are as follows. First, the existence of a wealthy class is a prerequisite for promoting GI, since they are prepared to pay for innovative products and technologies (Foellmi et al., 2014). In addition, residents in high-income regions are more concerned about the environment and more inclined to take part in conserva-

[6] $\ln(Patent+1)_{it} = 0.929Gini_{it} - 0.127Gini_{it}^2 + \gamma X_{it} + \mu_i + u_t + \varepsilon_{it}$, $V(inflection) = -0.929/(-0.127*2) = 3.66$.

tion initiatives (Liu et al., 2020). As Tselios (2011) states, the dynamic price effect outweighs the scale effect when inequality is low (as in Europe), and a rise in income inequality leads to an expansion of wealthy consumers, thus encouraging enterprises to innovate. Second, as the income gap widens further, the size of the market will shrink, as low- and middle-income groups will find it increasingly difficult to afford expensive green products (Edler & Georghiou, 2007). Finally, excessive income inequality expands the demand hierarchy, which is detrimental to upgrading the consumption structure and improving GI capacity (Greewood & Mukoyama, 2001).

When it comes to control variables, *Pop's* coefficients are significantly positive at a level of 1% in columns (2) to (4), implying that as population size increases, so do green patent applications. The economic significance is then determined by dividing the standard deviation of *Patent* by *Pop's* coefficient multiplied by *Pop's* standard deviation. In other words, there is a 49.32% standard deviation increase in green patent applications for every standard deviation rise in population size [(0.086*12.301)/2.145]. This regression result is in line with Tselios (2011), who demonstrates the significance of including this control variable in the correlation analysis of inequality and innovation, and the population is conducive to innovation. Moreover, estimation findings in columns (3) and (4) show that the *R&D* coefficients are 0.57, which is statistically significant at the 1% level and indicates that for every standard deviation rise in *R&D*, *Patent* increases by 25.46% of the standard deviation [(0.573*0.953)/2.145]. Our findings confirm the conclusion of prior research that there is a positive link between R&D expenditure and innovation (Choi & Yi, 2018; Pradhan et al., 2018). In Table 3, there is no statistically significant relationship between any of the other control variables and GI.

3.2. Time lag effects

Many studies have demonstrated that income inequality has long-term effects on economic development and environmental quality, implying that income inequality shocks persist into the future (Koh et al., 2020; Wu & Xie, 2020). Hence, the effect of income inequality on GI may be persistent, and this non-linear relationship may be significant not only in the current year but also for some time in the future, with no idea of the year. In other words, it requires time for the market to respond when income inequality influences GI development through price, scale, and consumption structure effects (Zweimüller, 2000; Croix & Doepke, 2004; Foellmi & Zweimüller, 2006). Therefore, we assume that there should be a time lag effect to go along with the significant impact that income inequality has on GI. To test the hypothesis, this study explores the lagged effects of income inequality on GI by delaying the number of green patent applications by 1–10 years.

Table 4 presents the empirical findings. The main explanatory variables' coefficients and levels of significance in columns (1) through (5) fall within the predicted range, suggesting that the impact of income inequality on GI will last over the next 1–9 years. Column (6) shows after the tenth year of the green patent applications lag that the coefficient of *Gini*, while still positive, is no longer significant. Therefore, the non-linear relationship between income inequality and GI, as depicted by the inverted U-shape, is not only significant this year but also persists for 9 years, as shown by the regression findings of the lagged effects model.

Table 4. Time lag effects

Variable	$Patent_{+1}$	$Patent_{+3}$	$Patent_{+5}$	$Patent_{+7}$	$Patent_{+9}$	$Patent_{+10}$
	(1)	(2)	(3)	(4)	(5)	(6)
Gini	0.787* (1.98)	0.847** (2.12)	0.929* (1.90)	0.743** (2.44)	0.675* (1.93)	0.711 (1.63)
Gini2	–0.110** (–2.11)	–0.108** (–2.05)	–0.111* (–1.77)	–0.103** (–2.54)	–0.099** (–2.27)	–0.096* (–1.72)
GDP	0.239 (1.53)	0.189 (1.41)	0.045 (0.30)	–0.132 (–1.01)	–0.084 (–0.70)	–0.045 (–0.42)
M2	–0.004 (–0.22)	–0.024 (–1.20)	–0.028 (–1.38)	–0.013 (–0.84)	–0.007 (–0.50)	–0.005 (–0.27)
Pop	0.083*** (8.62)	0.072*** (8.36)	0.066*** (8.50)	0.055*** (6.01)	0.055*** (4.84)	0.046*** (5.14)
R&D	0.500*** (3.72)	0.369** (2.46)	0.362** (2.07)	0.278* (1.69)	0.199* (1.77)	0.083 (0.71)
Urban	0.001 (0.00)	0.137 (0.62)	0.055 (0.29)	0.055 (0.35)	0.157 (0.91)	0.159 (1.02)
Literacy	0.026 (0.24)	0.080 (1.01)	–0.002 (–0.03)	–0.030 (–0.67)	–0.100*** (–3.44)	–0.060** (–2.19)
Constant	–0.701 (–0.38)	–1.797 (–0.98)	–0.412 (–0.25)	0.887 (0.74)	1.350 (0.97)	0.929 (0.70)
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.571	0.514	0.409	0.333	0.198	0.124
F	38.288	46.720	34.709	15.875	7.818	6.679

Notes: Same as Table 3.

3.3. Robustness tests

3.3.1. Alternative explanatory variables

To better measure income inequality, we use the variable of "share of the fifth quintile group in total income (proxied by *Fifthtile*)" in the test to replace the previous Gini coefficient metric. The fifth quintile is the income share of the richest 20% group, which is reported as a percentage in WIID. After replacing the measure of income inequality, the signs of *Fifthtile* and *Fifthtile2* are consistent with the basic model. According to the regression results in column (1) of Table 5, *Fifthtile* and *Fifthtile2* have statistically significant coefficients of 1.529 and –0.182, respectively, at the 5% level. Moreover, the sign and significance of the other variables are generally consistent with the basic regression, demonstrating the model's robustness.

3.3.2. Endogeneity concerns

Endogeneity can be caused by a variety of factors. The most fundamental is the bias that results from omitted explanatory variables and reverses causality (Acemoglu et al., 2019; Afesorgbor, 2019). For objective estimation findings, it is essential in empirical analysis to have a method for dealing with endogeneity.

(1) Considering omitted variables

The first possible cause of endogeneity issues is omitted variable bias. Since it is difficult to exhaust all of the elements that drive GI, this may result in explanatory and control variables that are concurrently correlated with random error terms. Controlling for other potential factors in the regression model as thoroughly as possible can greatly reduce estimation errors due to omitted variables bias. First, as stated by Frias et al. (2012), the association between industrial structure (proxied by *Industry*) and innovation capacity is positive, since a large proportion of the manufacturing industry provides better infrastructure for GI. Second, the degree of trade openness (proxied by *Openness*) of a country determines the rate of technology spillover, thus further influencing GI (Nasreen & Anwar, 2014; Sun et al., 2019). Third, employing the difference-in-difference (DID) model and the extended negative binomial model, Zecca and Nicolli (2021) propose that democratization (proxied by *Democracy*) facilitates GI significantly. These factors are included in the model investigating the effect of income inequality on GI to ensure the validity of the empirical findings.

Columns (2) to (5) in Table 5 report the empirical findings of the regression model when potential omitted variables are included on a case-by-case basis. The basic regression outcome is displayed in column (2). We introduce industrial structure in column (3), degree of trade openness in column (4), and democratization in column (5). Even if they fluctuate slightly, *Gini* and *Gini2* coefficients are statistically significant positive and negative, respectively, at the 10% and 5% statistical levels. Thus, the U-shaped association between income inequality and GI is confirmed to be strong.

(2) Difference and system GMM estimations

In addition to omitted variables, another underlying factor that can lead to endogeneity issues is reverse causality, which means that GI influences income inequality. It is widely known that income inequality not only affects innovation activities, but that innovation also affects income inequality by influencing corporate profits and economic growth (Breau et al., 2014; Aghion et al., 2019). By using time-series panel-data methods, Law et al. (2020) argue that innovation can exacerbate income inequality as a result of globalization and financial development.

In order to overcome potential endogeneity issues in multi-national data, GMM estimations are employed to examine the non-linear relationship between income inequality and GI. In this study, we perform both the difference GMM estimation (Arellano & Bond, 1991) and the system GMM estimation (Blundell & Bond, 1998) to improve the credibility of the regression findings. Columns (6) and (7) in Table 5 present the empirical outcomes of GMM estimations. *L.Patent* is the one-period lagged term of green patent applications, and the last four rows are the results of the test performed to determine the validity of the instrumental variables. The corresponding P-values for the AR(1) test are less than 0.05, whereas those for the AR(2) test are greater than 0.10, showing that serial correlation exists in the first order but not in the second. The findings suggest that the hypothesis that the residuals in the original model are not autocorrelated cannot be rejected. In addition, the P-values of the Sargan and Hansen tests are greater than 0.10, showing that the original hypothesis of the instrumental variables being jointly valid cannot be rejected. The empirical results demonstrate a strong positive correlation between the lag period of *Patent* and the current level of GI, implying that GI does exhibit "sustainability", which is consistent with our previous findings. Moreover, the coefficients of *Gini* and *Gini2* remain positive and negative, respectively, with both reaching a significant level of 10%. This outcome is consistent with prior panel fixed effect model estimates, lending credence to the conclusion that income inequality and GI have an inverted U-shaped relationship.

3.4. Heterogeneity analysis

3.4.1. The heterogeneity results of income level

Income levels vary considerably across countries, and existing research reveals that income levels can impact the relationship between income inequality and GI (Vona & Patriarca, 2011; Liu et al., 2020). Due to price effects, income inequality may contribute to a short-term increase in GI in low- and middle-income regions (Foellmi et al., 2014). However, Vona and Patriarca (2011) argue that pioneer consumers' externalities of green products only benefit the region as a whole if income inequality is relatively low. Long-term, as inequality increases, they will be unable to afford expensive green products, thereby hindering the development of local GI, as the primary desires of inhabitants in low-income countries are to meet fundamental necessities and increase income (Liu et al., 2020). In some high-income nations, such as the United States and Europe, that already have highly developed technological innovation capacities and are capable of manufacturing the most advanced green products, the income gap does not appear to have a substantial influence on GI ability (Napolitano et al., 2020).

To validate our hypothesis, we conduct separate regression analyses on low-/middle-income and high-income sample countries[7]. Table 6 displays the estimation results for the two sub-samples. According to the data, the impact of income inequality on GI varies significantly between samples with varying income levels. Column (1) reveals that the signs of *Gini* and *Gini2* are consistent with those in the basic regression at a 5% significance level, and the inflection point of the Gini coefficient is 0.375[8]. The findings demonstrate in low- and middle-income regions that the income gap promotes GI up to a certain level of inequality, but impedes GI as inequality rises too high. The empirical results of column (2) show that the non-linear link between income inequality and GI is not significant in high-income regions, which is similar to earlier research. To sum up, income level is the most important issue for low-/middle-income countries, and a certain degree of income inequality promotes the development of GI, but governments should take care to keep the Gini coefficient below 0.375.

3.4.2. The heterogeneity results of corruption degree

Employing a dynamic GMM model with multi-national data, Policardo and Carrera (2018) discover that income inequality has a positive impact on corruption and that corruption may be a reaction to perceived unequal income distribution. In the literature, there are two opposing academic perspectives on the influence of corruption on GI. Some academics argue

[7] The WDI database is used to classify countries' income criteria.

[8] $\ln(Patent+1)_{it} = 0.997Gini_{it} - 0.133Gini_{it}^2 + \gamma X_{it} + \mu_i + u_t + \varepsilon_{it}$, $V\left(inflection\right) = -0.997 / \left(-0.133 * 2\right) = 3.75.$

Table 6. Heterogeneity tests

Variable	Low income	High income	Low corruption	High corruption	Low government effectiveness	High government effectiveness
	(1)	(2)	(3)	(4)	(5)	(6)
Gini	0.997** (2.53)	1.552 (1.08)	0.656 (0.78)	0.755* (1.77)	1.229*** (3.33)	−0.118 (−0.13)
Gini2	−0.133** (−2.38)	−0.228 (−1.18)	−0.100 (−1.00)	−0.096* (−1.70)	−0.157*** (−3.15)	−0.075 (−0.67)
GDP	1.143 (1.37)	0.088 (0.54)	0.362 (1.19)	0.265 (0.47)	0.349 (1.54)	0.274 (1.12)
M2	0.001 (0.03)	−0.013 (−0.54)	−0.009 (−0.36)	0.040 (0.87)	0.075* (1.81)	−0.034 (−1.60)
Pop	0.094*** (9.63)	0.054 (1.25)	0.068 (1.53)	0.065*** (9.24)	0.077*** (10.40)	0.075* (1.80)
R&D	0.815*** (2.90)	0.486*** (3.19)	0.562*** (3.45)	0.861*** (3.73)	0.831*** (2.96)	0.539*** (4.62)
Urban	0.124 (0.49)	−0.570 (−1.69)	−0.169 (−0.48)	0.076 (0.32)	0.160 (0.65)	−0.202 (−0.75)
Literacy	−0.036 (−0.33)	0.609 (1.35)	−0.105* (−1.74)	0.208 (1.50)	0.021 (0.21)	−0.089 (−0.71)
Constant	−2.578 (−1.45)	−1.618 (−0.25)	2.413 (0.61)	−3.731 (−1.65)	−3.885** (−2.15)	5.538* (1.75)
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.614	0.657	0.586	0.653	0.573	0.665
F	21.771	21.564	16.383	23.791	18.340	23.558

Notes: Same as Table 3.

that corruption encourages innovation since bribery allows firms to avoid government supervision, save time, and obtain more financial subsidies (Chen et al., 2013; Fu & Jian, 2021). Other scholars suggest that corruption indirectly weakens firms' incentives to innovate by distorting resource allocation, weakening governance systems, and encouraging rent-seeking activities (Murphy et al., 1993; Hao et al., 2020). Therefore, it is critical to explore whether countries with differing levels of corruption react differently to income inequality and GI. For this purpose, we divide the sample into two groups based on corruption levels, using the median as a cut-off. The corruption data come from the database of International Country Risk Guide (ICRG)[9].

The data is presented in Table 6. According to column (3), in countries with lower levels of corruption, the correlation between income inequality and GI is not significant. The inverted U-shape association between inequality and GI remains significant at a 10% level in

[9] The ICRG database can be consulted for additional information about the setting of this variable.

countries with higher degrees of corruption, and the inflection point of the Gini coefficient is 0.393[10], as shown in column (4). The findings show in regions with high levels of corruption that income inequality encourages GI when the Gini coefficient is less than 0.393 but discourages GI when the Gini coefficient is greater than this threshold. As income inequality grows, wealth gradually accumulates in the hands of the rich, hastening corruption and, to some extent, promoting GI (Policardo et al., 2019). However, as inequality grows further, high corruption and excessive inequality will hinder GI (Ellis et al., 2020). This leads to the conclusion that GI is less tolerant of income inequality in countries with higher degrees of corruption, and governments should increase their efforts to reduce corruption generation and keep income inequality within healthy limits.

3.4.3. The heterogeneity results of government effectiveness

The previous literature suggests that a country's government effectiveness has considerable effects on economic development and innovation capacity (Wen et al., 2021). First, innovation closely relates to the institutional system, and an effective government can promote GI through an innovation compensation mechanism, a property rights protection system, and other innovation-driven policies (Flanagan et al., 2011; Hudson & Minea, 2013; Bronzini & Piselli, 2016). Second, a more efficient government can encourage GI by streamlining processes, improving resource allocation efficiency and fairness, and lowering transaction costs (Chen & Yoon, 2019). Finally, government support and intervention are two critical factors influencing GI (Lovett, 2011). On the one hand, government support can boost R&D spending through tax breaks and financial subsidies, thereby promoting GI (Zhu & Xu, 2003). On the other hand, excessive government intervention causes an investment crowding-out effect, increased rent-seeking costs, and corruption, all of which are barriers to developing GI (Murphy et al., 1993).

The data about government effectiveness are obtained from the Worldwide Government Indicator (WGI), whose value range is restricted to around –2.5 (weak) to 2.5 (strong). The sample is split in half based on the median level of government effectiveness. The regression findings for groups with lower and higher levels of government effectiveness are displayed in columns (5) and (6). In column (5), *Gini* and *Gini2* coefficients are 1.229 and –0.157, respectively, at a significant level of 1%. The inflection point of the Gini coefficient is 0.391[11]. It should be emphasized that the coefficients of *Gini* and *Gini2* for low-effective government groups are larger than the outcomes in the panel fixed effect model. This could be attributed to the fact that a less effective government has less intervention in innovation, and thus GI is more significantly affected by external factors. Additionally, the statistical results in column (6) indicate that countries with more efficient governments do not have a significant inverted U-shape relationship between inequality and GI. To summarize, to protect GI, governments in countries with low government effectiveness should strive to improve their effectiveness and regulate the income gap through policy instruments such as redistribution.

[10] $\ln(Patent+1)_{it} = 0.755Gini_{it} - 0.096Gini_{it}^2 + \gamma X_{it} + \mu_i + u_t + \varepsilon_{it}$, $V(inflection) = -0.755/(-0.096*2) = 3.93$.

[11] $\ln(Patent+1)_{it} = 1.229Gini_{it} - 0.157Gini_{it}^2 + \gamma X_{it} + \mu_i + u_t + \varepsilon_{it}$, $V(inflection) = -1.229/(-0.157*2) = 3.91$.

Conclusions and policy implications

Various governments have been compelled by the deterioration of the environment to take decisive action to combat the worsening environmental challenges, and green innovation has been highlighted as a viable solution (Chang et al., 2010). Employing the panel fixed effect model, this paper empirically investigates how income inequality affects GI using multinational data from 1991 to 2018. The findings indicate an inverted U-shaped link between income inequality and GI, with a Gini coefficient of 0.366 serving as the model's inflection point. Income inequality can either promote a country's GI through price effects or ultimately impede a country's ability to innovate through scale effects and consumption structure effects.

We further subdivide the sample into various sub-samples based on income, corruption, and government effectiveness, allowing us to investigate the heterogeneity of social development across countries. According to the empirical findings, the non-linear correlation between income inequality and GI is significant only in the sample countries with lower income, higher corruption, and weaker government effectiveness. In addition, the inflection point values of the Gini coefficient differ in those sub-samples. The Gini coefficient at the inflection point is 0.375 in lower-income countries, 0.393 in higher corruption countries, and 0.391 in weaker government effectiveness countries. In contrast to earlier studies, we investigate the heterogeneity of the relationship between income inequality and GI at the country level and calculate the inflection point of the inverted U-shaped association to better inform policymakers. This study further extends the economics of innovation toward socioeconomics, which is critical for investigating income inequality and green growth. As a result, we propose the following policy implications.

The empirical results reveal that there exists an optimal level of income inequality that maximizes GI, and this Gini coefficient is 0.366 in our total sample of this paper. Finding the inflection point of income inequality provides government policymakers with a crucial benchmark for maximizing the significance of income distribution policies in stimulating GI and achieving sustainable development. Governments in countries where the Gini coefficient has not reached the inflection point need not be concerned that income inequality will harm GI. For countries where the Gini coefficient has surpassed the inflection point, governments should actively pursue effective measures to control income disparities and improve GI capacity. At the national level, the government can enact redistribution changes, such as differential taxation for low- and high-income groups, to minimize the income gap between citizens. For the inequality caused by regional differences, the government can provide more policy support and financial subsidies to poor regions to assist them in achieving overall economic development and income growth. In terms of government governance, aside from strengthening GI by expanding R&D spending, the government can focus more on improving an innovation-friendly institutional system, reducing corruption opportunities, and improving government effectiveness.

Some limitations of this study merit investigation in future studies. For instance, the three effects of income inequality on GI (price effect, scale effect, and consumption structure effect) are not empirically tested. Additionally, the data in this paper only include a sample of 97 countries from 1991 to 2018 due to current data availability. It is hoped that future studies will include more country samples and more recent data.

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Conflict of interest

The authors declared that they have no conflicts of interest to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

References

Abban, O. J., Wu, J., & Mensah, I. A. (2020). Analysis on the nexus amid CO_2 emissions, energy intensity, economic growth, and foreign direct investment in Belt and Road economies: Does the level of income matter? *Environmental Science and Pollution Research*, *27*(10), 11387–11402. https://doi.org/10.1007/s11356-020-07685-9

Acemoglu, D., Naidu, S., Restrepo, P., & Robinson, J. A. (2019). Democracy does cause growth. *Journal of Political Economy*, *127*(1), 47–100. https://doi.org/10.1086/700936

Acs, Z. J., Anselin, L., & Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, *31*(7), 1069–1085. https://doi.org/10.1016/S0048-7333(01)00184-6

Afesorgbor, S. K. (2019). The impact of economic sanctions on international trade: How do threatened sanctions compare with imposed sanctions? *European Journal of Political Economy*, *56*, 11–26. https://doi.org/10.1016/j.ejpoleco.2018.06.002

Aghion, P., Akcigit, U., Bergeaud, A., Blundell, R., & Hemous, D. (2019). Innovation and top income inequality. *The Review of Economic Studies*, *86*(1), 1–45. https://doi.org/10.1093/restud/rdy027

Ahuja, M., Mondal, D., Mishra, D. P., Ghosh, S., & Kumar, M. (2023). Assessment of financial and environmental impacts of pre-mining methane drainage in Indian scenario: A case study using Jharia coal seams. *Innovation and Green Development*, *2*(3), 100065. https://doi.org/10.1016/j.igd.2023.100065

Arellano, M., & Bond, S. R. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

Arin, K. P., Berlemann, M., Koray, F., & Kuhlenkasper, T. (2011). *The taxation-growth-nexus revisited* (HWWI Research Paper No. 104). Hamburg Institute of International Economics.

Awan, A. G., & Yaqoob, R. (2023). Economic value of introducing technology to improve productivity: An ARDL approach. *Innovation and Green Development*, *2*(3), 100069. https://doi.org/10.1016/j.igd.2023.100069

Bai, C., Feng, C., Yan, H., Yi, X., Chen, Z., & Wei, W. (2020). Will income inequality influence the abatement effect of renewable energy technological innovation on carbon dioxide emissions? *Journal of Environmental Management*, *264*, 110482. https://doi.org/10.1016/j.jenvman.2020.110482

Berg, A., Ostry, J. D., Tsangarides, C. G., & Yakhshilikov, Y. (2018). Redistribution, inequality, and growth: New evidence. *Journal of Economic Growth*, *23*(3), 259–305. https://doi.org/10.1007/s10887-017-9150-2

Bernardino, J. P. R., & Araújo, T. (2013). On positional consumption and technological innovation: An agent-based model. *Journal of Evolutionary Economics*, *23*, 1047–1071. https://doi.org/10.1007/s00191-013-0317-5

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Brasington, D. M., & Hite, D. (2005). Demand for environmental quality: A spatial hedonic analysis. *Regional Science & Urban Economics*, *35*(1), 57–82. https://doi.org/10.1016/j.regsciurbeco.2003.09.001

Breau, S., Kogler, D. F., & Bolton, K. C. (2014). On the relationship between innovation and wage inequality: New evidence from Canadian cities. *Economic Geography*, *90*(4), 351–373. https://doi.org/10.1111/ecge.12056

Bronzini, R., & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. *Research Policy*, *45*(2), 442–457. https://doi.org/10.1016/j.respol.2015.10.008

Chai, J., Wu, H., & Hao, Y. (2022). Planned economic growth and controlled energy demand: How do regional growth targets affect energy consumption in China? *Technological Forecasting and Social Change*, *185*, 122068. https://doi.org/10.1016/j.techfore.2022.122068

Chancel, L., Piketty, T., Saez, E., & Zucman, G. (2022). *World inequality report 2022*. World Inequality Lab. Harvard University Press. https://doi.org/10.4159/9780674276598

Chang, C.-H. (2011). The influence of corporate environmental ethics on competitive advantage: The mediation role of green innovation. *Journal of Business Ethics*, *104*(3), 361–370. https://doi.org/10.1007/s10551-011-0914-x

Chang, Y., Ries, R. J., & Wang, Y. (2010). The embodied energy and environmental emissions of construction projects in China: An economic input-output LCA model. *Energy Policy*, *38*(11), 6597–6603. https://doi.org/10.1016/j.enpol.2010.06.030

Chen, H., & Yoon, S. S. (2019). Government efficiency and enterprise innovation – evidence from China. *Asian Journal of Technology Innovation*, *27*(3), 280–300. https://doi.org/10.1080/19761597.2019.1678389

Chen, J., Wang, L., & Li, Y. (2020). Natural resources, urbanization and regional innovation capabilities. *Resources Policy*, *66*, 101643. https://doi.org/10.1016/j.resourpol.2020.101643

Chen, X., Fu, Q., & Chang, C. P. (2021a). What are the shocks of climate change on clean energy investment: A diversified exploration. *Energy Economics*, *95*, 105136. https://doi.org/10.1016/j.eneco.2021.105136

Chen, Y., Liu, M., & Su, J. (2013). Greasing the wheels of bank lending: Evidence from private firms in China. *Journal of Banking & Finance*, *37*(7), 2533–2545. https://doi.org/10.1016/j.jbankfin.2013.02.002

Chen, Y. E., Li, C., Chang, C. P., & Zheng, M. (2021b). Identifying the influence of natural disasters on technological innovation. *Economic Analysis and Policy*, *70*, 22–36. https://doi.org/10.1016/j.eap.2021.01.016

Cheng, K. M. (2010). Theoretical mechanism and evidence of the technology innovation facilitated by the urbanization. *Science Research Management*, *31*(2), 26–34.

Choi, C., & Yi, M. H. (2018). The Internet, R&D expenditure and economic growth. *Applied Economics Letters*, *25*(4), 264–267. https://doi.org/10.1080/13504851.2017.1316819

Chu, A. C., Cozzi, G., & Furukawa, Y. (2016). Unions, innovation and cross-country wage inequality. *Journal of Economic Dynamics and Control*, *64*(3), 104–118. https://doi.org/10.1016/j.jedc.2015.12.004

Craney, T. A., & Surles, J. G. (2002). Model-dependent variance inflation factor cutoff values. *Quality Engineering*, *14*(3), 391–403. https://doi.org/10.1081/QEN-120001878

Croix, D., & Doepke, M. (2004). Public versus private education when differential fertility matters. *Journal of Development Economics*, *73*(2), 607–629. https://doi.org/10.1016/j.jdeveco.2003.05.005

Dickman, S. L., Himmelstein, D. U., & Woolhandler, S. (2017). Inequality and the health-care system in the USA. *The Lancet*, *389*(10077), 1431–1441. https://doi.org/10.1016/S0140-6736(17)30398-7

Dong, J., Li, W., Cao, Y., & Fang, J. (2016). How does technology and population progress relate? An empirical study of the last 10,000 years. *Technological Forecasting and Social Change*, *103*(4), 57–70. https://doi.org/10.1016/j.techfore.2015.11.011

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature*, *26*(3), 1120–1171.

Edler, J., & Georghiou, L. (2007). Public procurement and innovation – Resurrecting the demand side. *Research Policy*, *36*(7), 949–963. https://doi.org/10.1016/j.respol.2007.03.003

Ellis, J., Smith, J., & White, R. (2020). Corruption and corporate innovation. *Journal of Financial and Quantitative Analysis*, *55*(7), 2124–2149. https://doi.org/10.1017/S0022109019000735

Fernando, Y., Jabbour, C. J. C., & Wah, W. X. (2019). Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: Does service capability matter? *Resources, Conservation and Recycling*, *141*, 8–20. https://doi.org/10.1016/j.resconrec.2018.09.031

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the "policy mix" for innovation. *Research Policy*, *40*(5), 702–713. https://doi.org/10.1016/j.respol.2011.02.005

Foellmi, R., & Zweimüller, J. (2006). Income distribution and demand-induced innovations. *Review of Economic Studies*, *73*(4), 941–960. https://doi.org/10.1111/j.1467-937X.2006.00403.x

Foellmi, R., & Zweimüller, J. (2017). Is inequality harmful for innovation and growth? Price versus market size effects. *Journal of Evolutionary Economics*, *27*(2), 359–378. https://doi.org/10.1007/s00191-016-0451-y

Foellmi, R., Wuergler, T., & Zweimüller, J. (2014). The macroeconomics of Model T. *Journal of Economic Theory*, *153*, 617–647. https://doi.org/10.1016/j.jet.2014.03.002

Frías, J. A., Kaplan, D. S., & Verhoogen, E. (2012). Exports and within-plant wage distributions: Evidence from Mexico. *American Economic Review*, *102*(3), 435–440. https://doi.org/10.1257/aer.102.3.435

Fu, Q., Chen, Y. E., Jang, C. L., & Chang, C. P. (2020). The impact of international sanctions on environmental performance. *Science of The Total Environment*, *745*, 141007. https://doi.org/10.1016/j.scitotenv.2020.141007

Fu, Q., Gong, Q., Zhao, X. X., & Chang, C. P. (2023). The effects of international sanctions on green innovations. *Technological and Economic Development of Economy*, *29*(1), 141–164. https://doi.org/10.3846/tede.2022.17782

Fu, T., & Jian, Z. (2021). Corruption pays off: How environmental regulations promote corporate innovation in a developing country. *Ecological Economics*, *183*, 106969. https://doi.org/10.1016/j.ecolecon.2021.106969

Greewood, J., & Mukoyama, E. (2001). *The effect of income distribution on the timing of new product introduction*. University of Rochester, Mimeo.

Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, *28*(4), 1661–1707.

Hao, Y., Gai, Z. Q., & Wu, H. T. (2020). How do resource misallocation and government corruption affect green total factor energy efficiency? Evidence from China. *Energy Policy*, *143*, 111562. https://doi.org/10.1016/j.enpol.2020.111562

Hao, X., Li, Y., Ren, S., Wu, H., & Hao, Y. (2023). The role of digitalization on green economic growth: Does industrial structure optimization and green innovation matter? *Journal of Environmental Management*, *325*, 116504. https://doi.org/10.1016/j.jenvman.2022.116504

He, F., Ma, Y., & Zhang, X. (2020). How does economic policy uncertainty affect corporate innovation? Evidence from China listed companies. *International Review of Economics* & *Finance*, *67*, 225–239. https://doi.org/10.1016/j.iref.2020.01.006

Hojnik, J., & Ruzzier, M. (2016). The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia. *Journal of Cleaner Production*, *133*, 812–825. https://doi.org/10.1016/j.jclepro.2016.06.002

Huang, J. W., & Li, Y. H. (2017). Green innovation and performance: The view of organizational capability and social reciprocity. *Journal of Business Ethics*, *145*(2), 309–324. https://doi.org/10.1007/s10551-015-2903-y

Hudson, J., & Minea, A. (2013). Innovation, intellectual property rights, and economic development: A unified empirical investigation. *World Development*, *46*, 66–78. https://doi.org/10.1016/j.worlddev.2013.01.023

Jalles, J. T. (2010). How to measure innovation? New evidence of the technology – growth linkage. *Research in Economics*, *64*(2), 81–96. https://doi.org/10.1016/j.rie.2009.10.007

Jorgenson, A., Schor, J., & Huang, X. (2017). Income inequality and carbon emissions in the United States: A state-level analysis, 1997–2012. *Ecological Economics*, *134*, 40–48. https://doi.org/10.1016/j.ecolecon.2016.12.016

Kogan, L., Papanikolaou, D., Seru, A., & Stoffman, N. (2017). Technological innovation, resource allocation, and growth. *Quarterly Journal of Economics*, *132*(2), 665–712. https://doi.org/10.1093/qje/qjw040

Koh, S. G. M., Lee, G. H. Y., & Bomhoff, E. J. (2020). The income inequality, financial depth and economic growth nexus in China. *The World Economy*, *43*(2), 412–427. https://doi.org/10.1111/twec.12825

Kraus, S., Rehman, S. U., & García, F. J. S. (2020). Corporate social responsibility and environmental performance: The mediating role of environmental strategy and green innovation. *Technological Forecasting and Social Change*, *160*, 120262. https://doi.org/10.1016/j.techfore.2020.120262

Kremer, M. (1993). Population growth and technological change: One million B.C. To 1990. *Quarterly Journal of Economics*, *108*(3), 681–716. https://doi.org/10.2307/2118405

Law, S. H., Naseem, N. A. M., Lau, W. T., & Trinugroho, I. (2020). Can innovation improve income inequality? Evidence from panel data. *Economic Systems*, *44*(4), 100815. https://doi.org/10.1016/j.ecosys.2020.100815

Lee, C. C., Lee, C. C., & Lien, D. (2020). Income inequality, globalization, and country risk: A cross-country analysis. *Technological and Economic Development of Economy*, *26*(2), 379–404. https://doi.org/10.3846/tede.2019.11414

Li, D., Zheng, M., Cao, C., Chen, X., Ren, S., & Huang, M. (2017). The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100. *Journal of Cleaner Production*, *141*, 41–49. https://doi.org/10.1016/j.jclepro.2016.08.123

Li, S., Chang, G., & Zunong, R. (2023a) Does regional digital economy development influence green investment? *Innovation and Green Development*, *2*(3), 100053. https://doi.org/10.1016/j.igd.2023.100053

Li, X., Yu, G., Wen, L., & Liu, G. (2023b). Research on the effect of agricultural science and technology service supply from the perspective of farmers' differentiation. *Innovation and Green Development*, *2*(3), 100055. https://doi.org/10.1016/j.igd.2023.100055

Lin, H., Zeng, S. X., Ma, H. Y., Qi, G. Y., & Tam, V. W. Y. (2014). Can political capital drive corporate green innovation? Lessons from China. *Journal of Cleaner Production*, *64*, 63–72. https://doi.org/10.1016/j.jclepro.2013.07.046

Liu, Z., Zhang, H., Zhang, Y. J., & Qin, C. X. (2020). How does income inequality affect energy efficiency? Empirical evidence from 33 Belt and Road Initiative countries. *Journal of Cleaner Production*, *269*, 122421. https://doi.org/10.1016/j.jclepro.2020.122421

Long, H., Chang, C. P., Jegajeevan, S., & Tang, K. (2022). Can Central Bank mitigate the effects of the COVID-19 pandemic on the macroeconomy? *Emerging Markets Finance and Trade*, *58*(9), 2652–2669. https://doi.org/10.1080/1540496X.2021.2007880

Lovett, K. (2011). *Institutional design and economic growth: The relationship between bureaucracy and economic performance in a global economy* (Working Paper).

Luo, Y., Salman, M., & Lu, Z. (2021). Heterogeneous impacts of environmental regulations and foreign direct investment on green innovation across different regions in China. *Science of The Total Environment*, *759*, 143744. https://doi.org/10.1016/j.scitotenv.2020.143744

Luo, S., Yimamu, N., Li, Y., Wu, H., Irfan, M., & Hao, Y. (2022). Digitalization and sustainable development: How could digital economy development improve green innovation in China? *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3223

Mgomezulu, W. R., Edriss, A. K., Machira, K., & Pangapanga-Phiri, I. (2023). Towards sustainability in the adoption of sustainable agricultural practices: Implications on household poverty, food and nutrition security. *Innovation and Green Development*, *2*(3), 100054. https://doi.org/10.1016/j.igd.2023.100054

Moran, P., & Queralto, A. (2018). Innovation, productivity, and monetary policy. *Journal of Monetary Economics*, *93*, 24–41. https://doi.org/10.1016/j.jmoneco.2017.10.006

Murphy, K. M., Shleifer, A., & Vishny, R. (1989). Income distribution, market size, and industrialization. *Quarterly Journal of Economics*, *104*(3), 537–564. https://doi.org/10.2307/2937810

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1993). Why is rent-seeking so costly to growth? *American Economic Review*, *83*(2), 409–414.

Napolitano, L., Sbardella, A., Consoll, D., Barbieri, N., & Perruchas, F. (2020). *Green innovation and income inequality: A complex system analysis* (SPRU Working Paper Series (SWPS 2020-11). https://doi.org/10.2139/ssrn.3663871

Nasreen, S., & Anwar, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy*, *69*, 82–91. https://doi.org/10.1016/j.enpol.2014.02.009

Niessen, L. W., Mohan, D., Akuoku, J. K., Mirelman, A. J., Ahmed, S., Koehlmoos, T. P., Trujillo, A., Khan, J., & Peters, D. H. (2018). Tackling socioeconomic inequalities and non-communicable diseases in low-income and middle-income countries under the Sustainable Development agenda. *The Lancet*, *391*(10134), 2036–2046. https://doi.org/10.1016/S0140-6736(18)30482-3

Owens, A., Reardon, S. F., & Jencks, C. (2016). Income segregation between schools and school districts. *American Educational Research Journal*, *53*(4), 1159–1197. https://doi.org/10.3102/0002831216652722

Patel, V., Burns, J. K., Dhingra, M., Tarver, L., Kohrt, B. A., & Lund, C. (2018). Income inequality and depression: A systematic review and meta-analysis of the association and a scoping review of mechanisms. *World Psychiatry*, *17*(1), 76–89. https://doi.org/10.1002/wps.20492

Peng, X. Y., Zou, X. Y., Zhao, X. X., & Chang, C. P. (2023). How does economic policy uncertainty affect green innovation? *Technological and Economic Development of Economy*, *29*(1), 114–140. https://doi.org/10.3846/tede.2022.17760

Pickett, K. E., & Wilkinson, R. G. (2015). Income inequality and health: A causal review. *Social Science & Medicine*, *128*, 316–326. https://doi.org/10.1016/j.socscimed.2014.12.031

Policardo, L., & Carrera, E. J. S. (2018). Corruption causes inequality, or is it the other way around? An empirical investigation for a panel of countries. *Economic Analysis and Policy*, *59*, 92–102. https://doi.org/10.1016/j.eap.2018.05.001

Policardo, L., Sanchez Carrera, E. J., & Risso, W. A. (2019). Causality between income inequality and corruption in OECD countries. *World Development Perspectives*, *14*, 100102. https://doi.org/10.1016/j.wdp.2019.02.013

Pradhan, R. P., Arvin, M. B., Nair, M., Bennett, S. E., Bahmani, S., & Hall, J. H. (2018). Endogenous dynamics between innovation, financial markets, venture capital and economic growth: Evidence from Europe. *Journal of Multinational Financial Management*, *45*, 15–34. https://doi.org/10.1016/j.mulfin.2018.01.002

Qin, B., Gao, Y., Ge, L., & Zhu, J. (2023). The influence mechanism of outward FDI reverse technology spillovers on China's green innovation. *Technological and Economic Development of Economy*, *29*(2), 468–499. https://doi.org/10.3846/tede.2022.17930

Raihan, A. (2023). Nexus between greenhouse gas emissions and its determinants: The role of renewable energy and technological innovations towards green development in South Korea. *Innovation and Green Development*, *2*(3), 100066. https://doi.org/10.1016/j.igd.2023.100055

Ren, S., Hao, Y., & Wu, H. (2023). Digitalization and environment governance: does internet development reduce environmental pollution? *Journal of Environmental Planning and Management*, *66*(7), 1533–1562. https://doi.org/10.1080/09640568.2022.2033959

Roper, S., Love, J. H., & Bonner, K. (2017). Firms' knowledge search and local knowledge externalities in innovation performance. *Research Policy*, *46*(1), 43–56. https://doi.org/10.1016/j.respol.2016.10.004

Schmookler, J. (1966). *Inventions and economic growth*. Harvard University Press.

Shahzad, M., Qu, Y., Javed, S. A., Zafar, A. U., & Rehman, S. U. (2020). Relation of environment sustainability to CSR and green innovation: A case of Pakistani manufacturing industry. *Journal of Cleaner Production*, *253*, 119938. https://doi.org/10.1016/j.jclepro.2019.119938

Soava, G., Mehedintu, A., & Sterpu, M. (2020). Relations between income inequality, economic growth and poverty threshold: New evidences from EU countries panels. *Technological and Economic Development of Economy*, *26*(2), 290–310. https://doi.org/10.3846/tede.2019.11335

Song, M., Wang, S., & Zhang, H. (2020). Could environmental regulation and R&D tax incentives affect green product innovation? *Journal of Cleaner Production*, *258*, 120849. https://doi.org/10.1016/j.jclepro.2020.120849

Sun, H., Edziah, B. K., Sun, C., & Kporsu, A. K. (2019). Institutional quality, green innovation and energy efficiency. *Energy Policy*, *135*, 111002. https://doi.org/10.1016/j.enpol.2019.111002

Tselios, V. (2011). Is inequality good for innovation? *International Regional Science Review*, *34*(1), 75–101. https://doi.org/10.1177/0160017610383278

UNU-WIDER. (2021). *World Income Inequality Database* (*WIID*). Version 31 May 2021. https://doi.org/10.35188/UNU-WIDER/WIID-310521

Vona, F., & Patriarca, F. (2011). Income inequality and the development of environmental technologies. *Ecological Economics*, *70*(11), 2201–2213. https://doi.org/10.1016/j.ecolecon.2011.06.027

Wang, C., & Li, J. (2019). An evaluation of regional green innovation performance in China and its spatial-temporal differences based on the panel data of inter-provincial industrial enterprises from 2005 to 2015. *Science Research Management*, *40*(6), 29–42 (in Chinese).

Wang, Q. J., Feng, G. F., Chen, Y. E., Wen, J., & Chang, C. P. (2019). The impacts of government ideology on innovation: What are the main implications? *Research Policy*, *48*(5), 1232–1247. https://doi.org/10.1016/j.respol.2018.12.009

Wang, Q. J., Feng, G. F., Wang, H. J., & Chang, C. P. (2022). The influence of political ideology on greenhouse gas emissions. *Global Environmental Change*, *74*, 102496. https://doi.org/10.1016/j.gloenvcha.2022.102496

Wang, Q. J., Feng, G. F., Wang, H. J., & Chang, C. P. (2021). The impacts of democracy on innovation: Revisited evidence. *Technovation*, *108*, 102333. https://doi.org/10.1016/j.technovation.2021.102333

Warner, K., Hamza, M., Oliver-Smith, A., Renaud, F., & Julca, A. (2010). Climate change, environmental degradation and migration. *Natural Hazards*, *55*(3), 689–715. https://doi.org/10.1007/s11069-009-9419-7

Wei, Y. M., Mi, Z. F., & Huang, Z. (2015). Climate policy modeling: An online SCI-E and SSCI based literature review. *Omega*, *57*, 70–84. https://doi.org/10.1016/j.omega.2014.10.011

Wen, J., Deng, P., Zhang, Q., & Chang, C. P. (2021). Is higher government efficiency bringing about higher innovation? *Technological and Economic Development of Economy*, *27*(3), 626–655. https://doi.org/10.3846/tede.2021.14269

Wen, J., Hao, Y., Feng, G. F., & Chang, C. P. (2016). Does government ideology influence environmental performance? Evidence based on a new dataset. *Economic Systems*, *40*(2), 232–246. https://doi.org/10.1016/j.ecosys.2016.04.001

Wen, J., Yin, H. T., Jang, C. L., Uchida, H., & Chang, C. P. (2023a). Does corruption hurt green innovation? Yes – Global evidence from cross-validation. *Technological Forecasting and Social Change*, *188*, 122313. https://doi.org/10.1016/j.techfore.2022.122313

Wen, J., Zhang, S., & Chang, C. P. (2022). Legal origins and innovation: Global evidence. *Technological Forecasting and Social Change*, *174*, 121216. https://doi.org/10.1016/j.techfore.2021.121216

Wen, J., Zhao, X. X., Fu, Q., & Chang, C. P. (2023b). The impact of extreme weather events on green innovation: Which ones bring to the most harm? *Technological Forecasting and Social Change*, *188*, 122322. https://doi.org/10.1016/j.techfore.2023.122322

Wen, J., Zhao, X. X., Wang, Q. J., & Chang, C. P. (2020b). The impact of international sanctions on energy security. *Energy & Environment*, *32*(3), 458–480. https://doi.org/10.1177/0958305X20937686

Wen, J., Zheng, M., Feng, G. F., Chen, S. W., & Chang, C. P. (2020a). Corruption and innovation: Linear and nonlinear investigations of OECD countries. *The Singapore Economic Review*, *65*(01), 103–129. https://doi.org/10.1142/S0217590818500273

World Bank. (2020). *World development indicators*. World Bank, Washington DC.

Wu, R., & Xie, Z. (2020). Identifying the impacts of income inequality on CO_2 emissions: Empirical evidences from OECD countries and non-OECD countries. *Journal of Cleaner Production*, *277*, 123858. https://doi.org/10.1016/j.jclepro.2020.123858

Xue, Y., Jiang, C., Guo, Y., Liu, J., Wu, H., & Hao, Y. (2022). Corporate social responsibility and high-quality development: Do green innovation, environmental investment and corporate governance matter? *Emerging Markets Finance and Trade*, *58*(11), 3191–3214. https://doi.org/10.1080/1540496X.2022.2034616

Yang, H. C., Feng, G. F., Zhao, X. X., & Chang, C. P. (2022). The impacts of energy insecurity on green innovation: A multi-country study. *Economic Analysis and Policy*, *74*, 139–154. https://doi.org/10.1016/j.eap.2022.01.017

Yang, J., & Chen, S. (2023). Corporate financialization, digitalization and green innovation: A panel investigation on Chinese listed firms. *Innovation and Green Development*, *2*(3), 100068. https://doi.org/10.1016/j.igd.2023.100068

Yin, H. T., Chang, C. P., Anugrah, D. F., & Gunadi, I. (2023). Gender equality and central bank independence. *Economic Analysis and Policy*, *78*, 661–672. https://doi.org/10.1016/j.eap.2023.04.006

Yin, H.-T., Chang, C.-P., & Wang, H. (2022a). The impact of monetary policy on green innovation: Global evidence. *Technological and Economic Development of Economy*, *28*(6), 1933–1953. https://doi.org/10.3846/tede.2022.17020

Yin, H.-T., Wen, J., & Chang, C.-P. (2022b). Science-technology intermediary and innovation in China: Evidence from State Administration for Market Regulation, 2000–2019. *Technology in Society*, *68*, 101864. https://doi.org/10.1016/j.techsoc.2022.101864

Yolcan, O. O. (2023). World energy outlook and state of renewable energy: 10-Year evaluation. *Innovation and Green Development*, *2*(4), 100070. https://doi.org/10.1016/j.igd.2023.100070

Zecca, E., & Nicolli, F. (2021). Inequality, democracy and green technological change. *Journal of Cleaner Production*, *306*, 127061. https://doi.org/10.1016/j.jclepro.2021.127061

Zhao, W., Hafeez, M., Maqbool, A., Ullah, S., & Sohail, S. (2021). Analysis of income inequality and environmental pollution in BRICS using fresh asymmetric approach. *Environmental Science and Pollution Research*, *28*(37), 51199–51209. https://doi.org/10.1007/s1156-021-14209-6

Zhao, X. X., Wen, J., Zou, X. Y., Wang, Q. J., & Chang, C. P. (2023). Strategies for the sustainable development of China in the post-epidemic era. *Sustainable Development*, *31*(1), 426–438. https://doi.org/10.1002/sd.2401

Zhao, X. X., Zheng, M., & Fu, Q. (2022). How natural disasters affect energy innovation? The perspective of environmental sustainability. *Energy Economics*, *109*, 105992. https://doi.org/10.1016/j.eneco.2022.105992

Zheng, M., Feng, G.-F., Jiang, R.-A., & Chang, C.-P. (2023a). Does environmental, social, and governance performance move together with corporate green innovation in China? *Business Strategy and the Environment*, *32*(4), 1670–1679. https://doi.org/10.1002/bse.3211

Zheng, M., Feng, G. F., Zhao, X., & Chang, C. P. (2023b). The transaction behavior of cryptocurrency and electricity consumption. *Financial Innovation*, *9*(1), 44. https://doi.org/10.1186/s40854-023-00449-7

Zheng, M., Feng, G. F., Jang, C. L., & Chang, C. P. (2021). Terrorism and green innovation in renewable energy. *Energy Economics*, *104*, 105695. https://doi.org/10.1016/j.eneco.2021.105695

Zheng, M., Feng, G. F., Wen, J., & Chang, C. P. (2020). The influence of FDI on domestic innovation: An investigation using structural breaks. *Prague Economic Papers*, *29*(4), 403–423. https://doi.org/10.18267/j.pep.739

Zhongzheng, W. (2023). Extreme risk transmission mechanism between oil, green bonds and new energy vehicles. *Innovation and Green Development*, *2*(3), 100064. https://doi.org/10.1016/j.igd.2023.100064

Zhu, P. F., & Xu, W. M. (2003). On the impact of government's S&T incentive policy on the R&D input and its patent output of large and medium-sized industrial firms in Shanghai. *Economic Research Journal*, 6, 45–53.

Zou, X. Y., Peng, X. Y., Zhao, X. X., & Chang, C. P. (2023). The impact of extreme weather events on water quality: International evidence. *Natural Hazards*, *115*(1), 1–21. https://doi.org/10.1007/s11069-022-05548-9

Zweimüller, J. (2000). Schumpeterian entrepreneurs meet Engel's law: The impact of inequality on innovation-driven growth. *SSRN Electronic Journal*, *27*(1), 1–20.