Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Entrepreneurship and environmental sustainability in highly polluting Asian economies: the role of eco-innovation

Chuanbo Xing, Xitao Liu & Ilhan Ozturk

To cite this article: Chuanbo Xing, Xitao Liu & Ilhan Ozturk (2023) Entrepreneurship and environmental sustainability in highly polluting Asian economies: the role of eco-innovation, Economic Research-Ekonomska Istraživanja, 36:2, 2142821, DOI: 10.1080/1331677X.2022.2142821

To link to this article: https://doi.org/10.1080/1331677X.2022.2142821

© 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

Published online: 13 Dec 2022.

Submit your article to this journal

Article views: 496

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at https://www.tandfonline.com/action/journalInformation?journalCode=rero20

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 2, 2142821
https://doi.org/10.1080/1331677X.2022.2142821

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Entrepreneurship and environmental sustainability in highly polluting Asian economies: the role of eco-innovation

Chuanbo Xing[a], Xitao Liu[a] and Ilhan Ozturk[b,c,d]

[a]College of Public Finance and Administration, Harbin University of Commerce, Harbin, Heilongjiang, China; [b]College of Business Administration, University of Sharjah, Sharjah, United Arab Emirates; [c]Faculty of Economics, Administrative and Social Sciences, Nisantasi University, Istanbul, Turkey; [d]Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

ABSTRACT

We aim to investigate the impact of environmental entrepreneurship and green innovations on CO2 emissions in highly polluting Asian economies. For empirical estimation, we have applied ARDL and NARDL models. In the short run, the linear estimates of environmental entrepreneurship are significant in China and India. The short-run non-linear estimates of environmental entrepreneurship are significant in the case of China, India, and Japan. Similarly, the short-run linear estimates of green innovations are significant in China, India, and Japan, whereas the non-linear estimated coefficients of green innovation appeared to be significant in India, Japan, and Russia. In the long run, the linear estimates of environmental entrepreneurship are negative and significant in three countries, namely China, Japan, and Russia. Similarly, the estimates of green innovations are negative and significant in China, India, Japan, and Russia. In the non-linear model, the estimated coefficients of positive shock in environmental entrepreneurship are significant and negative in the case of China, India, and Japan; while, the estimates of negative shock in environmental entrepreneurship are negative and significant in India only.

ARTICLE HISTORY
Received 2 March 2022
Accepted 27 October 2022

KEYWORDS
Entrepreneurship; green innovation; CO2 emissions

JEL CODES
L26; Q55; Q56

1. Introduction

Firms, businesses, and companies are important because they contribute to the economic growth of a country; however, they also have an essential role in creating social and environmental issues. As a result, they are a big hurdle in achieving sustainable economic growth. In this context, a stringent environmental policy and strict rules and regulations are required to control business-related emissions. In such an environment, entrepreneurs need to comply with environment-related regulations to

CONTACT Xitao Liu liu200892@126.com

© 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

mitigate the impacts of environmental pollution. However, the over-involvement of government and non-governmental organisations in the whole process restricts the role of companies in society and negatively impacts their economic position (Schaltegger & Wagner, 2011).

Another side of the picture is that the management of large firms and companies could prove as a catalyst in sustainable development. One of the most prominent features of sustainable entrepreneurs and sustainable managers is their ability to develop innovative ideas and technologies that help achieve sustainable development. For instance, the contribution of automobiles, computers, and the internet has changed the world's economic and social outlook much more than various political programs (Volery, 2002). In order to be innovative, the firms and businesses need to improve their technical and organisational structure that can strengthen their place in the market. In a free-market design, the main requirements of sustainable development are sustainable innovations and entrepreneurs who can accomplish ecological or societal goals with top-quality products or procedures that are effective in the market of conventional clients (Schaltegger & Wagner, 2011). However, the market innovations necessary to attain sustainable development do not come into existence by accident, but these innovations are the results of continuous effort and investment of the entrepreneurs who give the innovations paramount importance and cornerstone of their business strategies. Entrepreneurs who put their utmost efforts into making environmental development a core business strategy are known as sustainable entrepreneurs (Schaltegger & Wagner, 2011). The most significant contribution of such entrepreneurs is that they develop new, innovative, and sustainable methods of production that produce products and services, which significantly reduce the negative impacts of environmental degradation and improve the quality of life (York & Venkataraman, 2010).

According to Schumpeter (1934), entrepreneurial activities can be called creative destruction. Sustainable entrepreneurs abolish current orthodox manufacturing approaches, products, market arrangements, and demand designs and substitute them with more sophisticated, ecologically friendly products and services. They develop a new market structure that prefers environmental and social progress. There are various approaches and thoughts available in the literature, such as ecopreneurship, sustainable entrepreneurship, social entrepreneurship, and to some extent, institutional entrepreneurship, that can describe the link between entrepreneurship and sustainable development. A large body of literature in the past has tried to explain the association between entrepreneurship and sustainable development in the light of ecopreneurship (Schaltegger, 2002; Cohen et al., 2008; Coulibaly et al., 2018; Sinatti, 2019; Sun et al., 2020). Ecopreneurship's essential incentive and key objectives are earning money while addressing environmental glitches. The end goal of any business is to make a profit. In other words, we can say the economic motive is the leading cause of any business, whereas, under the rationale of sustainable entrepreneurship, environmental aims are also interlinked with economic reasons. Against this backdrop, the most daunting challenge for sustainable firms and entrepreneurs is to assimilate the environmental goals of society into the firm's financial plan. Moreover, there is a need to increase the number of green enterprises in the economy (Hockerts & Wüstenhagen, 2010).

A growing body of empirical literature, in recent times, has focussed on the impact of entrepreneurial activities on environmental quality in various countries and regions, but their results are contradictory, inconclusive, and mixed. The first strand of studies confirmed that the relationship between entrepreneurship and environmental quality is negative. For example, Riti and Shu (2016) analysed the relationship between entrepreneurship and environmental quality in Nigeria by applying the fully modified least square (FMOLS). The findings of their study confirmed that entrepreneurship deteriorates the environmental quality, meaning that sustainable development is not achievable. Once again, with the application of the same method, Dhahri and Omri (2018) examined the relationship between entrepreneurship and environmental quality for 20 developing economies and observed a negative association between both of these variables. Another group of studies confirmed that entrepreneurship is vital for improving environmental quality. York and Venkataraman (2010) demonstrated that entrepreneurial activity helps to improve the environmental quality rather than degrade it. Likewise, Shepherd and Patzelt, (2011) confirmed that rising trends in entrepreneurship protect the environment, increase agricultural activities and plantations, diminish pollution, and offset climate change. Omri (2018) collected the data for 69 countries from different income groups and observed that the impact of entrepreneurship on CO2 emissions is low in high-income economies. Moreover, the analysis also confirmed that entrepreneurship increased CO2 emissions at the initial level, whereas CO2 emissions started to decline, at the later stage, once entrepreneurship got matured in the economy. Lastly, the third group of studies observed that some preconditions needed to be fulfilled before the appearance of positive effects entrepreneurship on environmental quality. Some of these preconditions include green innovations and better institutions because both these factors complement entrepreneurship in improving environmental quality and then realising the goal of sustainable development (Youssef et al., 2018).

In a broader perspective, sustainable entrepreneurship can be defined as a form of entrepreneurship based on green innovations and a free-market structure that ensures a clean and green environment without sacrificing its economic goals (Dean & McMullen, 2007). Previously, the role of sustainable entrepreneurship in improving environmental quality has not been extensively analysed. This study tries to fill this gap in the literature. This is the first-ever study that examines the relationship between sustainable entrepreneurship and environmental quality to the best of our knowledge. Moreover, this study also includes the role of green innovations in mitigating CO2 emissions for highly polluting Asian economies. China, India, Japan, Russia, and the USA are the top pollution emitters' economies of the world. Among these five economies, four economies belong to Asia. It is observed that China is responsible for producing 28% of CO2 emissions, India 7%, Russia 5%, and Japan 3% (UNEP, 2020). Thus, it is imperative to examine these four countries independently.

The study is organised into different sections. A brief literature review is presented in Section 2, and we presented the model and methods in Section 3. Section 4 illustrates the results, followed by a conclusion in Section 5.

2. Model and methods

Although, green technologies and green products have been considered important determinants of environmental sustainability that lead to green growth (Dhahri & Omri, 2018; Willis et al., 2020). Despite the significance of green entrepreneurship, there is still a lack of empirical work. The key reason for this deficiency of literature is that it is difficult to distinguish between green entrepreneurship and non-green entrepreneurship. However, the literature started growing in the 1990s. The terms 'ecopreneur', 'eco-entrepreneur, 'green entrepreneur', and 'environmental entrepreneur', were first introduced by Bennett (1991). After that various studies have adopted renewable energy as a leading determinant of environmental entrepreneurship (Gast et al., 2017). Following recent literature, e.g., Youssef et al. (2018) and Omri and Afi (2020) we adopt the following long-run CO2 emissions econometric model for polluted Asian economies:

$$CO_{2,t} = \varphi_0 + \varphi_1 EE_t + \varphi_2 GI_t + \varphi_3 Internet_t + \varphi_4 Trade_t + \varphi_5 FD_t + \varepsilon_t \quad (1)$$

where CO2 emissions () is dependent on environmental entrepreneurship (EE), green innovation (GI), internet (ICT), trade openness (Trade), and financial development (FD). In the next step, Equation (1) is respecified in the format of the error correction technique as seen underneath:

$$\begin{aligned} \Delta CO_{2,t} = {} & \varphi_0 + \sum_{k=1}^{n} \beta_{1k} \Delta CO_{2,t-k} + \sum_{k=0}^{n} \beta_{2k} \Delta EE_{t-k} + \sum_{k=1}^{n} \beta_{3k} \Delta GI_{t-k} \\ & + \sum_{k=0}^{n} \beta_{4k} \Delta Internet_{t-k} + \sum_{k=1}^{n} \beta_{5k} \Delta Trade_{t-k} + \sum_{k=0}^{n} \beta_{6k} \Delta FD_{t-k} \\ & + \omega_1 CO_{2,t-1} + \omega_2 EE_{t-1} + \omega_3 GI_{t-1} + \omega_4 Internet_{t-1} + \omega_5 Trade_{t-1} \\ & + \omega_6 FD_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

Equation (2) has now taken the form of the ARDL model, as suggested by Pesaran et al. (2001). This technique has the ability to provide short and long-run estimates simultaneously. As far as the short-run results are concerned, the estimates attached to the first differenced variables in Equation (2) represent them. On the other side, we can draw long-run results from the estimate of from Equation (2). However, long-run results are valid if co-integration between the long-run estimates is established through the F-test. In this regard, we need to prove that the calculated value of the bounds F-test is greater than the tabulated value presented by Pesaran et al. (2001). Several other time series techniques are available that can prove co-integration among the long-run variables (Bahmani-Oskooee et al., 2020; Usman et al., 2022). However, these techniques work only if the variables are integrated in the same order. On the other side, the main trait of the ARDL model is that it can handle the variables of different orders of integration, such as I(0) and I(1). All other time series methods need a large number of observations in order to provide consistent estimates. In contrast, the ARDL model performs well in the case of a small number of observations (Li & Ullah, 2022; Zhang et al., 2022).

The study's primary objective is to estimate the asymmetric impacts of environmental entrepreneurship and green innovation on carbon emissions in highly polluted economies. Therefore, we split the variables of environmental entrepreneurship and green innovations into their positive and negative series by using partial sum procedures as shown below:

$$EE^{+}{}_{t} = \sum_{n=1}^{t} \Delta EE^{+}{}_{t} = \sum_{n=1}^{t} \max\ (EE^{+}{}_{t},\ 0) \tag{3a}$$

$$EE^{-}{}_{t} = \sum_{n=1}^{t} \Delta EE^{-}{}_{t} = \sum_{n=1}^{t} \min\ (\Delta EE\ ^{-}{}_{t},\ 0) \tag{3b}$$

$$GI^{+}{}_{t} = \sum_{n=1}^{t} \Delta GI^{+}{}_{t} = \sum_{n=1}^{t} \max\ (GI^{+}{}_{t},\ 0) \tag{3c}$$

$$GI^{-}{}_{t} = \sum_{n=1}^{t} \Delta GI^{-}{}_{t} = \sum_{n=1}^{t} \min\ (\Delta GI\ ^{-}{}_{t},\ 0) \tag{3d}$$

Equations 3a–3d represent the positive and negative changes in the EE and GI, respectively. Then, replacing the partial sum variables into Equation (2) and the outcome is as under:

$$\begin{aligned}\Delta CO_{2,t} = {} & \varphi_0 + \sum_{k=1}^{n} \beta_{1k}\Delta CO_{2,t-k} + \sum_{k=0}^{n} \beta_{2k}\Delta EE^{+}{}_{t-k} + \sum_{k=0}^{n} \delta_{3k}\Delta EE^{-}{}_{t-k} \\ & + \sum_{k=0}^{n} \beta_{4k}\Delta GI^{+}{}_{t-k} + \sum_{k=0}^{n} \delta_{5k}\Delta GI^{-}{}_{t-k} + \sum_{k=0}^{n} \beta_{6k} Internet_{t-k} \\ & + \sum_{k=0}^{n} \beta_{7k} Trade_{t-k} + \sum_{k=0}^{n} \beta_{8k} FD_{t-k} + \omega_1 CO_{2,t-1} + \omega_2 EE^{+}{}_{t-1} + \omega_3 EE^{-}{}_{t-1} \\ & + \omega_4 GI^{+}{}_{t-1} + \omega_5 GI^{-}{}_{t-1} + \omega_6 Internet_{t-1} + \omega_7 Trade_{t-1} + \omega_8 FD_{t-1} + \varepsilon_t\end{aligned} \tag{4}$$

The NARDL model of Shin et al. (2014) is an advanced form of the ARDL model of Pesaran et al. (2001). Hence, the NARDL does not require any special estimation technique and can be handled with the method and techniques of the ARDL model. We need to check whether the short and long-run asymmetric effects are present or not. For short-run asymmetric effects, we first need to prove the significant difference between the sum of short-run estimates of Δ (and the sum of estimates (). Likewise, the long-run non-linear effects are proved if we can show that estimate attached to (significantly differs from the estimate attached to ().

Table 1. Definitions and data sources.

Variables	Symbol	Definitions	Sources
CO2 emissions	CO2	CO2 emissions (kt)	World Bank
Environmental entrepreneurship	EE	Nuclear, renewables, and other production (quad Btu)	EIA
Green innovation	GI	Development of environment-related technologies, % all technologies	OECD
Internet	Internet	Individuals using the Internet (% of population)	World Bank
Trade openness	Trade	Trade (% of GDP)	World Bank
Financial development	FD	Domestic credit to private sector by banks (% of GDP)	World Bank

Source: Authors' calculation.

3. Data

The study investigates the impact of environmental entrepreneurship and green innovation on carbon emissions in highly polluting Asian economies from 1990 to 2019. Highly polluting Asian economies include China, India, Japan, and Russia. Table 1 provides details of variable definitions and sources of data. The dependent variable, CO2 emissions is taken as carbon dioxide emissions in Kilotonnes. Focussed variables, environmental entrepreneurship is taken as nuclear, renewables, and other productions in quad Btu, while green innovations are taken as the development of environment-related technologies (% of all technologies). Internet, trade openness, and financial development have been taken as control variables. Where internet is taken as individuals using the internet in percentage of the population, trade is taken in percentage of GDP, and financial development is measured as domestic credit to the private sector by banks in percentage of GDP. All the required data have been sourced from EIA, OECD, and the World Bank.

4. Results and discussion

Due to the possibility of structural and asymmetric changes in the selected variables, unit root test without and with structural break has been performed in this study. These unit root tests are used to determine the stationary properties of the data to deliver more reliable decisions. Table 2 shows the findings of both unit root tests for all selected economies (i.e., China, India, Japan, and Russia). The results of both unit root tests reveal that all the variables of all selected economies are either stationary at I(0) or at the I(1). Thus, on the basis of unit root tests findings, ARDL approach is valid and can be applied for further analysis. The study explores the symmetric and asymmetric impact of environmental entrepreneurship and green innovation on CO2 emissions in the case of highly polluting Asian economies. This section also provides coefficient estimates for each country separately.

In Table 3, long-run coefficient estimates of ARDL models reveal that environmental entrepreneurship exerts a significant and negative impact on CO2 emissions in case of China, Japan, and Russia, while in case of India environmental entrepreneurship has an insignificant impact on CO2 emissions. It shows that due to 1% upsurges in environmental entrepreneurship, CO2 emissions declines by 0.024% in China, 0.009% in Japan, and 0.594% in Russia. In case of green innovations, findings reveal that green innovations tend to reduce CO2 emissions in case of all selected

Table 2. Unit root testing.

	Unit root without break			Unit root with break				
	I(0)	I(1)		I(0)	Break date	I(1)	Break date	
China								
CO2	−1.421	−2.627*	I(1)	−6.688***	2002			
EE	0.989	−2.689*	I(1)	2.754	2013	−4.359*	2011	I(1)
GI	−2.132	−6.985***	I(1)	−2.489	2010	−8.356***	2001	I(1)
Internet	0.654	−2.875*	I(1)	−1.623	2006	−6.656***	2006	I(1)
Trade	−2.678*		I(0)	−4.954***	2010			I(0)
FD	−0.465	−5.166***	I(1)	−3.023	2009	−5.452***	2008	I(1)
India								
CO2	−1.235	−2.745*	I(1)	−4.865**	2003			I(0)
EE	0.123	−4.235***	I(1)	0.845	2010	−6.655***	2015	I(1)
GI	−2.678*		I(0)	−6.356***	2007			I(0)
Internet	0.542	−2.875*	I(1)	1.203	2017	−4.256*	2016	I(1)
Trade	−1.523	−4.235***	I(1)	−2.778	2003	−5.145***	2013	I(1)
FD	−0.789	−2.841*	I(1)	−3.245	2001	−4.985***	2008	I(1)
Japan								
CO2	−2.879*		I(0)	−4.358*	2001			I(0)
EE	−1.045	−3.589**	I(1)	−6.654***	2011			I(0)
GI	−0.985	−5.265***	I(1)	−2.856	2008	−7.123***	2016	I(1)
Internet	−1.025	−3.055**	I(1)	−3.012	2000	−4.652**	2004	I(1)
Trade	−0.875	−5.321***	I(1)	−3.023	2004	−5.324***	2016	I(1)
FD	−2.673*		I(0)	−9.325***	2000			I(0)
Russia								
CO2	−1.355	−2.802*	I(1)	−4.562**	2018			I(0)
EE	0.452	−4.555***	I(1)	−1.023	2000	−4.965***	2012	I(1)
GI	−4.532***		I(0)	−5.356***	2011			I(0)
Internet	0.621	−4.012***	I(1)	−2.875	2009	−4.369*	2002	I(1)
Trade	−5.656***		I(0)	−7.358***	2007			I(0)
FD	−11.25***		I(0)	−12.35***	2012			I(0)

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$.
Source: Authors' calculation.

Table 3. Estimates of CO2 emissions (ARDL).

Variable	China Coefficient	t-Stat	India Coefficient	t-Stat	Japan Coefficient	t-Stat	Russia Coefficient	t-Stat
Short-run								
D(EE)	−0.034**	2.083	−0.224***	4.168	0.015	1.609	−0.501	1.285
D(EE(-1))			0.043	0.885			0.514	1.527
D(GI)	−0.031***	2.758	−0.014***	2.990	−0.010	1.615	−0.022	1.193
D(GI(-1))			0.005	1.334	−0.048***	7.000		
D(INTERNET)	0.003	0.976	−0.016***	9.355	0.002	1.509	0.007	0.943
D(INTERNET(-1))			0.046*	1.813	−0.001	0.486		
D(TRADE)	0.008***	5.238	−0.012***	3.736	0.005***	3.338	0.003	0.541
D(TRADE(-1))			−0.001	0.485	0.006***	3.571		
D(FD)	0.151	1.416	0.694***	3.222	0.018	0.511	0.137	1.397
D(FD(-1))	−0.271**	2.472	−0.113	0.603	−0.003	0.075		
Long-run								
EE	−0.024**	1.997	−0.580	0.918	−0.009*	1.756	−0.594*	1.841
GI	−0.126*	1.951	−0.040**	2.097	−0.016***	4.169	−0.038	0.950
INTERNET	−0.012	1.205	−0.143***	3.027	−0.001*	1.864	−0.002	0.495
TRADE	0.032***	4.525	−0.016	1.649	−0.007**	2.542	−0.005	0.504
FD	1.923**	2.160	1.134***	2.900	0.019	0.532	−0.238	1.300
C	4.466	0.977	9.355***	7.749	13.83***	8.487	13.02***	8.742
Diagnostics								
F-test	6.654***		10.21***		8.321***		5.321***	
ECM(-1)	−0.246***	3.539	−0.307***	2.901	−0.385***	9.000	−0.377***	2.840
LM	1.321		1.542		1.325		1.321	
RESET	1.035		0.987		0.879		1.325	
CUSUM	S		S		S		S	
CUSUM-sq	S		S		S		US	

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$.
Source: Authors' calculation.

economies except Russia in the long-run. It infers that 1% upsurge in green innovations result in reducing CO2 emissions by 0.126% in China, 0.040% in India, and 0.016% in case of Japan. In terms of control variables, findings display that internet tends to decline CO2 emissions in India and Japan, trade results in reducing CO2 emissions in China and Japan, while financial development reduces CO2 emissions in China and India in the long-run. Short-run coefficient estimates of ARDL models display that environmental entrepreneurship and green innovations result in reducing CO2 emissions in case of China and India, while these variables produce an insignificant impact on CO2 emissions in case of Japan and Russia. Our short and long-run results are different, and almost all studies that have applied the ARDL model support these findings (Usman et al., 2021a; Wei et al., 2022). The main reason behind the difference between the short and long-run estimates is that in the long run, the policymakers can exercise various options to adjust according to the changing environments and safeguard the suitable outcome (Usman et al., 2021b). Therefore, the difference between short- and long-run estimates is quite natural, per previous literature. The long-run outcomes are more important because most of the policies are made for the long term and on the basis of long-run estimates. In terms of control variables, short-run findings display that internet tends to decline CO2 emissions only in case of India, trade results in reducing CO2 emissions in all economies except Russia, and financial development reduces CO2 emissions only in case of India.

In Table 4, long-run coefficient estimates of all four asymmetric models show that positive shock in environmental entrepreneurship has a negative impact on CO2 emissions in all selected economies except Russia confirming that positive shock in environmental entrepreneurship results in improving the quality of the environment. Coefficient estimates demonstrate that in response of 1% increase in positive shock of environmental entrepreneurship, CO2 emissions decline by 0.054% in China, 0.277% in India, and 0.040% in Russia. However, in the long-run, negative shock in environmental entrepreneurship tends to increase CO2 emissions only in India. It shows that 1% fall in negative shock of environmental entrepreneurship, CO2 emissions increase by 0.098% in India. These findings imply that positive change in environmental entrepreneurship brings a stronger influence on environmental performance in India and Japan. The effect of negative change in environmental entrepreneurship is relatively smaller revealing that it exerts a little adverse effect on environmental quality. In short, positive change in environmental entrepreneurship impact is more prominent than a negative change in environmental entrepreneurship. In the long-run, positive shock in green innovations result in reducing CO2 emissions in all selected economies except India, while negative shock in green innovations results in increasing CO2 emissions in India and Japan. Coefficient estimates show that 1% increase in positive shock of green innovations results in reducing CO2 emissions by 0.030% in China, 0.013% in Japan, and 0.058% in Russia. In contrast, 1% decline in green innovations results in increasing CO2 emissions by 0.242% in India and 0.007% in Japan. These findings confirm that positive change in green innovation and negative change in green innovation have different effects on carbon emissions. The upsurge of green innovation improves the environmental quality while the decline in green innovation deteriorates environmental performance.

Table 4. Short and long-run estimates of CO2 emissions (NARDL).

Variable	China Coefficient	t-Stat	India Coefficient	t-Stat	Japan Coefficient	t-Stat	Russia Coefficient	t-Stat
Short-run								
D(EE_POS)	−0.013*	1.866	−0.243***	3.715	−0.079*	1.809	−0.593	0.775
D(EE_POS(-1))			−0.329***	6.563			−0.809	1.105
D(EE_NEG)	−0.022	1.022	−0.088	0.066	−0.034	0.958	−0.487	0.163
D(EE_NEG(-1))			1.002***	4.443	−0.023*	1.957		
D(GI_POS)	−0.008	0.665	−0.074***	3.384	−0.038***	4.491	−0.081	1.390
D(GI_POS(-1))			−0.046***	7.191	−0.058***	6.457	0.112***	2.686
D(GI_NEG)	0.010	0.914	−0.098***	4.483	−0.014	1.606	0.040	0.919
D(GI_NEG(-1))			−0.034***	3.565				
D(INTERNET)	−0.006*	1.932	−0.009***	6.599	−0.001	0.588	−0.011***	2.975
D(INTERNET(-1))			0.015	0.753				
D(TRADE)	0.006***	3.874	0.006	1.462	0.007***	4.044	0.000	0.049
D(TRADE(-1))			0.011***	3.813	0.005**	2.400	−0.020**	2.263
D(FD)	0.166	1.088	0.149	0.699	−0.042	0.967	0.360	0.521
D(FD(-1))	−0.193	1.487	0.948***	3.967	−0.032	1.100	−0.386	1.501
Long-run								
EE_POS	−0.054**	2.504	−0.277**	2.113	−0.040**	2.359	−0.078	0.656
EE_NEG	−0.122	1.233	−0.098**	2.449	−0.017	1.599	0.359	0.379
GI_POS	−0.030*	1.676	−0.030	1.007	−0.013*	1.697	−0.058**	2.517
GI_NEG	0.040	0.729	−0.242**	2.330	−0.007*	1.881	0.001	0.133
INTERNET	−0.024***	2.713	−0.242**	2.437	0.050	0.617	−0.003**	2.185
TRADE	0.023***	2.843	0.022**	2.077	−0.002*	1.846	0.005	1.189
FD	1.204	0.978	0.260***	2.651	−0.047**	2.255	0.306*	1.946
C	8.937	1.610	11.68***	7.874	14.21***	14.80	14.03***	5.221
Diagnostics								
F-test	4.123**		9.321***		7.325***		5.689***	
ECM(-1)	−0.250**	2.390	−0.347*	1.695	−0.397***	5.147	−0.413*	1.880
LM	0.754		1.023		1.235		0.987	
RESET	1.023		0.587		0.987		1.012	
CUSUM	S		S		S		S	
CUSUM-sq	S		S		S		S	
Wald-Short-EE	3.012*		1.023		0.388		2.002	
Wald-Long-EE	3.986**		4.012**		3.241**		1.022	
Wald-Short-GI	1.023		2.029		1.098		1.875	
Wald-Long-GI	4.325**		2.985*		3.875**		2.852*	

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$.
Source: Authors' calculation.

Firms and businesses are essential for increasing the production activities in the economy and improving the living standard of the people. On the other side, these firms and companies generate scale effects that can put an extra burden on the environment. However, the flip side of the coin is that entrepreneurs of large firms and industries can bring in innovative ideas and technologies in the production process that make the production process much more energy-efficient and environmentally friendly. Our findings confirm that environmental entrepreneurship is the need of the hour because it helps reduce the CO2 emissions significantly in highly polluting Asian economies. These findings are in line with the previous studies of McEwen (2013) and Youssef et al. (2018), which suggested that environmental entrepreneurship can solve various environmental and social problems and serve as the primary driver of sustainable development. Sustainable entrepreneurs make the environment a top priority while doing business and making any business strategy. The most striking feature of environmental entrepreneurship is that they contribute to developing green technology and products and inventing green and sustainable production techniques that significantly improve the environment (York & Venkataraman, 2010)

Moreover, a rise in environmental entrepreneurship and usage of environment-related products may lead to a superior quality environment because doing business in environment-friendly and green products and methods will halt the flow of carbon emissions into the atmosphere (Gast et al., 2017). Furthermore, environmental entrepreneurship along with increased usage of renewable energy, have significantly impacted CO2 emissions (Ullah et al., 2021). Hence, if the share of environment-friendly products could be expanded in the economy's total production, that would help attain sustainable development in the long run. Another important benefit of environmental entrepreneurship is that it helps develop green innovation, i.e., environment-related technologies that reduce CO2 emissions, as suggested by our findings and supported by Takalo and Tooranloo (2021). Last but not least, our results confirm that the increased use of the internet helps reduce CO2 emissions in highly polluting Asian economies. With the spread of internet services worldwide, economies are now relying on information and communication capital rather than physical capital. Moreover, the dematerialisation of the economy can also be achieved with the increased use of information and communication products and services that improve environmental quality (Usman et al. 2021a).

In the long-run internet tends to decline CO2 emissions in all selected economies except Japan, trade tends to increase CO2 emissions in China and India and reduce CO2 emissions in Japan, while financial development increases CO2 emissions in India and Russia and reduces CO2 emissions in Japan. The short-run estimates of NARDL model infer that positive shock in environmental entrepreneurship results in reducing CO2 emissions in all selected economies except Russia, while negative shock in environmental entrepreneurship produces an insignificant impact on CO2 emissions in all four models. In the short-term, positive shock in green innovation results in reducing CO2 emissions in India and Japan, while negative shock in green innovations results in increasing CO2 emissions only in India. We also find that the nonlinear ARDL offers more robust evidence than the linear ARDL in support of the short-run and long-run effects of environmental entrepreneurship and eco-innovation. Similar findings are also concluded by Ullah et al. (2021). In terms of control variables, short-run findings infer that internet tends to decline CO2 emissions in all economies except Japan, trade increases CO2 emissions in China and Japan, and financial development produces no significant impact on CO2 emissions in all four economies.

Diagnostic findings in the case of ARDL and NARDL models reveal that long-term co-integration exists among all variables as displayed by the findings of F-stat and ECM terms. No issue of autocorrelation was found in all four economies as shown by the findings of LM test. Ramsey RESET findings reveal that error terms are normally distributed in all four economies in ARDL and NARDL models. The finding of both CUSUM tests confirmed that the stability condition is also fulfilled in all four economies in ARDL and NARDL models except in Russia in case of CUSUM-sq test of ARDL model. The long-run asymmetries are also confirmed by Wald-test.

5. Conclusion and implications

There is no second opinion that entrepreneurship can help the economies produce goods and services at a much higher pace and improve the overall living standard.

However, the consensus on the association between entrepreneurship and environmental quality has not yet been reached. On one side, entrepreneurship can negatively affect the environment through scale effect that increases the economy's production activities and, consequently, CO2 emissions. On the other side, entrepreneurs can bring positive change to the environment by introducing technological innovations and environmentally friendly production techniques. Given the importance of environmental and economic sustainability, the policymakers emphasise the role of environmental entrepreneurship that can promote green growth without degrading the environment further. Consistent with this view, we aim to investigate the impact of environmental entrepreneurship and green innovations on CO2 emissions in highly polluting Asian economies. Due to the nonlinear nature of macroeconomic determinants, we also explore whether the effect of focussed variables on the dependent variable is linear or nonlinear. Thus, we adopted ADL and NARDL approaches in our analysis.

In the short run, the linear estimates of environmental entrepreneurship are significant in China and India. On the other side, the short-run non-linear estimates of environmental entrepreneurship are significant in the case of China, India, and Japan, one more than our linear model. Similarly, the short-run linear estimates of green innovations are significant in China, India, and Japan, whereas the non-linear estimated coefficients of green innovation appeared to be significant in India, Japan, and Russia. In the long run, the linear estimates of environmental entrepreneurship are negative and significant in three countries, namely China, Japan, and Russia. Similarly, the estimates of green innovations are negative and significant in China, India, Japan, and Russia. In the non-linear model, the estimated coefficient of positive shock in environmental entrepreneurship is significant and negative in the case of China, Japan, and India; however, the estimates of negative shock in environmental entrepreneurship are negative and significant in India only. These results imply that a positive shock in environmental entrepreneurship reduces the CO2 emissions in most of economies, whereas the negative shock increases CO2 emissions only in India. The positive estimated coefficient of green innovations is significant and negative in China, Japan, and Russia; however, the estimates of the negative part of green innovations are significantly negative in the case of India and Japan. In general, these findings convey that environmental entrepreneurship and green innovations can improve environmental quality in highly polluting Asian economies.

Policymakers can take some important guidelines from these results. Our results are clearly asymmetric, implying that policymakers should consider negative and positive changes in environmental entrepreneurship and green innovations while considering their impacts on environmental quality. A positive change in environmental entrepreneurship can improve environmental quality; therefore, policymakers should create a business environment that can promote environmental entrepreneurship and green innovations. In this context, they can remove the administrative barriers in the way of environment-friendly start-ups. Moreover, environmental entrepreneurship should be encouraged by providing them easy access to financial credits and technical support. One way of promoting environmental entrepreneurship is through educating business owners and end-users about environmental degradation and the benefits of producing and consuming environment-friendly products. Similarly, green innovations can also help reduce CO2 emissions significantly. Investment in research and development activities can promote green innovations in society that will ultimately lessen the burden on the environment.

Acknowledgments

(1) Planning subject for the 14th Five-Year Plan of Heilongjiang Province education sciences: Research on the cultivation system constructure of ideological and political education and innovation and entrepreneurship education integration under the background of high-quality development (No. GJB1421156).

(2) Research project of basic research expenses in Heilongjiang provincial universities in 2018: Research on innovation and Entrepreneurship of Minority College Students under the background of 'one belt and one road' construction (No. 2018-KYYWF-0982).

(3) Supported by Curriculum ideology and politics Education Reform Project of Jiamusi University: The Construction of innovation and Entrepreneurship 'Gold Courses' in Local Universities of the Curriculum ideology and politics (No. SZZX2020-13).

Disclosure statement

No conflict of interest has been reported by the authors.

References

Bahmani-Oskooee, M., Usman, A., & Ullah, S. (2020). Asymmetric impact of exchange rate volatility on commodity trade between Pakistan and China. *Global Business Review*, 972150920916287.

Cohen, B., Smith, B., & Mitchell, R. (2008). Toward a sustainable conceptualization of dependent variables in entrepreneurship research. *Business Strategy and the Environment*, *17*(2), 107–119. https://doi.org/10.1002/bse.505

Coulibaly, S. K., Erbao, C., & Mekongcho, T. M. (2018). Economic globalization, entrepreneurship, and development. *Technological Forecasting and Social Change*, *127*, 271–280. https://doi.org/10.1016/j.techfore.2017.09.028

Dean, T. J., & McMullen, J. S. (2007). Toward a theory of sustainable entrepreneurship: Reducing environmental degradation through entrepreneurial action. *Journal of Business Venturing*, *22*(1), 50–76. https://doi.org/10.1016/j.jbusvent.2005.09.003

Dhahri, S., & Omri, A. (2018). Entrepreneurship contribution to the three pillars of sustainable development: What does the evidence really say? *World Development*, *106*, 64–77. https://doi.org/10.1016/j.worlddev.2018.01.008

Gast, J., Gundolf, K., & Cesinger, B. (2017). Doing business in a green way: A systematic review of the ecological sustainability entrepreneurship literature and future research directions. *Journal of Cleaner Production*, *147*, 44–56. https://doi.org/10.1016/j.jclepro.2017.01.065

Hockerts, K., & Wüstenhagen, R. (2010). Greening Goliaths versus emerging Davids—Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship. *Journal of Business Venturing*, *25*(5), 481–492. https://doi.org/10.1016/j.jbusvent.2009.07.005

Li, W., & Ullah, S. (2022). Research and development intensity and its influence on renewable energy consumption: Evidence from selected Asian economies. *Environmental Science and Pollution Research*, 1–8.

McEwen, T. (2013). Ecopreneurship as a solution to environmental problems: Implications for college level entrepreneurship education. *International Journal of Academic Research in Business and Social Sciences*, *3*(5), 264.

Omri, A. (2018). Entrepreneurship, sectoral outputs and environmental improvement: International evidence. *Technological Forecasting and Social Change*, *128*, 46–55. https://doi.org/10.1016/j.techfore.2017.10.016
Omri, A., & Afi, H. (2020). How can entrepreneurship and educational capital lead to environmental sustainability? *Structural Change and Economic Dynamics*, *54*, 1–10. https://doi.org/10.1016/j.strueco.2020.03.007
Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326.
Riti, J. S., & Shu, Y. (2016). Renewable energy, energy efficiency, and eco-friendly environment (R-E5) in Nigeria. *Energy, Sustainability and Society*, *6*(1), 1–16.
Schaltegger, S. (2002). A framework for ecopreneurship: Leading bioneers and environmental managers to ecopreneurship. *Greener Management International*, (38), 45–58.
Schaltegger, S., & Wagner, M. (2011). Sustainable entrepreneurship and sustainability innovation: Categories and interactions. *Business Strategy and the Environment*, *20*(4), 222–237. https://doi.org/10.1002/bse.682
Schumpeter, J. A. (1934). *Theory of Economic Development*. Cambridge, MA: Harvard University Press.
Shepherd, D. A., & Patzelt, H. (2011). The new field of sustainable entrepreneurship: Studying entrepreneurial action linking "what is to be sustained" with "what is to be developed". *Entrepreneurship Theory and Practice*, *35*(1), 137–163. https://doi.org/10.1111/j.1540-6520.2010.00426.x
Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. *Festschrift in honor of Peter Schmidt* (pp. 281–314). Springer.
Sinatti, G. (2019). Return migration, entrepreneurship and development: Contrasting the economic growth perspective of Senegal's diaspora policy through a migrant-centred approach. *African Studies*, *78*(4), 609–623. https://doi.org/10.1080/00020184.2018.1555310
Sun, H., Pofoura, A. K., Mensah, I. A., Li, L., & Mohsin, M. (2020). The role of environmental entrepreneurship for sustainable development: Evidence from 35 countries in Sub-Saharan Africa. *The Science of the Total Environment*, *741*, 140132.
Takalo, S. K., & Tooranloo, H. S. (2021). Green innovation: A systematic literature review. *Journal of Cleaner Production*, *279*, 122474.
Ullah, S., Ozturk, I., Majeed, M. T., & Ahmad, W. (2021). Do technological innovations have symmetric or asymmetric effects on environmental quality? Evidence from Pakistan. *Journal of Cleaner Production*, *316*, 128239. https://doi.org/10.1016/j.jclepro.2021.128239
UNEP. (2020). Emissions gap Report 2020. UN Environment Programme.
Usman, A., Ozturk, I., Hassan, A., Zafar, S. M., & Ullah, S. (2021a). The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis. *Telematics and Informatics*, *58*, 101537. https://doi.org/10.1016/j.tele.2020.101537
Usman, A., Ozturk, I., Naqvi, S. M. M. A., Ullah, S., & Javed, M. I. (2022). Revealing the nexus between nuclear energy and ecological footprint in STIRPAT model of advanced economies: Fresh evidence from novel CS-ARDL model. *Progress in Nuclear Energy*, *148*, 104220. https://doi.org/10.1016/j.pnucene.2022.104220
Usman, A., Ozturk, I., Ullah, S., & Hassan, A. (2021b). Does ICT have symmetric or asymmetric effects on CO2 emissions? Evidence from selected Asian economies. *Technology in Society*, *67*, 101692. https://doi.org/10.1016/j.techsoc.2021.101692
Volery, T. (2002). Ecopreneurship: Rationale, current issues and future challenges. *Radical Change in the World: Will SMEs Soar or Crash*, 541–553.
Wei, X., Ren, H., Ullah, S., & Bozkurt, C. (2022). Does environmental entrepreneurship play a role in sustainable green development? Evidence from emerging Asian economies. *Economic Research-Ekonomska Istraživanja*, 1–13. https://doi.org/10.1080/1331677X.2022.2067887
Willis, D. B., Hughes, D. W., Boys, K. A., & Swindall, D. C. (2020). Economic growth through entrepreneurship: Determinants of self-employed income across regional economies. *Papers in Regional Science*, *99*(1), 73–95. https://doi.org/10.1111/pirs.12482

York, J. G., & Venkataraman, S. (2010). The entrepreneur–environment nexus: Uncertainty, innovation, and allocation. *Journal of Business Venturing*, *25*(5), 449–463. https://doi.org/10.1016/j.jbusvent.2009.07.007

Youssef, A. B., Boubaker, S., & Omri, A. (2018). Entrepreneurship and sustainability: The need for innovative and institutional solutions. *Technological Forecasting and Social Change*, *129*, 232–241. https://doi.org/10.1016/j.techfore.2017.11.003

Zhang, D., Ozturk, I., & Ullah, S. (2022). Institutional factors-environmental quality nexus in BRICS: A strategic pillar of governmental performance. *Economic Research-Ekonomska Istraživanja*, 1–13.