Heliyon 9 (2023) e16388

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Does being stricter mean doing better? Different effects of environmental policy stringency on quality of life, green innovation, and international cooperation

Viktor Prokop [a,*], Wolfgang Gerstlberger [b], Pavla Vrabcová [c], David Zapletal [a], Yee Yee Sein [a]

[a] *Science and Research Centre, Faculty of Economics and Administration, University of Pardubice, Pardubice, Czech Republic*
[b] *School of Business and Governance, Tallinn University of Technology, Tallinn, Estonia*
[c] *The Faculty of Economics of the Technical University of Liberec, The Department of Economic Statistics, Czech Republic*

ARTICLE INFO

Keywords:
Environmental policy stringency
International collaboration
Patents
Perceived health
Sustainable development

ABSTRACT

Nowadays, when we are facing several strict regulations, the question arises - does higher strictness lead to the desired results? This study addresses the fact that less research attention has focused on the effects of environmental policy stringency (EPS) on perceived health expressing quality of life, and on green international cooperation. In addition, previous research has provided rather mixed results on the impact of EPS on green innovation. Therefore, we fill an interesting research gap and help better understand the relationship between market-based and non-market-based EPS, perceived health, green innovations, and green international cooperation in OECD (Organization for Economic Co-operation and Development) countries. Using three complementary databases provided by OECD, Eurostat, and the World Bank and the classical linear regression model, we confirm hypotheses that strong market-based EPS and green international cooperation have positive effects on perceived health. Surprisingly, contrary to the findings of prior research, we do not confirm the positive effects of market-based and non-market-based EPS on green international cooperation. This study contributes to the literature on the Porter hypothesis, technological collaborations in green technological development, and environmental innovation theory. In addition, this study provides several practical implications for policymakers across OECD countries.

1. Introduction

There is no doubt that urgent actions (such as reduction of environmental footprint, reduced food waste, emission reduction) are necessary, to avoid the severe effects of climate change [1–3]. These effects could be the loss of biodiversity [4], extreme hydrological phenomena [5], extreme weather conditions [6], and other effects. What is even more severe is that these effects can cascade into multiple impacts across different countries [7]. According to Ref. [4], these adverse effects of climate change cannot be adequately predicted, especially if the measures are not included in the global strategic frameworks, because some impacts occur immediately,

* Corresponding author.
E-mail addresses: viktor.prokop@upce.cz (V. Prokop), wolfgang.gerstlberger@taltech.ee (W. Gerstlberger), vrabcovapavla@gmail.com (P. Vrabcová), david.zapletal@upce.cz (D. Zapletal), yeeyee.sein@student.upce.cz (Y.Y. Sein).

https://doi.org/10.1016/j.heliyon.2023.e16388
Received 24 November 2022; Received in revised form 13 April 2023; Accepted 16 May 2023
Available online 18 May 2023

some slowly, and some in different combinations simultaneously [5]. As a result, there is considerable uncertainty in calculating and expressing all the economic consequences of climate change and the pollution of the planet as well as the effects of the identified changes on the quality of life and human health.

In the light of such problems, (environmental) policymakers set goals leading to sustainable development [8,9], which is becoming a building block in European policies and documents, such as the White Paper on the Future of Europe or the European Green Deal. However, policymakers face several obstacles, such as the lack of information to help set appropriate measures to meet the mission to ensure sustainable development goals [10]. Moreover, it is not entirely clear whether being extremely strict means to be completely successful. Therefore, to provide relevant information, the implementation and the effects of strict environmental policies have been the subject of much discussion and research. More specifically, giving some examples, prior research has analysed the effects of environmental policies and its stringency on energy efficiency [11], air quality and pollution [12], or CO_2 emissions [13].

Another string of previous studies focused on the relationship between environmental policies and green innovations, which are seen as the driving force behind environmental policies [14]. However, the findings of prior studies are mixed. For example, [15] found that the stringency of foreign environmental policy helps drive clean technology innovations, which is similar to Porter's hypothesis [2,16]. Next, [17] state that a high affectedness by environmental regulation triggers firms' greenness [18]. add to these results that non-market-based environmental policy instruments stimulate environmental innovation more than market instruments, which contradicts the results of research by Ref. [19], who conclude that non-market-based environmental performance indicators have a negative impact on (general) innovation [12]. adds that higher-pollution industries innovate less than less-polluting sectors, which the author attributes to increasingly stringent regulations. Moreover, [2] reject the weak version of the Porter hypothesis in the case of Slovenia and the Czech Republic.

As this summary demonstrates, previous research is—to the best of our knowledge—associated with some limitations, while we highlight the two main ones to which our research responds. First, limited attention was paid to the effects of strict environmental policies on the perceived health that we use in our study as a proxy for quality of life (in line with prior studies linking the perceived health with quality of life, see Refs. [20–23]. Second, prior research into environmental policy stringency (EPS) impacts on green innovation did not show a consistent view, and few studies have analysed the effects of EPS on green (international) cooperation, which could lead to the emergence of sizeable benefits, such as cross-country knowledge spill-overs and technology exchange, that could trigger sustainable development and (green) growth [35]. According to Ref. [24], most prior studies have focused on green collaboration at the enterprise or organizational level, and only a few have used samples of countries to explore the effects of green international cooperation. Moreover, the authors point out that the EPS has not yet been considered a determinant of international (technological) cooperation. In addition, there are no studies empirically examining the impact of green innovation and green international cooperation on perceived health in OECD countries.

Against above background, two central research questions arise: *(1) Whether and how environmental policy stringency, green innovation and green international cooperation influence the quality of life expressed by the perceived health in OECD countries?* Moreover, since we are still unable to find clear answers to the impact of EPS on the green innovation and cooperation, we ask the second question: *(2) How does environmental policy stringency affect green innovation and green international cooperation in OECD countries?*

The motivation of this study is to overcome the previously mentioned limitations, fill the above research gaps, and answer the research questions defined above. In order to be able to do this, it is necessary to define the following aims. The first aim is to examine the effects of (i) market-based and non-market-based EPS, (ii) green innovation, and (iii) green international cooperation on the quality of life (expressed by perceived health). The second aim of this study is to test the effects of market-based and non-market-based EPS on green innovation and green international cooperation. For these purposes, we link the data on OECD countries from three databases (OECD, Eurostat, and the World Bank) and create three regression models.

This study contributes to the growing literature on the Porter hypothesis, technological collaborations in green technological development, and environmental innovation theory. In doing so, we help better understand the relationship among EPS, quality of life, green innovations, and green international cooperation in OECD countries. The main contribution of this study is that we are the first to create a link among green innovation, green international cooperation, and perceived health in OECD countries. Moreover, we provide new empirical evidence supporting the Porter hypothesis as we reveal the effects of EPS on green innovation, green international cooperation, and perceived health. For these purposes, we unpack the EPS index into two main components and test the effects of rigor (above average) non-market-based and market-based EPS. Next, because sustainable development is becoming a building block in European policies and documents (e.g., White Paper on the Future of Europe, European Green Deal, the European Commission Reflection paper: Towards a Sustainable Europe by 2030), this study also brings new practical implications for both European and national public policymakers. Moreover, since we examine the effects of EPS, green innovation, and green international cooperation on the quality of life, our findings can contribute to achieving the United Nations (UN) Sustainable Development Goals (also known as Agenda 2030).

This paper is structured as follows. Section 2 contains the theoretical background and hypothesis development, and Section 3 is devoted to the research methodology. Results are presented in Section 4 and discussed in Section 5. Section 6 provides conclusions, including theoretical and practical implications, as well as proposals for future research.

2. Theory and hypotheses

2.1. Linking environmental policy stringency with the quality of life

There is a need to adopt special regulatory measures to stimulate firms' and countries' environmental behaviour [14,25], because there are differences in countries' perceptions of the need to behave ecologically. [26,27] give a typical European example: the different environmental subconscious between Western and Eastern European states. [27] show that these differences may also occur between neighbouring countries that belong to the same group of "catching-up" countries from Central and Eastern Europe. Therefore, to reduce these differences, there is a need to adopt strict environmental policies [28,29]. For this purpose, the OECD's EPS indicator of the stringency of environmental regulations seems to be crucial [18] as the indicator "*accounts for the multi-dimensionality of environmental stringency and in this way overcomes some of the problems related to previously used indicators, such as the pollution abatement cost and expenditures (PACE), which has been used as a proxy for ER stringency in many empirical studies*" [30].

However, to our knowledge, no studies have addressed the context of EPS with the quality of life, which is a significant benefit of this research. Prior research has primarily focused on the relationship between sustainable development and quality of life [31–33]. Yet the analysis of the concept of quality of life in the context of the healthcare system concerning health perceptions is essential not only for meeting the UN Sustainable Development Goals; it is also a significant value in life. Quality of life has become one of the most commonly used terms in modern medicine, and medicine's primary goal is not to consider health or prolong life in itself but rather to maintain or improve the quality of life. For example, the popular health-related quality of life methodology focuses on measuring the relationship between health and quality of life [20–23].

To have a better picture of the effects of EPS on the quality of life (expressed by the perceived health), we divide EPS into market-based and non-market-based EPS [18] and hypothesize that:

H1a. Strong market-based EPS has positive effects on perceived health.

H1b. Strong non-market-based EPS has positive effects on perceived health.

2.2. Unanswered role of environmental policy stringency in promoting green innovation and green cooperation

2.2.1. Environmental policy stringency and green innovation

Green innovations are seen to have a higher societal value [34], to be a key component of sustainable development and growth [35], and a primary enabling factor towards a green economy [36]. Therefore, prior research has focused on finding determinants of green innovations and overall firms' greenness (for a comprehensive overview of these determinants, see Refs. [17,26]), whereas examining the role of environmental regulations in creating green innovation expresses researchers' efforts to find a missing component that complements technology push and demand-pull factors, defined by the general innovation theory [2]. Referring to [37], we put this study into the context of environmental innovation theory, which among the other determinants of green innovations also points out an essential role of institutional and political influences. Moreover, we link this theoretical framework with the ongoing discussion about the validity of the Porter hypothesis that environmental regulation could also support alternative business models based on the circular economy and climate change mitigation technologies [14,16,38].

Concerning the effects of environmental regulations and their stringency on green innovation, on the one hand, we can find several examples showing the positive relationship. For example, [39] confirmed the positive influence of EPS on green innovation on a sample of 77 countries between 2001 and 2007. This positive relationship was also established by Ref. [40] using a sample of nine case studies of firms in the UK and China. On the other hand, improperly applied EPS can displace the emergence of a win–win situation and can go against the Porter hypothesis, as shown by Ref. [41], who reviewed the empirical literature on the impacts of environmental regulations on firms' competitiveness (including also green innovation performance). [14] provide a broad view on this issue and conclude that the effects of environmental regulation on firms' innovation behaviour are complex. Moreover, [28] adds that, although researchers have been analysing the relationship between environmental regulations (and their stringency) and (green) innovation for more than two decades, the answer as to whether this relationship is positive or negative is still unclear, and empirical findings are mixed.

Here, we lean towards an optimistic wave of research and hypothesize that:

H2a. Strong market-based EPS has positive effects on green innovation.

H2b. Strong non-market-based EPS has positive effects on green innovation.

2.2.2. Environmental policy stringency and green cooperation

To bring new impetus to existing research on the validity of the Porter hypothesis and to contribute to the growing literature on green collaborations [35], we also focus on the effects of EPS on green international cooperation, which we express in our study by international collaboration in environmental-related technologies (ICERTD). Support for this step can be found in the study of [24], which states that "*some studies have pointed out that environmental regulations do not directly affect the green technological innovation of enterprises, but environmental regulations have promoted enterprises to obtain external knowledge resources through technological alliances*."

Generally, we can state that green cooperation can be justified for several reasons, such as the transfer of knowledge, experience, and capital between countries, but mainly due to its positive effects on the environment, as evidenced by Ref. [42]. The authors state that green cooperation (expressed by ICERTD) is seen as a new way to improve environmental quality among several countries. In contrast, they confirm that green cooperation led to decarbonization in the U.S. from 1990 to 2018. However, putting the issue of green cooperation into the context of the Porter hypothesis, the question of how EPS will affect green cooperation is growing. For example, [35] use a sample of OECD and BRICS countries to show that the distance in the stringency of environmental policy between countries could hinder the intensity of green cooperation in energy-related technologies. The authors state that "*environmental regulation is very heterogeneous across countries not only in terms of content but also in the extent to which the regulation puts an explicit or implicit price on* *pollution or other environmentally harmful behaviors*" and point out that it is, therefore, necessary to "*understand how technological collaborations develop and unfold in different institutional settings*" [35].

From the limited empirical evidence on the effects of EPS on green cooperation, we can see that strict EPS can act in both positive and negative ways. [43] show that a country's more stringent market-based EPS can lead to firms' increased sourcing of international knowledge about green technology compared to domestic knowledge. The authors use a sample of OECD countries from 1991 to 2010. However, the authors point out that, after a certain point, a turnaround occurs and an inverted U-shaped relationship emerges between market-based EPS and international knowledge sourcing. In the case of non-market-based EPS, the authors confirm a positive (linear) relationship with international knowledge sourcing (relative to domestic knowledge sourcing). According to Ref. [44], the regulatory framework does not directly influence the generation of green technologies, as shown on their sample of European firms, but it rather stimulates firms to search for new and qualified collaborations, which can subsequently trigger firms to generate new green technological knowledge. Environmental regulation could therefore act as a determinant of green cooperation.

Following the findings of [24], which point out the positive relationship between countries' stricter environmental regulations and engagement in green technological collaboration, we expect positive effects of EPS on green international cooperation and hypothesize that:

H3a. Strong market-based EPS has positive effects on green international cooperation.

H3b. Strong non-market-based EPS has positive effects on green international cooperation.

2.3. Nexus among green innovation, green cooperation, and quality of life

Green innovations, influenced by increased green organizational identity (among other factors) leading to the creation of green innovation strategies, are seen as factors enhancing the improvement of the quality of life [45] as well as factors that cause sustainable benefits, such as lower greenhouse gas emissions [46]. These assumptions are also confirmed by Ref. [13], who state that green innovation, including "*CO_2 control, pollution reduction, waste management, energy and water efficiency, green packaging, carbon sequestration, and green supply chain and logistics*," could help prevent far-reaching negative impacts on wildlife, human well-being, and ecosystems at large. Therefore, to protect human health and the environment, the authors state that governments and firms allocated significant funds in green innovation. Moreover, according to Ref. [42], green technological innovation and open green innovation are seen as the catalyst in shaping the green economy and green transformation and the most effective ways to achieve sustainable development goals.

According to Ref. [47], the innovation process should be evaluated in a broader spectrum of implications that include the influence of innovations on all dimensions of quality of life. Prior literature, therefore, has expressed the quality of life through various variables, with gross domestic product (GDP), gross national product (GNP), and the Human Development Index (HDI) being the most commonly used [48]. For example, [49] confirm a positive relationship between green innovation and sustainable development expressed by the Environmental Performance Index, HDI, and GDP per capita on the sample of 20 OECD countries from 2014 to 2016. In contrast, [47] link quality of life with happiness and confirm the positive relationship between green innovations and happiness on a sample of 10 European countries between 1981 and 2011.

Therefore, we expect a positive relationship between green innovation and quality of life (perceived health) and hypothesize that:

H4a. Green innovation has positive effects on perceived health.

In addition, due to the public nature of climate change [35] that could act as a negative externality, it is also necessary to ensure international support and cooperation [50–53]. [46] state that joint efforts are a crucial element of sustainability. It is reasonable because green cooperation could trigger sustainable benefits by (i) creating legitimacy of sustainable technologies, (ii) reducing waste, and (iii) improving the environmental and social performance of firms [46]. Therefore, following the arguments of [54] that the creation of green innovation nationally as well as through international cooperation could be a cornerstone of energy policy but also the way to (i) reach sustainable development goals and (ii) transform toward an emission-free society. Thus, we hypothesize that:

H4b. Green international cooperation has positive effects on perceived health.

3. Materials and methods

Concerning the data availability and the purpose of this study, we collected data on 21 OECD countries between 2008 and 2012 from three complementary publicly available databases: OECD, Eurostat, and the World Bank. More specifically, we created and used pooled datasets spanning five calendar years, whereas the final sample used for the empirical model specification consisted of 105 observations. Our dataset contains the following countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, and United Kingdom. Please note that the chosen time period is due to the fact that there were no more available years for the variables meeting the purposes of this paper, due to a high amount of missing data. For the purposes of this study, our data can be considered the most recent.

Our empirical strategy leading to the decision about our hypotheses required the creation of three regression models operating with three output variables as follows:

- **Model (1)** measures the quality of life as an output (*qualife*), where we used self-perceived health as the proxy variable [55].

- **Model (2)** measures the green innovation as an output (*greeninno*), where we used environmentally related technologies (patents) as the proxy variable [13].
- **Model (3)** measures the green international cooperation as an output (*greencoop*), where we used international collaboration in environmentally related technologies as the proxy variable [42].

The explanatory variables, including the control variables (see below), were the same in all models. The variables expressing green innovation (*greeninno*) and green international cooperation (*greencoop*) were also considered as independent variables in the models, where they did not play the role of outputs. The variables expressing EPS were divided into market-based and non-market-based EPS (according to Ref. [18]). Market-based EPS (*markeps*) includes environmentally related taxes and charges (taxes and charges on the source of emissions) and trading scheme. Non-market-based EPS (*nomarkeps*) provides command and control regulations and technical support policies. Compared to prior research, we consider this variable as a factor (dichotomous), where 1 indicates that the value of the variable is above the average of the analysed countries (0 – otherwise). All variables are presented in Table 1.

For the control variables, based on the literature research and the data availability, we selected variables expressing countries' economic performance indicators, such as R&D expenditures (*rdexp*), gross domestic product (*gdp*), and foreign direct investment (*forinv*). These indicators represent driving forces for economic development, technological performance, and competitiveness of countries [56] as well as factors influencing the environment, such as in the form of the generation of CO_2 emissions [57]. Next, we also controlled our results for the variables expressing environmental pollution (municipal waste (*waste*) and emissions of carbon monoxide (*carbox*), nitrogen oxides (*nitrox*), sulphur oxides (*sulphox*), and particulate matter (*particulate*)). Previous research offers support for the relationship between these variables and, for example, green cooperation or green innovations (see Refs. [13,58]). We also controlled our results for the effects of population density (*popdens*), which were proved to affect the changing per capita emissions [59].

Because all three dependent variables considered are continuous, the classical linear regression model was used. The general form of such a model is given by the following equation:

$$y_i = \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} + \varepsilon_i \tag{1}$$

where y_i is the value of dependent variable, x_{ij} is the value of the j-th independent variable for the i-individual, and ε_i is the residual

Table 1
Variables description.

Type	Variable	Description	Type; Unit	Source
Outputs/ inputs	*qualife*	The concept is operationalized by a question of how a person perceives his/her health in general using one of the answer categories very good/good/fair/bad/very bad.	Continuous; Percentage of people with very good health	EUROSTAT
	greeninno	Environmentally related technologies (Patents)—the number of inventions developed by a country's inventors, independent of the jurisdictions where patent protection is sought (i.e., all known patent families worldwide are considered).	Continuous; Ratio of patents to no. of R&D personnel	OECD
	greencoop	International collaboration in environmentally related technologies—the number of co-inventions (simple patent families) developed jointly by at least two inventors.	Continuous; Percentage within OECD	
Inputs	*Markeps* *nomarkeps*	Environmental Policy Stringency Index is a country-specific and internationally comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour.	Factor; 1 = higher than the average of the analysed countries; 0 = otherwise	
Controls	*forinv*	Foreign direct investment net inflows.	Continuous;	WORLD
	rdexp	Gross domestic expenditures on research and development, including both capital and current expenditures in the four main sectors: business enterprise, government, higher education, and private non-profit.	% of GDP	BANK
	popdens	Population density that counts all residents regardless of legal status or citizenship, except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin.	Continuous; People per sq. km of land area	
	gdp	Gross domestic product per capita.	Continuous; GDP per capita in PPP	
	carbox *nitrox* *sulphox* *particulate*	Emission data are based on the best available engineering estimates for a given period; they concern man-made emissions of carbon monoxide (COx), nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM).	Continuous; Kilograms per capita	OECD
	waste	Municipal waste expressing the amount of waste generated in each country, related to the rate of urbanisation, the types and pattern of consumption, household revenue, and lifestyles.		

Source: adapted from OECD, Eurostat, and the World Bank (unobservable) random variable meeting classical assumptions (for details see, for example [60]). The unknown parameters of the model $\beta_0, \beta_1, \ldots, \beta_p$ can then be estimated using the ordinary least squares method.

In addition to the estimated parameters of the model, the well-known measures that give some information about the goodness of fit of the model were also calculated. These included the coefficients of determination (*R*-squared), the adjusted coefficient of determination (adjusted *R*-squared), and the significance test of the coefficient of determination (*F*-statistics and corresponding *p*-value); see Ref. [60] for details.

4. Empirical results

In this Section, we present the results of our three models. These results are subsequently discussed in the next discussion Section.

4.1. Model (1)

The analysis of our first output variable representing quality of life (*qualife*) in the selected OECD countries (proxied by perceived health) shows that above-average market-based EPS (*markeps: 1*) positively increases perceived health (see Table 2). We also found strong positive effects of green international cooperation (*greencoop*) on perceived health. These results allowed us to accept hypotheses *H1a* and *H4b*. However, we did not prove (but also did not reject at a usual level of significance) hypotheses *H1b* and *H4a*.

Considering the effects of other control variables, we show that most of the variables expressing environmental pollution have negative effects on perceived health in OECD countries. Similar effects were found for population density (*popdens*).

4.2. Model (2)

On the one hand, the findings of the second regression model (Table 3) indicate that above-average market-based EPS (*markeps: 1*) has negative effects on green innovation (*greeninno*), thereby leading us to reject hypothesis *H2a*. On the other hand, we accept hypothesis *H2b*. The results also show that increased green international cooperation (*greencoop*) has negative effects on green innovation.

Referring to control variables and their significance, the effects of the variables expressing environmental pollution are mixed. The positive effects were found for population density (*popdens*) and R&D expenditures (*rdexp*). The effects of foreign direct investment (*forinv*) on green innovation are negative.

4.3. Model (3)

The empirical results obtained for green international cooperation (*greencoop*) did not allow us to accept hypotheses *H3a* and *H3b* (Table 4). More specifically, we showed that above-average market-based EPS (*markeps: 1*) has negative effects on green cooperation. Therefore, we rejected hypothesis *H3a*. Hypothesis *H3b* was not proved (but also not rejected at a usual level of significance). Moreover, we also showed that increased green innovation (*greeninno*) has negative effects on green cooperation.

From the perspective of the effects of control variables, we showed that higher emissions of nitrogen oxides (*nitrox*) and carbon monoxide (*carbox*) decrease green cooperation, while increased emissions of sulphur oxides (*sulphox*) and particulate matter (*particulate*) have positive effects on green cooperation. The increased gross domestic product per capita (*gdp*) has positive effects on green cooperation.

Table 2
Measures of goodness of fit and estimated parameters of Model (1).

Dependent/Output	*R*-squared	Adjusted *R*-squared	*F*-statistics	*p*-value
qualife	0.564	0.507	9.918	0.000 ***
Independent	**Coeff. Estimate**	**Std. Error**	***t* value**	***p*-value**
Intercept	26.770	7.965	3.361	0.001 **
markeps: 1	3.456	1.806	1.914	0.059.
nomarkeps: 1	−0.085	2.037	−0.042	0.967
greeninno	−169.300	866.000	−0.196	0.845
greencoop	0.274	0.056	4.905	0.000 ***
carbox	−0.121	0.069	−1.750	0.083.
nitrox	1.195	0.155	7.720	0.000 ***
sulphox	−0.228	0.118	−1.930	0.057.
particulate	−5.049	1.083	−4.663	0.000 ***
waste	−0.009	0.012	−0.787	0.433
popdens	−0.042	0.011	−3.776	0.000 ***
forinv	−0.041	0.106	−0.387	0.699
rdexp	−1.431	1.583	−0.904	0.368

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1.

Table 3
Measures of goodness of fit and estimated parameters of Model (2).

Dependent/Output	Rsquared	Adjusted R-squared	*F*-statistics	*p*-value
greeninno	0.862	0.845	52.610	0.000 ***
Independent	**Coeff. Estimate**	**Std. Error**	***t* value**	***p*-value**
Intercept	−2.659e-03	9.130e-04	−2.913	0.004 **
markeps: 1	−7.081e-04	2.034e-04	−3.482	0.000 ***
nomarkeps: 1	6.496e-04	2.345e-04	2.771	0.007 **
greencoop	−2.460e-05	6.191e-06	−3.974	0.000 ***
carbox	3.092e-05	7.604e-06	4.066	0.000 ***
nitrox	1.782e-05	1.845e-05	0.966	0.336
sulphox	−2.578e-05	1.389e-05	−1.855	0.067.
particulate	−3.864e-04	1.233e-04	−3.134	0.002 **
waste	8.625e-06	1.168e-06	7.386	0.000 ***
popdens	4.695e-06	1.252e-06	3.751	0.000 ***
forinv	−3.395e-05	1.222e-05	−2.778	0.007 **
rdexp	7.470e-04	1.729e-04	4.320	0.000 ***

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1.

Table 4
Measures of goodness of fit and estimated parameters of Model (3).

Dependent/Output	*R*-squared	Adjusted *R*-squared	*F*-statistics	*p*-value
greencoop	0.467	0.404	7.415	0.000 ***
Independent	**Coeff. Estimate**	**Std. Error**	***t* value**	***p*-value**
Intercept	−0.202	12.320	−0.016	0.987
markeps: 1	−6.730	2.917	−2.307	0.023 *
nomarkeps: 1	0.001	3.480	0.000	0.998
greeninno	−2303.000	1179.000	−1.954	0.054.
carbox	−0.192	0.098	−1.959	0.053.
nitrox	−0.837	0.332	−2.519	0.013 *
sulphox	0.839	0.242	3.464	0.001 **
particulate	4.983	2.007	2.483	0.015 *
popdens	0.043	0.018	2.363	0.020 *
forinv	0.178	0.184	0.966	0.336
gdp	0.001	0.0002	5.828	0.000 ***
rdexp	−2.252	2.878	−0.782	0.436

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1.

5. Discussion

Going back to the beginning of this study, our motivation was, among others, to answer the following research questions: *(1) Whether and how environmental policy stringency, green innovation and green international cooperation influence the quality of life expressed by the perceived health in OECD countries? (2) How does environmental policy stringency affect green innovation and green international cooperation in OECD countries?* Analysing and discussing our hypotheses allows us to find the necessary answers.

Starting with the first hypothesis, *H1a*, we confirmed that strong market-based EPS, including environmentally related taxes and charges and trading scheme, has positive effects on perceived health. To the best of our knowledge, this is the first study examining such relationship, so there is no empirical support for these findings. Notwithstanding, we can find support for our results in the nexus between the negative impact of the environment on perceived health [61,62], with regard to reducing the risk of immune-mediated diseases [63] and in the context of a higher level of hedonic well-being [64] especially in an urban environment [65] → the need for action by environmental policymakers [2,66,67] → the positive effects of environmental taxes on the environment [68,69] also in the context of stimulating technological innovations that are related to the environment [70,71]. In contrast, we did not prove hypothesis *H1b* expecting the positive effects of command and control regulations and technical support policies, representing strong non-market-based EPS, on the perceived health. To our knowledge, no one has yet tested this hypothesis and this is the first study testing these relationships.

Considering hypotheses *H2a* and *H2b*, the findings are not consistent [18,19], similar to prior research providing mixed results on the effects of EPS on green innovation. However, the division of EPS into its two components has allowed us to get a better picture of the impact of market-based and non-market-based EPS on green innovation in OECD countries (see also [72]). On the one hand, we rejected hypothesis *H2a*, which stated that strong market-based EPS has positive effects on green innovation. These results run counter to the findings of [70], which confirmed the positive effects of environmental taxes on environmentally relevant technological innovations in 42 high- and middle-income countries, these results also confirm [66]. However, we have tested the effects of the strictness of environmental regulations, thereby proving that green innovation does not require as much strictness (above average) in the area of market-based regulations. On the other hand, above-average non-market-based EPS seems to be vital for green innovations. Acceptance of hypothesis *H2b* that strong non-market-based EPS has positive effects on green innovation is basically in line with the findings of [39,40] pointing out the importance of environmental regulations. In contrast, we reject the findings of [73], which state that command-and-control regulation harms green innovation efficiency in the short term.

Compared to the limited prior research on the relationship between EPS and green (international) cooperation, providing rather mixed results [44], the results related to hypotheses *H3a* and *H3b* are consistent but surprising: we did not confirm the positive impact of market-based and non-market-based EPS on green international cooperation. More specifically, we rejected hypothesis *H3a* that strong market-based EPS has positive effects on green international cooperation. This fact is despite the ambitions to support green cooperation [35,72,74,75] and these results go against the findings of [24] that identified a positive link between stricter environmental regulations and countries' involvement in green technology cooperation as well as the findings of [43], which showed that a country's more stringent market-based EPS could lead to an increase in firms' sourcing of international knowledge. Referring to hypothesis *H3b*, which expected that strong non-market-based EPS has positive effects on green international cooperation, we did not prove the hypothesis (but we also did not reject *H3b* at a statistically significant level of significance).

Concerning hypotheses *H4a* and *H4b* considering the effects of green innovation and green international cooperation on perceived health, we accepted hypothesis *H4b* that green international cooperation has positive effects on perceived health. In this case, as with the effects of EPS on perceived health, there is a lack of empirical support for our results. Therefore, we refer to studies that confirmed the positive effects of green (international) cooperation on sustainable development in general [35,46,54,76,77], whereas we assume that the improved environment, thanks to increased green international cooperation, will subsequently be reflected in the perceived health in society [78,79]. These results also represent an interesting cornerstone of future research. Concerning hypothesis *H4a*—that green innovation has positive effects on perceived health—our data did not support it, but we also did not reject it at a statistically significant level of significance. Despite no current study has yet investigated this hypothesis, we can find fragments of prior studies dealing with such topic. For example, [13] strongly recommend allocation of funds to stimulate green innovations to support public health.

6. Conclusions, contributions, and implications

This paper highlighted several important results. More specifically, we confirmed hypotheses that strong market-based EPS and green international cooperation have positive effects on perceived health. Surprisingly, contrary to the findings of prior research, we did not confirm the positive effects of market-based and non-market-based EPS on green international cooperation. We also showed that green innovation does not require as much strictness (above average) in the area of market-based regulations. Moreover, we can say that this is one of the first studies testing effects of command and control regulations and technical support policies, representing strong non-market-based EPS, on the perceived health, which we use as a proxy for a quality of life. The same can be applied to the relationship between green innovation and perceived health.

Our findings therefore brought several contributions to the existing literature. First, we provided new empirical evidence of the Porter hypothesis, whereas we tested the effects of different forms of environmental regulations on perceived health, green innovation, and green international cooperation in the sample of OECD countries. Moreover, we brought to the discussion the effects of market-based and non-market-based EPS, representing the missing element complementing "traditional" innovation determinants (technology push and demand-pull factors), on green innovation. It allowed us to contribute to the current research providing rather mixed results under the conditions of the environmental innovation theory. In doing so, our effort led to another contribution, which could be seen in the field of research dealing with technological collaborations in green technological development. More specifically, we focused on (i) green international cooperation as a determinant of perceived health and green innovation and (ii) determinants of green international cooperation. Finally, yet importantly, as this is the first study empirically examining the impact of green innovation and green international cooperation on perceived health in OECD countries, it can be considered the starting point for future research in individual countries.

From the perspective of practical contributions, we offer several implications for policymakers. Based on our results, to contribute to a higher level of perceived health and to deal with a degraded environment in general, policymakers in OECD countries should focus on market-based environmental regulations (e.g., environmental pricing through taxation) and on green international cooperation. Here, we refer to Ref. [80], who state that "*properly defined tax base coupled with acceptable and easy-to-calculate tax rate with preferential tax measures as encouragement under modern collection and administration framework among ministries is desirable in the development of environmental taxation*". The authors also provide an interesting instruction on how to establish environmental taxation systems in accordance with different national conditions.

Next, we postulate that it is essential to focus on promoting green growth that may, together with green innovation, shift the industrial structure from non-renewable to renewable sources [69]. To do so, the countries could also standardize the green and clean production requirements, formulate regulations to adopt green technologies, and introduce industry-level policies to provide incentives and subsidies on the adoption of environmentally friendly technologies that could subsequently trigger sector-wise (green) innovations [66]. Moreover, by clearly setting the environmental regulations that this article analyses, it is possible to steer the economy towards a low-carbon economy with high social standards, which is one of the overriding goals of sustainable development. In this context, it is necessary to focus on values other than GDP, such as a clean environment and mental and physical health, while emphasizing international cooperation in achieving these goals. In addition, it is necessary to redefine the breadth of the benefits of reducing environmental pollution, as recommended, for example, by Ref. [81]. Strict measures only make sense in cases involving significant social, environmental, and economic benefits, which should be significantly higher than society's costs.

To trigger green innovation and green international cooperation, as [82] conclude, policymakers should "*consider the interactions or complementarities between command and control regulation and market-based regulation and their joint effects*" on both green innovation and green (international) cooperation. More specifically, "*they should not only strengthen the utilization of command and control instruments such as emissions standards and fines but also accelerate incentive-based approaches such as green taxation to efficiently induce green innovation*". In addition, green international cooperation should take place between partners who are geographically closer and have greater social similarity, and policymakers can encourage cross-border collaboration between firms and institutions [24].

By contrast, despite those recommendations and efforts, we can say that there is still a lack of greater and more comprehensive coherence among the various agents in Europe regarding the perception of environmental problems, resulting in inequalities across EU member states as well as regions. Moreover, referring to Ref. [83], we can say that "*progress towards sustainable production and consumption patterns is too slow, and that high-income countries generate significant environmental, economic, and security spillover effects that undermine other countries' efforts to achieve the SDGs*". Therefore, considering the recommendations enshrined in European Commission documents (e.g., the Reflection paper: Towards a Sustainable Europe by 2030), regions, communities, businesses, and civil society must act in their diversity to work together to implement the SDGs and reduce inequalities across Europe. To achieve these goals, it seems crucial to support the emergence of cross-agent (innovation) cooperation (e.g., based on the principles of triple, quadruple, or quintuple helix cooperation, see Ref. [84] and (green) partnerships, which could help drive transformations in the environment, society, and the economy, especially as called from by the European Green Deal [85]. However, as shown in our study, it is necessary to clarify what specific goals we are pursuing, because environmental policies affect the quality of life, green international cooperation, and green innovation to a different extent.

Referring to Ref. [86], there is also a need to formulate policies for the syndication of countries' economic and financial instruments with environmental and technological incentives to promote international cooperation to achieve sustainable development. Moreover, we see the need for public policy makers to focus on urban development, which is seen to be essential to meet the SDGs, approved by the 193 UN Member States in 2015. In line with [87], to increase quality of life, we also recommend investments in green public spaces, improving urban planning and management in participatory and inclusive ways, or creating business opportunities.

We are also aware that this study has limitations. For example, not all green innovations or inventions are patented simultaneously [88]; therefore, it is not possible to fully describe the entire reality in OECD countries. Next, we use only one indicator that captures the quality of life. In contrast, our results bring a new perspective on the relationship among EPS, green innovation, green cooperation, and perceived health, thereby creating a stimulus for future research that could focus on single countries or on the effects that occur at the regional level. The investigated time period can also be perceived as a limitation of this study, therefore we recommend for future research the verification of our results using newer, more available data, even for a smaller number of countries, for example. Moreover, considering the negative effects of our controls (various factors expressing environmental pollution and increased population density) on perceived health and the mixed results for the effects of environmental pollution factors on green innovation and green international cooperation, future research could follow this path. In additional, we recommend additional analyses focused on firms, or a combination of macro and micro analyses including country and firm analysis. From the firm perspective, we see the area of the influence of human resources and managerial characteristics as an interesting line of future research. Therefore, in line with [17] and, for example with theories of (natural) resource-based view, gender socialization or board gender diversity, we recommend analysing the role of human capital resources (e.g., gender, age, skills, knowledge, training, or relationships/creation of social capital) in increasing firms' green behaviour.

Author contribution statement

David Zapletal, Yee Yee Sein, Viktor Prokop: Conceived and designed experiments; Performed the experiments; Analyzed and interpreted the data; Collected and conducted the analysis data; Wrote the paper.

Viktor Prokop, Wolfgang Gerstlberger, Pavla Vrabcová, David Zapletal, Yee Yee Sein: Conceived and designed experiments; Performed the experiments; Analyzed and interpreted the data; Collected and conducted the analysis data; Wrote the paper.

Data availability statement

Data are available online.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are grateful for the financial support of the Technical University of Liberec.

References

[1] B.M. Campbell, J. Hansen, J. Rioux, C.M. Stirling, S. Twomlow, Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems, Curr. Opin. Environ. Sustain. 34 (2018) 13–20.
[2] J. Hojnik, V. Prokop, J. Stejskal, R&D as bridge to sustainable development? Case of Czech Republic and Slovenia, Corp. Soc. Responsib. Environ. Manag. 29 (1) (2022) 146–160, https://doi.org/10.1002/csr.2190.
[3] D. Šulyová, M. Kubina, Creating smart, sustainable cities: results from best practice smart cities and cities in Slovakia, Scient. Pap. Univer. Pard. Seri. D. Fac. Econ. Admin. 30 (3) (2022) 1606, https://doi.org/10.46585/sp30031606.
[4] G.T. Pecl, M.B. Araújo, J.D. Bell, J. Blanchard, T.C. Bonebrake, I.C. Chen, S.E. Williams, Biodiversity redistribution under climate change: impacts on ecosystems and human well-being, Science 355 (6332) (2017), https://doi.org/10.1126/science.aai9214.
[5] J. Lawrence, P. Blackett, N.A. Cradock-Henry, Cascading climate change impacts and implications, Clim. Risk Manag. 29 (2020), 100234, https://doi.org/10.1016/j.crm.2020.100234.
[6] M.R. Sisco, V. Bosetti, E.U. Weber, When do extreme weather events generate attention to climate change? Climatic Change 143 (1) (2017) 227–241, https://doi.org/10.1007/s10584-017-1984-2.
[7] G. Hilly, Z. Vojinovic, S. Weesakul, A. Sanchez, D.N. Hoang, S. Djordjevic, B. Evans, Methodological framework for analysing cascading effects from flood events: the case of sukhumvit area, bangkok, Thailand, Water 10 (1) (2018) 81, https://doi.org/10.3390/w10010081.
[8] S. Zhang, D. Zhu, Have countries moved towards sustainable development or not? Definition, criteria, indicators and empirical analysis, J. Clean. Prod. (2020), 121929, https://doi.org/10.1016/j.jclepro.2020.121929.
[9] R. Korsakienė, A.G. Raišienė, Sustainability drivers of small and medium sized firms: a review and research agenda, Scient. Pap. Univer. Pard. Seri. D. Fac. Econ. Admin. 30 (1) (2022) 1380, https://doi.org/10.46585/sp30011380.
[10] N. Gunningham, D. Sinclair, Leaders & Laggards: Next-Generation Environmental Regulation, Routledge, 2017, https://doi.org/10.4324/9781351282000.
[11] M. Galeotti, S. Salini, E. Verdolini, Measuring environmental policy stringency: approaches, validity, and impact on environmental innovation and energy efficiency, Energy Pol. 136 (2020), 111052, https://doi.org/10.1016/j.enpol.2019.111052.
[12] S. Milani, The impact of environmental policy stringency on industrial R&D conditional on pollution intensity and relocation costs, Environ. Resour. Econ. 68 (3) (2017) 595–620, https://doi.org/10.1007/s10640-016-0034-2.
[13] M. Ahmad, J. Zheng, Do innovation in environmental-related technologies cyclically and asymmetrically affect environmental sustainability in BRICS nations? Technol. Soc. 67 (2021), 101746 https://doi.org/10.1016/j.techsoc.2021.101746.
[14] S. Shao, Z. Hu, J. Cao, L. Yang, D. Guan, Environmental regulation and enterprise innovation: a review, Bus. Strat. Environ. 29 (3) (2020) 1465–1478, https://doi.org/10.1002/bse.2446.
[15] K.S. Herman, J. Xiang, Induced innovation in clean energy technologies from foreign environmental policy stringency? Technol. Forecast. Soc. Change 147 (2019) 198–207, https://doi.org/10.1016/j.techfore.2019.07.006.
[16] M.E. Porter, C. Van der Linde, Toward a new conception of the environment-competitiveness relationship, J. Econ. Perspect. 9 (4) (1995) 97–118.
[17] J. Horbach, V. Prokop, J. Stejskal, Determinants of Firms' Greenness towards Sustainable Development: A Multi-Country Analysis, Business Strategy and the Environment, 2022, pp. 1–14, https://doi.org/10.1002/bse.3275.
[18] M. Hassan, D. Rousselière, Does increasing environmental policy stringency lead to accelerated environmental innovation? A research note, Appl. Econ. (2021) 1–10, https://doi.org/10.1080/00036846.2021.1983146.
[19] R. De Santis, C.J. Lasinio, Environmental policies, innovation and productivity in the EU, Global Econ. J. 16 (4) (2016) 615–635, https://doi.org/10.1515/gej-2015-0060.
[20] B.L. Cohen, S. Noone, A. Muñoz-Furlong, S.H. Sicherer, Development of a questionnaire to measure quality of life in families with a child with food allergy, J. Allergy Clin. Immunol. 114 (5) (2004) 1159–1163, https://doi.org/10.1016/j.jaci.2004.08.007.
[21] U. Jakobsson, Using the 12-item Short Form health survey (SF-12) to measure quality of life among older people, Aging Clin. Exp. Res. 19 (6) (2007) 457–464, https://doi.org/10.1007/BF03324731.
[22] E. Colucci, S. Nadeau, J. Higgins, E. Kehayia, T. Poldma, A. Saj, E. De Guise, COVID-19 lockdowns' effects on the quality of life, perceived health and well-being of healthy elderly individuals: a longitudinal comparison of pre-lockdown and lockdown states of well-being, Arch. Gerontol. Geriatr. 99 (2022), 104606.
[23] S. Giusiano, L. Peotta, B. Iazzolino, E. Mastro, M. Arcari, F. Palumbo, R. Vasta, Amyotrophic lateral sclerosis caregiver burden and patients' quality of life during COVID-19 pandemic, Amyotroph. Later. Scler. Fron. Degener 23 (1–2) (2022) 146–148.
[24] Y. Li, Y. Zhang, C.C. Lee, J. Li, Structural characteristics and determinants of an international green technological collaboration network, J. Clean. Prod. 324 (2021), 129258, https://doi.org/10.1016/j.jclepro.2021.129258.
[25] G. Hu, X. Wang, Y. Wang, Can the green credit policy stimulate green innovation in heavily polluting enterprises? Evidence from a quasi-natural experiment in China, Energy Econ. 98 (2021), 105134.
[26] J. Horbach, Empirical determinants of eco-innovation in European countries using the community innovation survey, Environ. Innov. Soc. Transit. 19 (2016) 1–14, https://doi.org/10.1016/j.eist.2015.09.005.
[27] V. Prokop, W. Gerstlberger, D. Zapletal, M.K. Striteska, The double-edged role of firm environmental behaviour in the creation of product innovation in Central and Eastern European countries, J. Clean. Prod. 331 (2022), 129989, https://doi.org/10.1016/j.jclepro.2021.129989.
[28] K. Ahmed, Environmental policy stringency, related technological change and emissions inventory in 20 OECD countries, J. Environ. Manag. 274 (2020), 111209, https://doi.org/10.1016/j.jenvman.2020.111209.
[29] P. Vrabcová, H. Urbancová, Approaches of selected organisations in the Czech Republic to promoting the concept of sustainable development and corporate social responsibility, Agric. Econ. 67 (7) (2021) 255–265, https://doi.org/10.17221/8/2021-AGRICECON.
[30] I. Martínez-Zarzoso, A. Bengochea-Morancho, R. Morales-Lage, Does environmental policy stringency foster innovation and productivity in OECD countries? Energy Pol. 134 (2019), 110982 https://doi.org/10.1016/j.enpol.2019.110982.
[31] I.S.A. Baud, S. Grafakos, M. Hordijk, J. Post, Quality of life and alliances in solid waste management: contributions to urban sustainable development, Cities 18 (1) (2001) 3–12, https://doi.org/10.1016/S0264-2751(00)00049-4.
[32] A. Hedlund-de Witt, Rethinking sustainable development: considering how different worldviews envision "development" and "quality of life", Sustainability 6 (11) (2014) 8310–8328, https://doi.org/10.3390/su6118310.
[33] J.C.F. De Guimarães, E.A. Severo, L.A.F. Júnior, W.P.L.B. Da Costa, F.T. Salmoria, Governance and quality of life in smart cities: towards sustainable development goals, J. Clean. Prod. 253 (2020), 119926, https://doi.org/10.1016/j.jclepro.2019.119926.
[34] A. Dechezleprêtre, E. Neumayer, R. Perkins, Environmental regulation and the cross-border diffusion of new technology: evidence from automobile patents, Res. Pol. 44 (1) (2015) 244–257, https://doi.org/10.1016/j.respol.2014.07.017.
[35] N. Corrocher, M.L. Mancusi, International collaborations in green energy technologies: what is the role of distance in environmental policy stringency? Energy Pol. 156 (2021), 112470 https://doi.org/10.1016/j.enpol.2021.112470.
[36] I. Beretta, The social effects of eco-innovations in Italian smart cities, Cities 72 (2018) 115–121, https://doi.org/10.1016/j.cities.2017.07.010.
[37] J. Horbach, Determinants of environmental innovation—new evidence from German panel data sources, Res. Pol. 37 (1) (2008) 163–173, https://doi.org/10.1016/j.respol.2007.08.006.
[38] X. Wang, T. Zhang, J. Nathwani, F. Yang, Q. Shao, Environmental regulation, technology innovation, and low carbon development: revisiting the EKC Hypothesis, Porter Hypothesis, and Jevons' Paradox in China's iron & steel industry, Technol. Forecast. Soc. Change 176 (2022), 121471.
[39] N. Johnstone, I. Haščič, J. Poirier, M. Hemar, C. Michel, Environmental policy stringency and technological innovation: evidence from survey data and patent counts, Appl. Econ. 44 (17) (2012) 2157–2170, https://doi.org/10.1080/00036846.2011.560110.
[40] R. Ramanathan, Q. He, A. Black, A. Ghobadian, D. Gallear, Environmental regulations, innovation and firm performance: a revisit of the Porter hypothesis, J. Clean. Prod. 155 (2017) 79–92, https://doi.org/10.1016/j.jclepro.2016.08.116.

[41] A. Dechezleprêtre, M. Sato, The impacts of environmental regulations on competitiveness, Rev. Environ. Econ. Pol. 11 (2) (2017) 183–206, https://doi.org/10.1093/reep/rex013.
[42] C. You, S.I. Khattak, M. Ahmad, Do international collaborations in environmental-related technology development in the US pay off in combating carbon dioxide emissions? Role of domestic environmental innovation, renewable energy consumption, and trade openness, Environ. Sci. Pollut. Control Ser. (2021) 1–21, https://doi.org/10.1007/s11356-021-17146-6.
[43] G. Choi, S.H. Cho, Effect of market versus nonmarket environmental policy stringency on knowledge sourcing behavior for green technology: evidence from OECD countries, Rev. Int. Bus. Strategy (2021), https://doi.org/10.1108/RIBS-09-2020-0113 ahead-of-print No. ahead-of-print.
[44] F. Fusillo, F. Quatraro, S. Usai, Going green: the dynamics of green technological alliances, Econ. Innovat. N. Technol. (2020) 1–25, https://doi.org/10.1080/10438599.2020.1799143.
[45] N. Soewarno, B. Tjahjadi, F. Fithrianti, Green innovation strategy and green innovation: the roles of green organizational identity and environmental organizational legitimacy, Manag. Decis. 57 (11) (2019) 3061–3078, https://doi.org/10.1108/MD-05-2018-0563.
[46] E. Niesten, A. Jolink, A.B.L. de Sousa Jabbour, M. Chappin, R. Lozano, Sustainable collaboration: the impact of governance and institutions on sustainable performance, J. Clean. Prod. 155 (2017) 1–6, https://doi.org/10.1016/j.jclepro.2016.12.085.
[47] L. Aldieri, B. Bruno, C.P. Vinci, Does environmental innovation make us happy? An empirical investigation, Soc. Econ. Plann. Sci. 67 (2019) 166–172, https://doi.org/10.1016/j.seps.2018.10.008.
[48] M. Gustafson, D. Gounopoulos, T. Nguyen, Warming Temperature and the Role of Environmental Policy in Protecting the US Quality of Life, 2021. Available at: SSRN 3956921.
[49] M.A. Galindo-Martín, M.S. Castaño-Martínez, M.T. Méndez-Picazo, The relationship between green innovation, social entrepreneurship, and sustainable development, Sustainability 12 (11) (2020) 4467, https://doi.org/10.3390/su12114467.
[50] D.T. Rübbelke, International support of climate change policies in developing countries: strategic, moral and fairness aspects, Ecol. Econ. 70 (8) (2011) 1470–1480, https://doi.org/10.1016/j.ecolecon.2011.03.007.
[51] A. Bostrom, R.E. O'Connor, G. Böhm, D. Hanss, O. Bodi, F. Ekström, I. Sælensminde, Causal thinking and support for climate change policies: international survey findings, Global Environ. Change 22 (1) (2012) 210–222, https://doi.org/10.1016/j.gloenvcha.2011.09.012.
[52] C. Peñasco, P. del Río, D. Romero-Jordán, Analysing the role of international drivers for eco-innovators, J. Int. Manag. 23 (1) (2017) 56–71.
[53] J. Hojnik, M. Ruzzier, T.S. Manolova, Internationalization and economic performance: the mediating role of eco-innovation, J. Clean. Prod. 171 (2018) 1312–1323.
[54] Y. Wolde-Rufael, E.M. Weldemeskel, Do environmental taxes and environmental stringency policies reduce CO2 emissions? Evidence from 7 emerging economies, Environ. Sci. Pollut. Control Ser. 28 (18) (2021) 22392–22408, https://doi.org/10.1007/s11356-020-11475-8.
[55] R. Puertas, L. Marti, J.M. Guaita-Martinez, Innovation, lifestyle, policy and socioeconomic factors: an analysis of European quality of life, Technol. Forecast. Soc. Change 160 (2020), 120209, https://doi.org/10.1016/j.techfore.2020.120209.
[56] V. Prokop, P. Hajek, J. Stejskal, Configuration paths to efficient national innovation ecosystems, Technol. Forecast. Soc. Change 168 (2021), 120787, https://doi.org/10.1016/j.techfore.2021.120787.
[57] I. Hanif, S.M.F. Raza, P. Gago-de-Santos, Q. Abbas, Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence, Energy 171 (2019) 493–501, https://doi.org/10.1016/j.energy.2019.01.011.
[58] Q. Wang, J. Qu, B. Wang, P. Wang, T. Yang, Green technology innovation development in China in 1990–2015, Sci. Total Environ. 696 (2019), 134008, https://doi.org/10.1016/j.scitotenv.2019.134008.
[59] Y. Liu, C. Gao, Y. Lu, The impact of urbanization on GHG emissions in China: the role of population density, J. Clean. Prod. 157 (2017) 299–309, https://doi.org/10.1016/j.jclepro.2017.04.138.
[60] J.O. Rawlings, S.G. Pantula, D.A. Dickey, Applied Regression Analysis: A Research Tool, second ed., Springer, 1998.
[61] T. Egondi, C. Kyobutungi, N. Ng, K. Muindi, S. Oti, S.V.D. Vijver, J. Rocklöv, Community perceptions of air pollution and related health risks in Nairobi slums, Int. J. Environ. Res. Publ. Health 10 (10) (2013) 4851–4868, https://doi.org/10.3390/ijerph10104851.
[62] M. Van den Bosch, Å.O. Sang, Urban natural environments as nature-based solutions for improved public health–A systematic review of reviews, Environ. Res. 158 (2017) 373–384, https://doi.org/10.1016/j.envres.2017.05.040.
[63] M.I. Roslund, R. Puhakka, M. Grönroos, N. Nurminen, S. Oikarinen, A.M. Gazali, ADELE Research Group, Biodiversity intervention enhances immune regulation and health-associated commensal microbiota among daycare children, Sci. Adv. 6 (42) (2020), eaba2578, https://doi.org/10.1126/sciadv.aba2578.
[64] A. Pritchard, M. Richardson, D. Sheffield, K. McEwan, The relationship between nature connectedness and eudaimonic well-being: a meta-analysis, J. Happiness Stud. 21 (2020) 1145–1167, https://doi.org/10.1007/s10902-019-00118-6.
[65] R.W. Cameron, P. Brindley, M. Mears, K. McEwan, F. Ferguson, D. Sheffield, M. Richardson, Where the wild things are! Do urban green spaces with greater avian biodiversity promote more positive emotions in humans? Urban Ecosyst. 23 (2020) 301–317, https://doi.org/10.1007/s11252-020-00929-z.
[66] U. Shahzad, Environmental taxes, energy consumption, and environmental quality: theoretical survey with policy implications, Environ. Sci. Pollut. Control Ser. 27 (20) (2020) 24848–24862, https://doi.org/10.1007/s11356-020-08349-4.
[67] Q. Yirong, Does environmental policy stringency reduce CO2 emissions? Evidence from high-polluted economies, J. Clean. Prod. 341 (2022), 130648, https://doi.org/10.1016/j.jclepro.2022.130648.
[68] D.M. McEvoy, M. McGinty, Negotiating a uniform emissions tax in international environmental agreements, J. Environ. Econ. Manag. 90 (2018) 217–231, https://doi.org/10.1016/j.jeem.2018.06.001.
[69] L.N. Hao, M. Umar, Z. Khan, W. Ali, Green growth and low carbon emission in G7 countries: how critical the network of environmental taxes, renewable energy and human capital is? Sci. Total Environ. 752 (2021), 141853 https://doi.org/10.1016/j.scitotenv.2020.141853.
[70] S.C. Karmaker, S. Hosan, A.J. Chapman, B.B. Saha, The role of environmental taxes on technological innovation, Energy 232 (2021), 121052, https://doi.org/10.1016/j.energy.2021.121052.
[71] S. Li, A. Samour, M. Irfan, M. Ali, Role of renewable energy and fiscal policy on trade adjusted carbon emissions: evaluating the role of environmental policy stringency, Renew. Energy 196 (2023) 1376–1384, https://doi.org/10.1016/j.renene.2022.07.084.
[72] T. Kruse, A. Dechezleprêtre, R. Saffar, L. Robert, Measuring Environmental Policy Stringency in OECD Countries: an Update of the OECD Composite EPS Indicator, OECD Publishing, Paris, 2022, p. 1703, https://doi.org/10.1787/18151973.
[73] M. Tang, X. Li, Y. Zhang, Y. Wu, B. Wu, From command-and-control to market-based environmental policies: optimal transition timing and China's heterogeneous environmental effectiveness, Econ. Modell. 90 (2020) 1–10, https://doi.org/10.1016/j.scitotenv.2019.136362.
[74] K. Ahmed, S. Ahmed, A predictive analysis of CO2 emissions, environmental policy stringency, and economic growth in China, Environ. Sci. Pollut. Control Ser. 25 (16) (2018) 16091–16100, https://doi.org/10.1007/s11356-018-1849-x.
[75] E.M. De Angelis, M. Di Giacomo, D. Vannoni, Climate change and economic growth: the role of environmental policy stringency, Sustainability 11 (8) (2019) 2273, https://doi.org/10.3390/su11082273.
[76] J.D. Sachs, G. Schmidt-Traub, M. Mazzucato, D. Messner, N. Nakicenovic, J. Rockström, Six transformations to achieve the sustainable development goals, Nat. Sustain. 2 (9) (2019) 805–814, https://doi.org/10.1038/s41893-019-0352-9.
[77] C. Cuiyun, G. Chazhong, Green development assessment for countries along the belt and road, J. Environ. Manag. 263 (2020), 110344, https://doi.org/10.1016/j.jenvman.2020.110344.
[78] J. Zhang, Z. Yu, B. Zhao, R. Sun, H. Vejre, Links between green space and public health: a bibliometric review of global research trends and future prospects from 1901 to 2019, Environ. Res. Lett. 15 (6) (2020), 063001, https://doi.org/10.1088/1748-9326/ab7f64.
[79] S. Sarwar, D. Streimikiene, R. Waheed, Z. Mighri, Revisiting the empirical relationship among the main targets of sustainable development: growth, education, health and carbon emissions, Sustain. Dev. 29 (2) (2021) 419–440, https://doi.org/10.1002/sd.2156.
[80] Z. Tan, Y. Wu, Y. Gu, T. Liu, W. Wang, X. Liu, An overview on implementation of environmental tax and related economic instruments in typical countries, J. Clean. Prod. 330 (2022), 129688, https://doi.org/10.1016/j.jclepro.2021.129688.

[81] A. Farmer, J.R. Kahn, J.A. McDonald, R. O'Neill, Rethinking the optimal level of environmental quality: justifications for strict environmental policy, Ecol. Econ. 36 (3) (2001) 461–473, https://doi.org/10.1016/S0921-8009(00)00244-5.
[82] J. Zhang, G. Liang, T. Feng, C. Yuan, W. Jiang, Green innovation to respond to environmental regulation: how external knowledge adoption and green absorptive capacity matter? Bus. Strat. Environ. 29 (1) (2020) 39–53, https://doi.org/10.1002/bse.2349.
[83] P.P. Walsh, E. Murphy, D. Horan, The role of science, technology and innovation in the UN 2030 agenda, Technol. Forecast. Soc. Change 154 (2020), 119957.
[84] E.G. Carayannis, D.F. Campbell, E. Grigoroudis, Helix trilogy: the triple, quadruple, and quintuple innovation helices from a theory, policy, and practice set of perspectives, J. Knowled. Econ. 13 (3) (2022) 2272–2301.
[85] European Commission, A European Green Deal, Available online:, 2021 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. (Accessed 26 February 2023). accessed on.
[86] S. Afshan, I. Ozturk, T. Yaqoob, Facilitating renewable energy transition, ecological innovations and stringent environmental policies to improve ecological sustainability: evidence from MM-QR method, Renew. Energy 196 (2022) 151–160, https://doi.org/10.1016/j.renene.2022.06.125.
[87] N. Tura, V. Ojanen, Sustainability-oriented Innovations in Smart Cities: A Systematic Review and Emerging Themes, 2022, 103716, https://doi.org/10.1016/j.cities.2022.103716. Cities.
[88] I. Haščič, M. Migotto, Measuring environmental innovation using patent data, in: OECD Environment Working Papers, 89, 2015, p. 59.