Environmental Science and Pollution Research (2021) 28:63751–63768
https://doi.org/10.1007/s11356-020-11379-7

RESEARCH IN ENVIRONMENTAL PLANNING AND MANAGEMENT

Green innovation and environmental regulations: a systematic review of international academic works

Jaluza Maria Lima Silva Borsatto[1] · Camila Lima Bazani[2]

Received: 7 July 2020 / Accepted: 21 October 2020 / Published online: 3 November 2020

Abstract

The relationship between green innovation and environmental regulations has received increasing attention from researchers, gaining prominence both in academia and in organizations. Thus, this study aims to present a summary of the most relevant academic researches that relate the environmental regulations and green innovation, knowing in a standardized way the scientific information of this field of study. Through a systematic literature review, 96 academic papers published in the journals of Science Direct, Scopus, and Web of Science databases, between 2011 and 2019, were analyzed. The results showed that environmental regulations are among the main factors that induce companies to green innovation, given that most of the articles analyzed have a positive relationship. However, as there are still contradictions in the literature, new studies are emerging addressing this relationship with other organizational aspects, and considering the different mechanisms of environmental regulations to try to explain how and under what conditions these policies affect green innovation in companies. These findings can contribute to the researchers for the formation of a solid conceptual base on the subject, guiding for future research.

Keywords Green innovation · Environmental regulations · Literature review · International papers

Introduction

Environmental issues currently have considerable attention on the part of organizations as a result of the intensification of commercial flows since several aspects propel them into a competitive context that requires rapid innovation. For Lustosa (2003), the preservation of the environment can be considered a distinguishing factor in relation to the competition, becoming, therefore, a challenge to organizations. Dangelico and Pujari (2010) assure that green innovation is a factor to simultaneously improve three aspects of companies, namely, environmental, social, and financial performance. However, the current literature shows that the benefits arising from the adoption of green innovation by companies can still be considered by some scholars as inconclusive or even contradictory (Bernauer et al. 2007; Gauthier and Wooldridge 2012).

Many factors lead organizations to adopt sustainable practices, and one of them is environmental regulation (Lustosa 2002). Environmental policies are inserted in this context as a way of defining rules and incentives to be used by countries in order to shape the path of technological development (Jaffe et al. 2005). In addition, the type and purpose of environmental regulations drive companies' efforts in green innovation differently and also promote different effects on their performance (Rennings and Rammer 2011), and can offset the cost of compliance generated by environmental investments (Yuan and Xiang 2018).

According to Lustosa (2002), environmental regulation is capable of influencing the development of environmental innovations. For Arenhardt et al. (2012), environmental legislation is a fundamental factor in the decision of organizations regarding the adoption of innovative practices. Aguilera-Caracuel and Ortiz-de-Mandojana (2013) ensure that green innovative companies are in contexts characterized by stricter environmental standards and higher regulatory standards. For Van Leeuwen and Mohnen (2017), the use of environmental taxes seems to be an important element in the decision-making

Responsible Editor: Philippe Garrigues

✉ Jaluza Maria Lima Silva Borsatto
jaluza.silva@ufu.br

[1] FAGEN/UFU School of Management and Business of the Federal University of Uberlandia, Uberlândia, Minas Gerais, Brazil

[2] IERIUFU Institute of Economics and International Relations of the Federal University of Uberlandia, Uberlândia, Minas Gerais, Brazil

of companies to invest in green R&D and the introduction of eco-innovations. In the same direction, Rubashkina et al. (2015) found that there is a positive impact of environmental regulation on innovation. On the other hand, other studies demonstrate a negative association between the strictness of environmental regulations and green innovation (Borghesi et al. 2015; Lanoie et al. 2011). Bernauer et al. (2007) stated that the effects of environmental regulation on innovation are still considered inconclusive and contested.

In addition to studies addressing the direct relationship between environmental regulations and green innovation, another stream of research exploring different regulatory mechanisms, such as command and control regulations and market-based regulations, is being developed to identify how and under what conditions they affect green innovation (Zhao et al. 2015; Schilke 2018; Zhang et al. 2019). Another aspect addressed in the literature refers to the mediating role of both green innovation and environmental regulations in relation to other organizational factors that affect green industrial development (Feng and Chen 2018).

It should be noted that in addition to the normative character, environmental regulation also has an informative aspect, reflecting the need for environmental protection and signaling the demands to polluters and suppliers of environmental technologies (Lustosa 2002).

In this context, considering that green innovation is a type of innovation that promotes economic development and reduces adverse effects on the environment (Polzin et al. 2016), and knowing that environmental regulations are one of the main factors that induce companies to these innovations, the present study aims to present a summary of the most relevant academic researches that relate environmental regulations and green innovation, knowing in a standardized way the scientific information of this field of study.

Although there is a growing number of researches addressing this relationship, the literature still presents inconsistencies that can be clarified through a mapping gathering information that helps both researchers in the direction of future research, as well as managers in their decision-making process.

In addition, forming an adequate understanding of relevant issues in the current context, such as environmental regulations and green innovation, helps to identify trends for the development of new studies that more efficiently promote the green growth of companies.

Research method

To identify trends and patterns in scientific production related to green innovation and environmental regulations, a systematic literature review was carried out. According to Petticrew and Roberts (2006), a systematic literature review is a technique to deal with a greater amount of information and answer questions about what works and what does not, from a practical point of view. In addition, it aims to identify, evaluate, and synthesize relevant studies in order to answer a particular question.

For Tranfield et al. (2003), the systematic review must adopt a rigorous scientific process of bibliographic research and evaluation methods, so that the search process can be easily understood and replicable. It is also noteworthy that a systematic review can be valuable since the absence of data can be highlighted, and, thus, it is possible to identify gaps and future research efforts (Petticrew and Roberts 2006; Morandi and Camargo 2015).

In this review, you can see how the integration of these themes works and what scholars have found about the relationship between green innovation and environmental regulations.

The bibliographic survey on the topic was developed based on secondary data through a systematic review, where the studies were identified using the following procedures:

(1) Iterative search for scientific articles related to green innovation and environmental regulations carried out in the Science Direct, Scopus, and Web of Science databases, limited to the period from 2011 to 2019. To obtain the data, the articles were filtered by the keywords "Green innovation and Environment regulation" and "Eco-innovation and Environment regulation." Only articles were included in the selection, and the words searched should be in titles and abstracts. Some articles, although not showing a possible relationship between green innovation and environmental regulations, were selected because they presented content relevant to the theme and that could contribute to the discussion of this research.

(2) Categorization of the character and content of these studies, presenting the general characteristics of the articles (Table 1).

(3) Qualitative analysis of the content of the articles obtained, identifying the main contributions of the studies at the interface between green innovation and environmental regulation, which is the focus of this study.

After completing this step, it resulted in 79 articles that will be analyzed in the next section.

Environmental regulations and green innovation

In recent decades, governments have been concerned with the relationship between economic growth and environmental issues. This concern stems mainly from the scarcity of resources and the degradation of the environment, which causes socioeconomic problems worldwide. In order to face these problems, governments began to define rules and incentives, also called environmental regulations, which are used by several countries. Cleff and Rennings (1999) defined environmental regulation as the pressure effect of government

Table 1 Categorization of analyzed studies

Categories	Classification
Estrato Qualis	A1 A2 Other Without classification
Area	Business, accounting, and tourism Interdisciplinary Other area Without classification
Methodology	Quantitative Qualitative Theoretical review
Sample origin	Developed countries (DC) Emerging countries (EC) DC/EC Not applicable (NA)
Relationship between environmental regulations and green innovation	Positive Negative Not applicable

Source: Prepared by the authors

policies. Frondel et al. (2007) pointed out that environmental regulation is a tool for government environmental policies and is also an important driving force for ecological innovation. Wang et al. (2016) considered environmental regulation a kind of traditional tool to solve environmental problems. For Liao (2018), environmental regulations, in a broad sense, must be a comprehensive system, which is composed of laws, regulations, industry standards, suggestions, supervision, punishments, rewards, environmental protection advertising, education, and other means adopted by various subjects to provide feedback on various aspects of environmental problems.

With the complexity of environmental policy systems and the diversity of tools, some authors have classified environmental regulation into three types of instruments: command and control instruments (they establish laws and regulations that require polluters to reduce emissions); market-based instruments (aimed at encouraging polluters to reduce pollution emissions); and voluntary regulatory instruments (provides incentives for pollution control) (Gunningham et al. 1998; Huang et al. 2016; Ren et al. 2018).

According to Mickwitz (2003), environmental policy instruments are measures taken by governments to address air, water, solid waste, and the depletion of natural resources and to achieve environmental governance. These regulatory instruments have been analyzed by several authors, as their use is not standardized, and they are adapted for each type of environmental problem and for each type of region.

Margulis (1996) addressed the lessons learned from the implementation of environmental regulation in several developing countries and concluded that copying the legislation of OECD countries is not enough and is often unproductive, as policies and instruments must adapt to local socioeconomic and cultural conditions to environmental conditions. Kathuria (2007) analyzed the effect of informal environmental regulation on controlling the discharge of pollutants in India and found that external pressures represented by environmental news reports play a positive role in controlling companies' pollution. Arimura et al. (2008) found that voluntary regulation is effective in reducing the discharge of pollutants. Zhao et al. (2015) empirically investigated the impacts of three different environmental regulations on production efficiency and CO_2 emissions and found that market-based regulations have significant impacts on improving efficiency and reducing CO_2. Ren et al. (2018) analyzed the effect of the three types of environmental regulation on eco-efficiency in different regions of China and found that the impact of regulations is different for each type of region, so the tools must be adjusted according to the needs of each region.

Besides considering regional differences in the implementation of environmental regulations, companies also play a key role in this process. Liberalization of trade and investment encourages more efficient use of resources globally, especially if institutional and political strategies that value environmental issues are implemented. Also, globalization encourages the expansion of markets and competitiveness, motivating the business world to adapt and innovate.

In addition, the requirement of governments with strict environmental policies can also influence the competitiveness of countries and encourage companies to invest in green innovation. Authors such as Cleff and Rennings (1999) and Frondel et al. (2008) have suggested that stricter environmental regulations drive companies to promote green innovation and these differences in regulatory rigor occur in countries with different levels of development in their eco-innovation capabilities.

Although there are divergences and inconclusions regarding the findings of the literature, environmental regulations are considered an antecedent of green innovation in several researches. Thus, discussing its advantages and disadvantages in this context is beneficial. Porter and Van der Linde (1999) already argued the relationship between environmental adequacy and competitiveness, since, for the authors, there is no impasse between ecology and economics. Like Barbieri (2011), the authors consider that sustainable development is a strategic tool for organizations as they contribute to increasing productivity and competitiveness. Barbieri (2011) also asserts that there must be proactive and anticipatory actions.

If reducing the environmental impact as a result of complying with environmental regulations can be an evident factor, it is also noteworthy that the organization starts to present a sustainable image before its stakeholders, contributing, also, to the formation of environmental awareness of consumption

and appreciation of its brand, creating a greater reputation and better image with society (Forsman 2013; Santin 2007), which, according to Martín-Tapia et al. (2010), can favor the international insertion of business. Santin (2007) also points out that adapting to environmental legislation avoids the payment of fines and other penalties by the company.

On the other hand, the adoption of the triple bottom line, which involves social, financial, and environmental perspectives, by companies is not simple and adapting to this new dynamic requires that the adopted strategies be rethought, which also means that the need for high investments can become a difficulty. According to Barbieri (2011), the adoption of the strategy also results from leveraging opportunities and mitigating threats in the market, which can be substantially complex.Thus, because of the importance of environmental regulations as a relevant factor that interferes in some way in the green innovation of companies, studies that establish this relationship will be addressed in the next topic. However, it is emphasized that the survey is concentrated in studies in which collaboration is inserted in the context of environmental regulations as an antecedent of green innovation.

Systematic literature review: Green innovation and environmental regulations

In the survey carried out, it was found that there are not many studies on the topic considering the total set of published articles. Although some articles had the words searched, the studies were not adapted to the objectives proposed in this work. Despite this, it can be seen that between 2015 and 2016, the production on the topic had considerable growth compared to previous years. In contrast, in recent years (2017–2019), there has been a decrease in production (Fig. 1).

Table 2 presents a summary of the journals and their classification in the Qualis list, their impact factor (JCR—Journal Citation Reports), the area of these journals, and the number of articles selected. Qualis is the set of procedures used by CAPES (Coordination for the Improvement of Higher Education Personnel) to stratify the quality of intellectual production in graduate programs in Brazil. This process was designed to meet the specific needs of the evaluation system and is based on the information provided through the "CAPES Data Collection" application. As a result, it provides a list of the classification of journals.

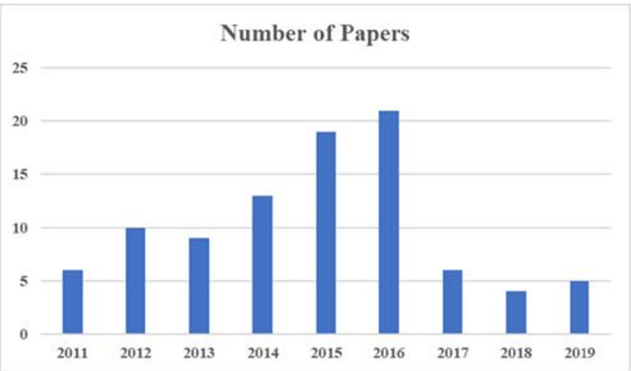

Fig. 1 Distribution of papers published by year. Source: Prepared by the authors

The impact factor (JCR) is one of the most legitimate indicators in the international scientific community, published by Thomson Reuters, and its purpose is to quantitatively assess the relevance of a given scientific journal in its respective area.

It is observed that the 93 selected articles are distributed in 31 different journals, most of them with A1 classification in the Qualis list and in the area of administration, accounting, and tourism, which demonstrate the relevance of the research theme (Figs. 2 and 3).

About 92% of these 93 articles were published in journals with Qualis A1 classification, and the journals with the largest number of publications were the Journal Cleaner of Production (31 articles); Ecological Economics (8 articles); and Technological Forecasting & Social Change (6 articles)—all of them with Qualis A1 classification in the area of administration, accounting, and tourism and with JCR greater than 2.

Regarding the methodology used in the studies, it is noted that most of the articles analyzed had a quantitative approach and used multivariate analysis through regression. Regarding qualitative studies, only a few studies use this approach. Furthermore, most of those who use it apply the case study through interviews (Fig. 4).

Another important information about the analyzed studies is the origin of the samples, which were separated into DC, developed countries; EC, emerging countries; DC and EC; and NA—not applicable (Fig. 5). It appears that 33 articles are from DC and 31 articles from EC, and most studies with samples from China. It is also noticed that only 9 articles address both DC and EC companies, demonstrating a gap for research that uses samples from both regions.

Finally, the studies were analyzed in terms of addressing the relationship between environmental regulations and green innovation. The contributions of these surveys will be explained as follows: (a) positive relationship between environmental regulations and green innovation; (b) negative relationship between environmental regulations and green innovation; and (c) studies where this relationship does not apply, that is, the studies do not address a direct relationship between environmental regulations and green innovation; however, it was considered relevant for the discussion of the theme (Table 3).

Results and discussions

Among studies that found a positive relationship between environmental regulations and green innovation, many sought to explore and identify the determining factors, drivers,

Table 2 Survey of papers

Journal	Qualis	Impact factor	Area	Number of papers
Applied Economics	A1	0.750	Business, accounting, and tourism	01
Business Strategy and the Environment	A1	5.355	Business, accounting, and tourism	05
China Industrial Economics	–	3.850	Business, accounting, and tourism	01
Comparative Economic Research	–	0.122	–	01
Corporate Social Responsibility and Environmental Management	A1	4.918	–	01
Ecological Economics	A1	2.713	Business, accounting, and tourism	08
Energy Economics	A1	3.910	Business, accounting, and tourism	02
Energy Policy	A1	4.039	Business, accounting, and tourism	03
Environmental Science & Technology	A1	6.653	Interdisciplinary	01
Environmental Science and Pollution Research	A2	3.208		01
European Journal of Innovation Management	A1	1.385	Business, accounting, and tourism	01
Gretha	–			01
Harvard Environmental Law Review	–	6.567	–	01
International Journal of Production Economics	A1	4.407	Business, accounting, and tourism	01
Journal of Cleaner Production	A1	5.651	Business, accounting, and tourism	31
Journal of Construction and Engineering and Management	A1	1.735	Business, accounting, and tourism	01
Journal of Environmental Management	A1	4.005	Business, accounting, and tourism	02
Journal of Environmental Economics and Management	–	2.635	–	01
Management Communication Quarterly	–	1.444	–	01
Management Decision	A1	1.525	Business, accounting, and tourism	01
Munich Personal RePEc	–	–	–	01
Organization & Environment	–	5.094	–	02
Procedia—Social and Behavioral Sciences	B1	–	Interdisciplinary	03
Renewable and Sustainable Energy Reviews	A1	9.184	Business, accounting, and tourism	02
Research Policy	A1	4.661	Interdisciplinary	06
Resources, Conservation & Recycling	A1	7.044	Business, accounting, and tourism	01
Sustainability	B1	2.075	Interdisciplinary	02
Technological Forecasting & Social Change	A1	3.129	Business, accounting, and tourism	06
The B. E. Journal of Economic Analysis & Policy	A2	0.306	Business, accounting, and tourism	01
TQM Journal	A1	2.470	Business, accounting, and tourism	01
Urban Forestry & Urban Greening	A1	3.043	Architecture, urbanism, and design	01

Source: Prepared by the authors

background, and origins of green innovation in companies in different countries (Belin et al. 2011; Horback et al. 2012; Doran and Ryan 2012; Cai and Zhou 2014; Li 2014; Zailani et al. 2015; Dangelico 2016; Li and Hamblin 2016; Doran and Ryan 2016).

In this search, Belin et al. (2011) tried to recognize the international determinants and regional characteristics of eco-innovations in industries in France and Germany and they confirmed the central role of regulations and cost savings as drivers of eco-innovation. Horback et al. (2012) tested whether different types of eco-innovation are driven by different factors in industries in Germany, and they found that the current regulation is important for leading companies to invest in reducing gas emissions, water or noise emissions and to avoid dangerous substances and increase product recycling. Doran and Ryan (2012) analyzed the drivers of eco-innovation and their impact on performance in Irish companies and pointed that regulation and customer perception can explain the company's decision to engage in green innovation.

Similarly, Cai and Zhou (2014) empirically investigated the main factors that influence the adoption of green innovation in Chinese companies and revealed that the external pressures of environmental regulations and the green demands of customers and competitors affect the green innovation of companies. Corroborating these results, Li (2014) examined the relationships between institutional pressures, environmental innovation practices and industrial

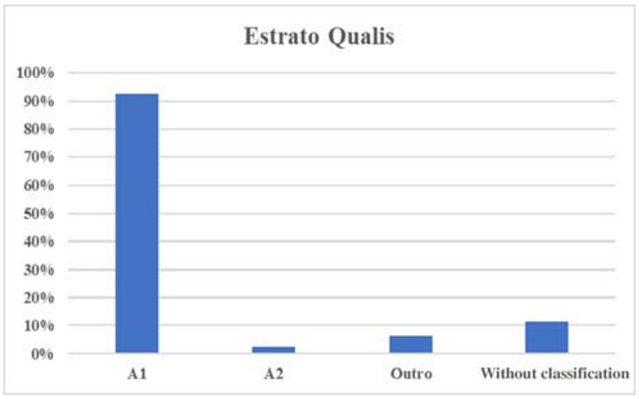

Fig. 2 Estrato qualis. Source: Prepared by the authors

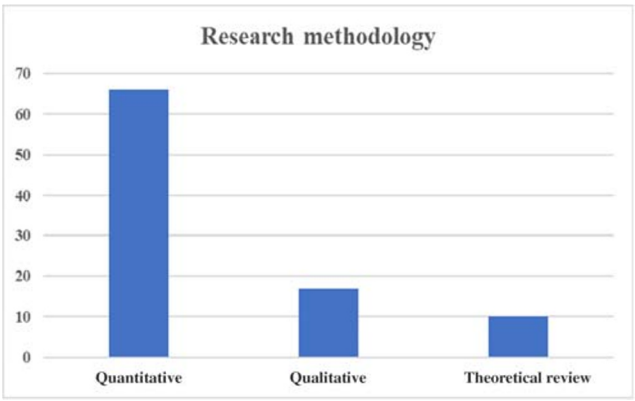

Fig. 4 Research methodology. Source: Prepared by the authors

performance in China. The results revealed that institutional pressures from government command and control instruments, the pressure of customers abroad, and the pressure of competition have a positive impact on environmental innovation practices, as an instrument of economic incentive by the government, and that pressures from internal customers do not affect environmental innovation practices.

Zailani et al. (2015) also investigated the determinants of the adoption of green innovation and its effects on the performance of Malaysian automotive industries. The results showed that environmental regulations, the market demand, and the companies' internal initiatives are the main factors that positively affect the adoption of green innovation. Dangelico (2016), through a systematic literature review, sought to identify the background, the results, and the success factors of the development of green products. As a result, he found that many external and internal factors drive the development of green products, and among the external factors, the most important are environmental regulations and market demand.

Other research that also showed a positive relationship between environmental regulations and green innovation sought to analyze the impact of environmental policies on green innovation (Johnstone et al. 2012; Bergek and Berggren, 2014; Lin et al. 2014; Rubashkina et al. 2015; Zhao et al. 2015; Chan et al. 2016; Stucki and Woerter 2016; Huang et al. 2016; Chakraborty and Chatterjee 2017; Ren et al. 2018; Pan et al. 2019; Borsatto and Amui 2019).

Johnstone et al. (2012) used patent data to examine the impact of environmental policies on innovations in environmental technology in 77 countries and confirmed that greater rigidity in environmental policies has a positive effect on environmental innovation. Aguilera-Caracuel and Ortiz-de-Mandojana (2013) demonstrated that green innovative companies are situated in contexts characterized by stricter environmental standards and higher environmental normative levels than non-green innovative companies.

Bergek and Berggren (2014) analyzed, through empirical studies, the impact of policy instruments from two high-emission sectors in the USA on innovation and found that politics plays a fundamental role in the development and diffusion of innovation in the sectors studied. Rubashkina et al. (2015) investigated the impact of environmental regulation on the economic performance of industries in European countries and found evidence of the positive impact of environmental regulation on the departure of innovation activities such as patents. Zhao et al. (2015) demonstrated that environmental regulations promote a change in the behavior of companies towards green development and also increase the competitiveness of companies.

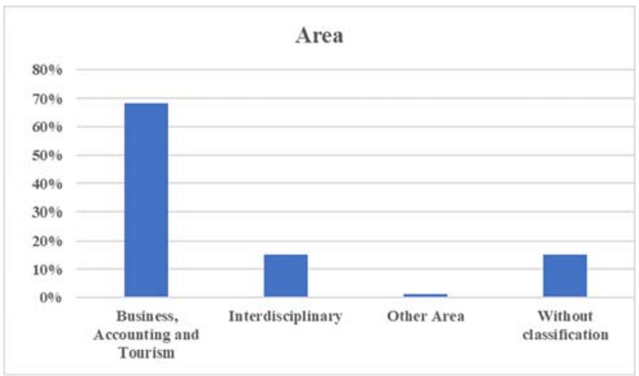

Fig. 3 Area of publication. Source: Prepared by the authors

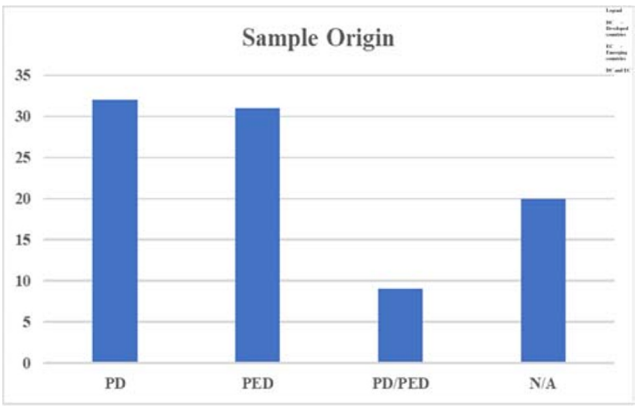

Fig. 5 Origin of the analyzed studies. Source: Prepared by the authors

Table 3 Studies on environmental regulations and green innovation

Reference	Research objective	Method
(a) Positive relation		
Belin et al. (2011)	Exploring and explaining the determinants of ecoinnovations for different countries	Probit model
Kemp and Pontoglio (2011)	Examine the innovation effects of environmental policy instruments in four literatures: theoretical models on incentives for eco-innovation econometric studies based on observed data, survey analysis based on stated information, and technology case studies	Literature review
Rennings and Rammer (2011)	To test whether different types of eco-innovation (according to their environmental impacts) are driven by different factors	Regression with panel data
Testa et al. (2011)	Analyze: (1) whether environmental policy stringency affects the competitive performance of firms in the building and construction sector (2) and how a specific form of environmental regulation (direct regulation, economic instruments, and soft instruments) affects this performance?	Regression analysis
Kesidou and Demirel (2012)	Provides empirical insights on the drivers of eco-innovations based on a novel dataset of 1566 UK firms	Heckman selection model
Chen et al. (2012)	Explore the origins of the two types of green innovations: proactive and reactive green innovations	Estudo de Caso e questionnaire survey method
Doran and Ryan (2012)	Analyze the drivers of eco-innovation and to compare the impact of eco-innovation and non-eco-innovation on firm performance	CDM model
Johnstone et al. (2012)	Examinar o impacto da política ambiental pública sobre inovações em tecnologia ambiental	Regression with panel data
Aguilera-Caracuel and Ortiz-de-Mandojana (2013)	Analyze if the level of green innovation improves the company's financial performance, and identify the national institutional conditions that can favor or prevent these	Regression
Yabar et al. (2013)	This work seeks to clarify the impact of environmental policy on technological innovation	Regression
Li et al. (2013)	Estimate the nonlinear relationship between environmental regulation and the transformation of China's industrial development mode, and calculate the corresponding threshold value	Panel threshold model
Epicoco et al. (2014)	Investigate the dynamics of scientific knowledge underlying this emerging field, the main countries and organizations involved, and the factors that shaped the evolution of the field of Chemistry	Theoretical review
Bergek et al. (2014)	It analyzes the impact of environmental policy instruments on innovation in two high-emission sectors	Literature review
Cai and Zhou (2014)	Verify the main factors that influence the adoption of eco-innovation in Chinese companies. To achieve this, a conceptual model is developed and tested on a large database of companies from various industries, using hierarchical regression analysis	Correlation and regression analysis
De Medeiros et al. (2014)	Este trabalho (i) consolida a pesquisa existente e agrega descobertas de diferentes estudos sobre a inovação de produtos ambientalmente sustentável através de um quadro interpretativo de literatura publicada sobre o tema e (ii) mapeia fatores críticos de sucesso que impulsionam o sucesso da inovação de produto desenvolvida	Literature review
Ford et al. (2014)	We approach this dichotomy by investigating the innovation introduced by Australian oil and gas companies in light of	Survey and regression analysis

Table 3 (continued)

Reference	Research objective	Method
	the burden of environmental regulatory compliance and company-level characteristics, including competitive capabilities	
Li (2014)	Examine the links between institutional pressures and environmental innovation practices and performance. In addition, we tested the moderating effect of the commitment of resources on the consequences of green innovation practices	Structural equation model and regression
Lin et al. (2014)	This article seeks empirical evidence on how pressures from political capital and stakeholders affect companies' investments in green innovation. We investigate the effects of political capital and stakeholder pressures on corporate green innovation	Pearson's correlation and Probit regression model
Rubashkina et al. (2015)	Investigate the impact of environmental regulation on the economic performance of industries in European countries, analyzing the strong and weak versions of Porter's hypotheses	Regression with panel data
Zailani et al. (2015)	Investigate the determinants of the adoption of a green innovation and its effects on the company's performance	Structural equation model
Chassagnon and Haned (2015)	Discuss the contribution of the innovation leadership to address the implementation of eco-innovations and, thus, the corporate movement of environmental responsibility through the relationship between industrial performance and eco-ecological concerns	Regression analysis
Zhao et al. (2015)	Explore the impact of environmental regulations—Management-based environmental regulation (command and control regulation) (AER) and market-based environmental regulation (MER)—on the behavior of the Chinese company and competitiveness	Structural equation model
Noailly and Ryfisch (2015)	This article presents new empirical evidence on the internationalization of green R&D by multinational companies (MNCs), as measured by patent data	Multivariate analysis
Ghisetti and Pontoni (2015)	After a qualitative discussion of this literature, we evaluate empirically, through the exploration of meta-regression analysis techniques to test the effectiveness of two determinants: policies and R&D	Meta-analysis
Korhonen et al. (2015)	The study assesses the effectiveness of environmental regulation by identifying its positive and negative aspects for the future success of the pulp and paper industry and uses the reduction of sulfur emissions as an example	Delphi-prospective method
López and Montalvo (2015)	This article informs the literature on sustainability transitions, providing an account of the evolution in the chemical industry's effort to design, use, and produce environmentally sound chemical processes and products based on eco-innovation	Longitudinal content analysis
Rassier and Earnhart (2015)	Jointly assess the effects of environmental regulation (clean water) on two different aspects of profitability: profitability on sales (ROS) and expected profitability (Qde Tobin)	Regression with panel data
Borghesi et al. (2015)	We investigate whether the first phase of the European Emissions Trading Scheme (EU ETS) had any effects on EI in reducing CO2 and energy efficiency	Regression analysis
Dangelico (2016)	This study identifies the background, outputs, and success factors for the development of green product innovation	Systematic literature review
Chan et al. (2016)	This study (i) examines the effect of green product innovation on the relationship between pressure from environmental regulations (or policies) and company performance; and (ii) assesses the	Survey and structural equation model

Table 3 (continued)

Reference	Research objective	Method
	moderating effect of environmental dynamism on the relationship between green production innovation and company performance	
Chang et al. (2016)	This article investigates the policy system in China, which aims to facilitate the transition to sustainable construction. The related laws, policies, and regulations are analyzed and three main functions are identified, namely, regulation and control, economic incentives, and support activities	Document analysis
Stucki and Woerter (2016)	Investigated how different types of policies are directly and in combination and affect the number of different green energy technologies adopted by a single company (intra-firm diffusion).	Fractional logistic regression
Lewandowska (2016)	The objective of this work is to present a cross-sectional analysis of the connection between eco-innovation and its main drivers in companies from selected countries in the EEC (Bulgaria, Czech Republic, Romania) and Germany	Regression analysis
Doran and Ryan (2016)	This article examines the factors that drive nine different types of eco-innovation in Ireland and assesses how these innovations influence company performance	Multivariate Probit Estimate
Zhao and Sun (2016)	This work makes an empirical study to explore this mechanism, using panel data samples from Chinese companies in the pollution industry during 2007e2012	Regression with panel data
Muñoz-García and Akhundjanov (2016)	This article investigates the production decisions of companies with asymmetric environmental damage and how their profits are affected by environmental regulations	duopoly model
Huang et al. (2016)	Investigate the influence of regulatory and customer pressure on green innovations	Structural Equation Model
Fengzhang & Xiaochuan (2016)	This article empirically examines the role of local government governance in influencing environmental regulation in green business process innovation	Regression with panel data
Hojnik and Ruzzier (2016)	We focus on process eco-innovation in order to identify which motives spur companies into implementation of process eco-innovation and we explore the outcomes of process eco-innovation in terms of company profitability, company growth, and competitive benefits	Survey and structural equation model
Chakraborty and Chatterjee (2017)	The study causally examined the effect of the German ban on "azo dyes" (international regulations) on innovation activities by upstream dye manufacturers in India 1990–2002	Regression analysis
Li and Wu (2017)	Investigate the influence of local and civil environmental regulations and their spatial overflow effect on total factor productivity in 273 cities in China in 2003 and 2013	Non-spatial panel data model
Ramanathan et al. (2017)	This article examines the relationship between environmental regulations, business innovation, and private companies. Sustainability benefits using nine case studies from British and Chinese companies	Case study
Xie et al. (2017)	This article attempts to examine whether the "strong" version of Porter's hypothesis is supported in China, investigating how different regulatory instruments and relative rigidity impact "green" productivity	Panel threshold model
Ren et al. (2018)	This document divides environmental regulation into three types: command and control regulation, market-based regulation, and voluntary regulation and tests the effects of these three	Regression with panel data

Table 3 (continued)

Reference	Research objective	Method
	environmental regulations on eco-efficiency in eastern, central, and western China	
Li et al. (2018)	Explore how environmental technological innovation responds to changes in command and control regulations and three other traditional determinants (environmental investments in R&D, contributions from the environmental workforce, and the level of provincial economic development) during the 2004 study period and 2016	Spatial econometric model
Liao (2018)	This study builds a relationship model of environmental policy instruments, environmental innovation and corporate reputation along the logical line of "policy-behavior-performance"	Multiple regression and Structural equation model
Pan et al. (2019)	To study the dynamic internal relationship between environmental regulation, technological innovation and energy efficiency in China, from 2006 to 2015	Structural equation model
Borsatto and Amui (2019)	Analyze how the degree of severity of environmental regulations and the international competitiveness of countries affects the green innovation efforts of companies in the industrial sector in developed and developing countries	Structural equation model
Zhang et al. (2019)	Investigate how two dimensions of environmental regulations (i.e., command and control regulation and market-based regulation) affect green product innovation and green process innovation	Structural equation model
(b) Negative relation		
Love et al. (2011)	The case study presented in this article describes how a customer acted as a catalyst to drive the sustainability agenda	Case study
Cainelli and Mazzanti (2013)	This article investigates the relevant factors behind the almost untapped mastery of environmental innovation in services. We test whether the integration of manufacturing services is important for environmental innovations. In addition, we analyze whether environmental policies for the construction of human beings transmit the effects of "induction" to services	Probit model
Triguero et al. (2013)	We explore the drivers of different types of eco-innovation in European SMEs	Survey and Probit model
Lin et al. (2014)	This article seeks empirical evidence on how pressures from political capital and stakeholders affect companies' investments in green innovation. We investigate the effects of political capital and stakeholder pressures on corporate green innovation	Pearson's correlation and Probit regression model
Triguero et al. (2014)	This article examines the relative influence of energy prices on various environmental practices at company level	Probit model
Gabaldón-Estevan et al. (2014)	This article looks at how environmental issues have affected and continue to affect the evolution of European manufacturing industries based on the example of the Spanish ceramic industry (SCTI)	Case study
Kunapatarawong and Martínez-Ros (2016)	We examined the relationship between green innovation and employment from data taken from the Spanish Technological Innovation Panel (PITEC) for the period 2007–2011	Regression analysis
Wang and Shen (2016a, 2016b)	This study adopts the GML index to calculate China's industrial productivity considering environmental factors. In addition, the author examines the nonlinear relationship between China's	GlobalMalmquist—Luenberger (GML) and panel data analysis

Table 3 (continued)

Reference	Research objective	Method
	environmental regulation and environmental productivity and calculated the ideal regulatory environment for industries	
Chen et al. (2016)	This study establishes an index system for assessing China's green industrial development and explores the relevant factors influencing China's green industrial development using the dynamic panel data model and a panel threshold test	Regression with panel data
Yuan et al. (2017)	This document uses panel data from 28 subsectors of China's manufacturing industry during 2003–2013, divides these subsectors into three groups—the high, medium, and low eco-efficiency industries according to the level of eco-efficiency—and explores the effects of environmental regulation technical innovation (Porter hypothesis "weak") and eco-efficiency (Porter hypothesis "strong"), respectively	Regression with panel data
(c) Not applicable		
Popp et al. (2011)	We use patent data to examine the evolution of two competitive bleaching technologies in five major paper-producing countries, which reduce the use of chlorine in the pulping process. The use of patent data allows us to focus on the stage of the invention	Regression analysis
Mazon et al. (2012)	This work intends to verify the applicability of the concept of sustainable innovation system in developing countries, through a comparative and investigative study, exploring how environmental regulations	Case study
Costantini and Mazzanti (2012)	Explore how the competitiveness of European Union exports has been affected by environmental regulation and innovation. Starting from Porter's idea that environmental policies can promote competitiveness	Regression analysis
Matus et al. (2012a)	This article investigates the conditions under which companies are able to develop and implement innovations with sustainable development benefits	Interviews with leaders from industry, academia, NGOs, and government
Matus et al. (2012b)	Identifies the different factors that drive innovation in the fields of green chemistry and green engineering in China, which we consider to be driven largely by energy efficiency policy, increasingly stringent application of pollution regulations and national attention to more production concepts clean, like "circular economy"	Semi structured interview
Yarahmadi and Higgins (2012)	The aim of this paper is to examine the green innovation literature using a conceptual framework developed to explain the driving forces behind the companies' environmental cooperative activities	Literature review
Van den Bergh (2013)	This article offers a critical perspective on the role of technological innovation in solving environmental problems	Literature review
O'connor and Gronewold (2013)	This study examines 21 environmental sustainability reports from the Fortune Global 500 oil companies to determine how competitive advantages and institutional language are used by corporations to explain their corporate social responsibility (CSR)	document analysis
Wong (2013)	This research develops an integrative model that explores the determinants of green innovation with a focus on being placed on knowledge sharing	Survey and structural equation model
Coleman (2014)	This article answers how regulators can encourage, rather than discourage, action in other countries, describing three ways in which unilateral regulation influences incentives to regulate in other countries	Literature review
Cuerva et al. (2014)		Regression analysis

Table 3 (continued)

Reference	Research objective	Method
	The main objective of this study is to analyze the factors that influence the adoption of green and wide-ranging innovations in small and medium-sized enterprises (SMEs) in a specific sector: the food and beverage industry	
Fiott (2014)	Este artigo pergunta em que medida, como e por que elementos do setor de defesa na Europa se envolveram em ecologias	
Amores-Salvadó et al. (2015)	The present work analyzes the complementarity that exists between environmental management systems (EMS) and environmental innovation capacities and the effect of this relationship on the company's performance	Regression analysis
Barbieri (2015)	The article investigates the conditions under which the European environmental transport policy portfolio and the intrinsic characteristics of the knowledge push of the worldwide green patent transferees	Regression Analysis
Cosimato and Troisi (2015)	The aim of this paper is to investigate how logistics organizations try to address recent ecological challenges and the role that emerging green technologies play in making them ultimately "green" and competitive	Case study
Apak and Atay (2015)	This article presents a research related to the knowledge production process as the basic requirements of green innovation activities especially and international competitiveness	Theoretical review
Souto and Rodriguez (2015)	This article focuses on the obstacles faced by companies involved in environmental innovations and how they still manage to achieve these innovations	Binary logistic regression
Criscuolo and Menon (2015)	This article provides a detailed description of venture capital investment in the green sector in 29 countries over the 2005–2010 period and identifies the role that policies can play in explaining the differences	Tobit regression
Al-Saleh and Mahroum (2015)	This article provides a critical review of the interaction between green policy instruments and green business models from a behavioral perspective	Literature review
Li and Hamblin (2016)	This study will identify the key factors in the literature that impact clean production. The factors analyzed are ISO14001 certification, eco-innovation of products and processes, industrial and government regulations, and the environmentally friendly culture	Case study
Chang et al. (2016)	Explore the positive effects of corporate environmental commitment and green human capital on the performance of ecological product innovation through the mediator: green adaptability. Green adaptability is the ability to comply with uncertain environmental regulations and environmentalism	Structural Equation Model
Sáez-Martínez et al. (2016)	Com base em evidências do "Eurobarómetro 381 Inquérito às PME, Eficiência de Recursos e Mercados Verdes", analisamos a responsabilidade ambiental das PME europeias, estudando a conformidade com a legislação ambiental e a forma como vários fatores impulsionam a orientação ambiental entre as PME	OLS regression
Blohmke et al. (2016)	This article takes the analysis of the determinants of environmental policy a step further by studying the effects of interaction between the determinants	Structural equation model
Aalbers et al. (2019)		Case study

Table 3 (continued)

Reference	Research objective	Method
	This article covers two years of research on the factors that determine the success or failure of initiatives taken by companies, citizens, or municipalities in or for green space in urban regions in the Netherlands	

Source: Prepared by the authors

Chan et al. (2016) examined the effect of green product innovation on the relationship between pressure from environmental regulations and the performance of 250 Chinese companies. They demonstrated that pressure from environmental regulation has a positive impact on green product innovation, which influences the company's efficiency and profitability. Huang et al. (2016) created a conceptual model based on institutional theory and a resource-based view to explore the effects of regulatory and customer pressure on the performance of green innovation through green organizational responses. The modeling results showed that regulatory and customer pressure promotes green organizational responses and improves the performance of green innovation.

The study by Ramanathan et al. (2017) found that depending on the resources and capabilities of companies, those that take a more dynamic approach to respond to environmental regulations in an innovative way and adopt a proactive approach to manage their performance generally are more prepared to get the benefits of sustainability.

Chakraborty and Chatterjee (2017) analyzed the effect of German international regulation on innovation activities by upstream dye manufacturers in India and found robust evidence of a significant increase in innovation spending for dye manufacturers. Ren et al. (2018) tested the effects of the three types of environmental regulations on eco-efficiency in three regions of China and revealed that for each region, the types of regulations impact eco-efficiency in different ways, with a positive impact or without significant impact.

Pan et al. (2019) studied the dynamic internal relationship between environmental regulation, technological innovation, and energy efficiency in China and pointed three findings: (i) the environmental regulation of market incentives contributes directly to energy efficiency; (ii) the environmental regulation of market incentives drives energy efficiency through technological innovation: and (iii) the environmental regulation of command control directly contributes to energy efficiency.

Finally, the study by Borsatto and Amui (2019) analyzed how the degree of severity of environmental regulations and the international competitiveness of countries affects the green innovation efforts of companies in the industrial sector in developed and developing countries. The results showed that among the antecedents of green innovation analyzed, the rigor of environmental regulations in the countries and the size of companies had a positive impact on green innovation efforts. The results also showed that the relationship between environmental regulation and green innovation is moderated positively by the size of the companies and negatively moderated by the degree of internationalization.

From these studies, it can be seen that, regardless of the region of origin of the analyzed industries, environmental regulations proved to be one of the main factors that motivate companies to invest in green innovation, and that different

types of environmental regulations can impact the green development of companies in different ways as well.

On the other hand, many researchers found a negative relationship between environmental regulations and green innovation. Love et al. (2012) presented a case study from Australia describing how a client acted as a catalyst to drive the sustainability agenda and demonstrated that existing construction regulations and a lack of government incentives were identified as the main barriers to the implementation of sustainable technologies. Cainelli and Mazzanti (2013) investigated the relevant factors behind green innovation in Italian service companies and found that the transfer of environmental regulations from industries to service companies does not positively affect the diffusion of environmental innovations in these companies.

Triguero et al. (2014) examined the influence of energy prices on different environmental practices of different European SMEs and pointed that neither existing nor future environmental regulations have a significant impact on innovative and friendly practices to the environment.

Guo et al. (2017) developed an integrated model to investigate the relationship between environmental regulation, technological innovation, and regional green growth performance considering 30 provincial administrative regions in China. The results show that environmental regulation has a significant negative effect on regional green growth performance. However, it was found that environmental regulation positively influences technological innovation and technological innovation has a positive impact on regional green growth performance.

In addition to these two approaches to the positive and negative relationship between environmental regulations and green innovation, in the survey of articles, studies were found that address environmental regulations without making a direct relationship with green innovation, considering it as a moderating factor in relation to other factors organizational changes that could affect companies' environmental and financial performance.

Mazon et al. (2012) verified how environmental regulations related to electronic waste in Brazil mobilize heterogeneous networks (academia, private companies, and government) for the generation and diffusion of innovation to comply with these regulations. They found that the development of developed and developing countries has different levels of technology development and legislation on electronic waste, but international regulation affects the competitiveness of its electronic industry equally.

Fiott (2014) evaluated how and why elements of the European defense sector became involved in ecology and found that Europe's military, defense institutions, and defense companies have a strong interest in greening and tend to delegate innovation market in an increasingly regulated context. Souto and Rodriguez (2015) demonstrated that the obstacles faced by Spanish companies involved in green innovation are greater and different from those faced by other companies, which requires different action plans that include public funding and cooperation.

Li and Hamblin (2016) revealed that companies that have ISO14001 certification are probably one step ahead, but this is not the only factor that leads these manufacturing companies to be active in cleaner production—green process innovations and a culture environment has a greater influence in promoting cleaner production. Blohmke et al. (2016) examined the determinants of environmental policy in 47 countries and found that green defense and governance capacity are the main structural determinants of the quality of environmental regulation and that access to the Internet also has a positive influence on the environmental regulation through the defense and green governance.

Dong et al. (2019) demonstrated that clean and unclean technologies have a strong effect on environmental quality. Unclean technology can improve environmental quality by promoting energy efficiency and the environmental benefits of clean technology include increasing new vehicles energetic. However, it is difficult for clean technology to replace unclean technology as a dominant technological application. Furthermore, subsidies to research and development can change the technological direction to affect environmental quality.

For two years, Aalbers et al. (2019) researched, through a case study, the factors that determine the success or failure of initiatives taken by companies, citizens, or municipalities for green space in urban regions in the Netherlands. The authors identify that the initiatives lead to a broader meaning and the involvement of more actors around green spaces. In addition, they integrate green space with social and economic development.

As a summary of what was exposed, it is observed that studies on environmental regulations and green innovation do not come to a consensus, despite having mostly positive results, confirming that environmental regulations are among the main external factors that induce companies to environmental innovation (Liao 2018). Another aspect to be considered is related to the division of regulations into different mechanisms such as command and control regulation and market-based regulation. New studies are emerging analyzing the effect of these different environmental policy instruments on companies' green innovation, trying to explain the divergences in research that did not give a clear answer to this relationship (Zhang et al. 2018; Hojnik and Ruzzier 2016; Ren et al. 2018; Liao 2018; Feng & Chen 2018; Zhang et al. 2019). In addition, it appears that the studies still focus on an analysis or DP or PED, without the concern of a comparative approach in view of the different context of the rigorous regulations of these countries.

Conclusions

The present study aimed to present a summary of the most relevant academic researches that relate environmental regulations and green innovation, knowing in a standardized way the scientific information of this field of study. It is believed that studies with this approach contribute to map the knowledge on the topic, assisting professionals and researchers in gathering information for decision-making and to direct future research on the topic.

It is considered that the study fulfilled the proposed objective by analyzing 93 academic articles and presenting contributions for forming a research agenda that contributes to the advancement of discussions in this area based on future work. It was found that although most studies have shown a positive relationship between environmental regulations and green innovation, there are still inconsistencies in the literature, giving rise to research opportunities to explore how and under what conditions this relationship is established, considering the different environmental policy mechanisms and different approaches to green innovation in companies.

It was also found that most studies used quantitative methods mainly regression models for data analysis, identifying a gap for the development of qualitative research that addresses organizational aspects of behavior and management that can influence the relationship between environmental regulations and green corporate innovation.

With regard to the sample of studies, there was a need for research that carries out a comparison between countries in different contexts, that is, a comparison between developed and developing countries, as environmental regulations may present divergences both in rigor, in type and regional differences. In addition, research that addresses developing countries largely uses China and its industries as a sample, so a study that uses other developing countries is necessary considering that China, although is a developing country, has a high representation on the world stage, being the second largest economy in the world.

A limitation to be considered in this research is the selection of articles. As the focus of the study was to address the relationship between environmental regulations and companies' green innovation, many studies on environmental regulations analyze the impacts of environmental policies on the development and green growth of regions, which is not the focus of this review. Another limitation of the study refers to the analysis of academic articles in journals of only three bases, in addition to delimiting the research of the works to the expressions "Green innovation and Enviroment regulation" and "Eco-innovation and Enviroment regulation" and for the period from 2011 to 2019.

Authors' contributions JMLSB: Research Development, Data Analysis, Final Review.

CLB: Contribution to the contextualization of the theme, Literature Review and Final Review.

Data availability Not applicable.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

References

Aalbers CBEM, Kamphorst DA, Langers F (2019) Fourteen local governance initiatives in greenspace in urban areas in the Netherlands. Discourses, success and failure factors, and the perspectives of local authorities. Urban For Urban Green 42:82–99

Aguilera-Caracuel J, Ortiz-de-Mandojana N (2013) Green innovation and financial performance: an institutional approach. Organ Environ 26(4):365–385

Al-Saleh Y, Mahroum S (2015) A critical review of the interplay between policy instruments and business models: greening the built environment a case in point. J Clean Prod 109:260–270

Amores-Salvadó J, Martin-de Castro G, Navas-López JE (2015) The importance of the complementarity between environmental management systems and environmental innovation capabilities: a firm level approach to environmental and business performance benefits. Technol Forecast Soc Chang 96:288–297

Apak S, Atay E (2015). Global competitiveness in the EU through green innovation technologies and knowledge production

Arimura TH, Hibiki A, Katayama H (2008) Is a voluntary approach an effective environmental policy instrument?: a case for environmental management systems. J Environ Econ Manag 55(3):281–295

Barbieri JC (2011). *Gestão ambiental empresarial*: conceitos, modelos e instrumentos. 3. ed. São Paulo: Saraiva

Barbieri N (2015) Investigating the impacts of technological position and European environmental regulation on green automotive patent activity. Ecol Econ 117:140–152

Belin J, Horbach J, Oltra V (2011). *Determinants and specificities of eco-innovations–An econometric analysis for the French and German industry based on the Community Innovation Survey* (No. 2011-17). Groupe de Recherche en Economie Théorique et Appliquée (GREThA)

Bergek A, Berggren C, KITE Research Group (2014) The impact of environmental policy instruments on innovation: a review of energy and automotive industry studies. Ecol Econ 106:112–123

Bernauer T, Engel S, Kammerer D, Sejas Nogareda J (2007) Explaining green innovation: ten years after Porter's win-win proposition: how to study the effects of regulation on corporate environmental innovation? Politische Vierteljahresschrift 39:323–341

Blohmke J, Kemp R, Türkeli S (2016) Disentangling the causal structure behind environmental regulation. Technol Forecast Soc Chang 103: 174–190

Borghesi S, Cainelli G, Mazzanti M (2015) Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry. Res Policy 44(3):669–683. https://doi.org/10.1016/j.respol.2014.10.014

Borsatto JMLS, Amui LBL (2019) Green innovation: unfolding the relation with environmental regulations and competitiveness. Resour Conserv Recycl 149:445–454

Cai WG, Zhou XL (2014) On the drivers of eco-innovation: empirical evidence from China. J Clean Prod 79:239–248
Cainelli G, Mazzanti M (2013) Environmental innovations in services: manufacturing–services integration and policy transmissions. Res Policy 42(9):1595–1604
Chakraborty P, Chatterjee C (2017) Does environmental regulation indirectly induce upstream innovation? New evidence from India. Res Policy 46(5):939–955
Chan HK, Yee RW, Dai J, Lim MK (2016) The moderating effect of environmental dynamism on green product innovation and performance. Int J Prod Econ 181:384–391
Chang RD, Soebarto V, Zhao ZY, Zillante G (2016) Facilitating the transition to sustainable construction: China's policies. J Clean Prod 131:534–544
Chassagnon V, Haned N (2015) The relevance of innovation leadership for environmental benefits: a firm-level empirical analysis on French firms. Technol Forecast Soc Chang 91:194–207
Chen YS, Chang CH, Wu FS (2012) Origins of green innovations: the differences between proactive and reactive green innovations. Manag Decis 50:368–398
Chen C, Han J, Fan P (2016) Measuring the level of industrial green development and exploring its influencing factors: empirical evidence from China's 30 provinces. Sustainability 8(2):153
Cleff T, Rennings K (1999) Determinants of environmental product and process innovation. Eur Environ 9(5):191–201
Coleman JW (2014) Unilateral climate regulation. Harv Envtl L Rev 38: 87
Cosimato S, Troisi O (2015) Green supply chain management: practices and tools for logistics competitiveness and sustainability. The DHL case study. The TQM Journal 27(2):256–276
Costantini V, Mazzanti M (2012) On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. Res Policy 41(1):132–153
Criscuolo C, Menon C (2015) Environmental policies and risk finance in the green sector: cross-country evidence. Energy Policy 83:38–56
Cuerva MC, Triguero-Cano Á, Córcoles D (2014) Drivers of green and non-green innovation: empirical evidence in low-tech SMEs. J Clean Prod 68:104–113
Dangelico RM (2016) Green product innovation: where we are and where we are going. Bus Strateg Environ 25(8):560–576
Dangelico RM, Pujari D (2010) Mainstreaming green product innovation: why and how companies integrate environmental sustainability. J Bus Ethics 95(3):471–486
De Medeiros JF, Ribeiro JLD, Cortimiglia MN (2014) Success factors for environmentally sustainable product innovation: a systematic literature review. J Clean Prod 65:76–86
Dong Z, He Y, Wang H (2019) Dynamic effect retest of R&D subsidies policies of China's auto industry on directed technological change and environmental quality. J Clean Prod 231:196–206
Doran J, Ryan G (2012) Regulation and firm perception, eco-innovation and firm performance. Eur J Innov Manag 15(4):421–441. https://doi.org/10.1108/14601061211272367
Doran J, Ryan G (2016) The importance of the diverse drivers and types of environmental innovation for firm performance. Bus Strateg Environ 25(2):102–119
Epicoco M, Oltra V, Saint Jean M (2014) Knowledge dynamics and sources of eco-innovation: mapping the green chemistry community. Technol Forecast Soc Chang 81:388–402
Fiott D (2014) Reducing the environmental bootprint? Competition and regulation in the greening of Europe's defense sector. Organ Environ 27(3):263–278
Ford JA, Steen J, Verreynne ML (2014) How environmental regulations affect innovation in the Australian oil and gas industry: going beyond the Porter hypothesis. J Clean Prod 84:204–213
Forsman H (2013) Environmental innovations as a source of competitive advantage or vice-versa? Business Strategy and Environment 22(5): 306–320. https://doi.org/10.1002/bse.1742
Frondel M, Horbach J, Rennings K (2007) End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries. Bus Strateg Environ 16(8):571–584
Frondel M, Horbach J, Rennings K (2008) What triggers environmental management and innovation? Empirical evidence for Germany. Ecol Econ 66(1):153–160
Gabaldón-Estevan D, Criado E, Monfort E (2014) The green factor in European manufacturing: a case study of the Spanish ceramic tile industry. J Clean Prod 70:242–250
Gauthier J, Wooldridge B (2012) Influences on sustainable innovation adoption: evidence from leadership in energy and environmental design. Bus Strateg Environ 21(2):98–110
Ghisetti C, Pontoni F (2015) Investigating policy and R&D effects on environmental innovation: a meta-analysis. Ecol Econ 118:57–66
Gunningham N, Grabosky P, Sinclair D (1998) Smart regulation. Regulatory Theory 133
Guo LL, Qu Y, Tseng ML (2017) The interaction effects of environmental regulation and technological innovation on regional green growth performance. J Clean Prod 162:894–902
Hojnik J, Ruzzier M (2016) The driving forces of process eco- innovation and its impact on performance: insights from Slovenia. J Clean Prod 133:812–825. https://doi.org/10.1016/j.jclepro.2016.06.002
Huang XX, Hu ZP, Liu CS, Yu DJ, Yu LF (2016) The relationships between regulatory and customer pressure, green organizational responses, and green innovation performance. J Clean Prod 112: 3423–3433
Johnstone N, Haščič I, Poirier J, Hemar M, Michel C (2012) Environmental policy stringency and technological innovation: evidence from survey data and patent counts. Appl Econ 44(17):2157–2170
Kathuria V (2007) Informal regulation of pollution in a developing country: evidence from India. Ecol Econ 63(2-3):403–417
Kemp R, Pontoglio S (2011) The innovation effects of environmental policy instruments—a typical case of the blind men and the elephant? Ecol Econ 72:28–36
Kesidou E, Demirel P (2012) On the drivers of eco-innovations: empirical evidence from the UK. Res Policy 41(5):862–870
Korhonen J, Pätäri S, Toppinen A, Tuppura A (2015) The role of environmental regulation in the future competitiveness of the pulp and paper industry: the case of the sulfur emissions directive in northern Europe. J Clean Prod 108(Part A):864–872. https://doi.org/10.1016/j.jclepro.2015.06.003
Kunapatarawong R, Martínez-Ros E (2016) Towards green growth: how does green innovation affect employment? Res Policy 45(6):1218–1232
Lewandowska MS (2016) Do government policies foster environmental performance of enterprises from CEE region? Comparative Economic Research 19(3):45–67
Li Y (2014) Environmental innovation practices and performance: moderating effect of resource commitment. J Clean Prod 66:450–458
Li X, Hamblin D (2016) Factors impacting on cleaner production: case studies of Chinese pharmaceutical manufacturers in Tianjin, China. J Clean Prod 131:121–132
Li B, Wu S (2017) Effects of local and civil environmental regulation on green total factor productivity in China: a spatial Durbin econometric analysis. J Clean Prod 153:342–353
Li B, Peng X, Ouyang MK (2013) Environmental regulation, green total factor productivity and the transformation of China's industrial development mode: analysis based on data of China's 36 industries. China Industrial Economics 4:56–68
Li W, Gu Y, Liu F, Li C (2018) The effect of command-and-control regulation on environmental technological innovation in China: a

spatial econometric approach. Environ Sci Pollut Res:1–12. https://doi.org/10.1007/s11356-018-3678-3

Liao Z (2018) Environmental policy instruments, environmental innovation and the reputation of enterprises. J Clean Prod 171:1111–1117. https://doi.org/10.1016/j.jclepro.2017.10.126

Lin H, Zeng SX, Ma HY, Qi GY, Tam VW (2014) Can political capital drive corporate green innovation? Lessons from China. J Clean Prod 64:63–72

López FJD, Montalvo C (2015) A comprehensive review of the evolving and cumulative nature of eco-innovation in the chemical industry. J Clean Prod 102:30–43

Love PE, Niedzweicki M, Bullen PA, Edwards DJ (2012) Achieving the green building council of Australia's world leadership rating in an office building in Perth. J Constr Eng Manag 138(5):652–660

Lustosa MCJ (2002) *Meio ambiente, inovação e competitividade na indústria brasileira: a cadeia produtiva do petróleo. 2002. 267 f* (Doctoral dissertation, Tese (Livre-Docência em Economia)–Faculdade de Economia, Administração e Contabilidade, Universidade Federal do Rio de Janeiro, Rio de Janeiro)

Lustosa MCJ (2003) Industrialização, meio ambiente, inovação e competitividade. *MAY, PH; LUSTOSA, MC; VINHA, V. da. Economia do meio ambiente. Rio de Janeiro: Campus*, pp 155–172

Margulis S (1996). A regulamentação ambiental: instrumentos e implementação

Martín-Tapia I, Aragón-Correa JA, Rueda-Manzanares A (2010) Environmental strategy and exports in medium, small and micro-enterprises. J World Bus 45(3):266–275. https://doi.org/10.1016/j.jwb.2009.09.009

Matus KJ, Clark WC, Anastas PT, Zimmerman JB (2012a) Barriers to the implementation of green chemistry in the United States. Environmental science & technology 46(20):10892–10899

Matus KJ, Xiao X, Zimmerman JB (2012b) Green chemistry and green engineering in China: drivers, policies and barriers to innovation. J Clean Prod 32:193–203

Mazon MT, de Azevedo AMM, Pereira NM, Silveira MA (2012) Does environmental regulation foster the diffusion of collaborative innovations? A study on electronics waste regulation on Brazil. Procedia Soc Behav Sci 52:259–268

Muñoz-García F, Akhundjanov SB (2016). Can polluting firms favor regulation?. The BE Journal of Economic Analysis & Policy, 16(4)

Noailly J, Ryfisch D (2015) Multinational firms and the internationalization of green R&D: a review of the evidence and policy implications. Energy Policy 83:218–228

O'Connor A, Gronewold KL (2013) Black gold, green earth: an analysis of the petroleum industry's CSR environmental sustainability discourse. Manag Commun Q 27(2):210–236

Pan X, Ai B, Li C, Pan X, Yan Y (2019) Dynamic relationship among environmental regulation, technological innovation and energy efficiency based on large scale provincial panel data in China. Technol Forecast Soc Chang 144:428–435

Petticrew M, Roberts H (2006) How to appraise the studies: an introduction to assessing study quality. Systematic reviews in the social sciences: A practical guide:125–163

Popp D, Hafner T, Johnstone N (2011) Environmental policy vs. public pressure: innovation and diffusion of alternative bleaching technologies in the pulp industry. Res Policy 40(9):1253–1268

Porter M, Van Der Linde C (1999). Verde e competitivo: acabando com o impasse. In: Porter, M. *Competição:* estratégias competitivas essenciais. Rio de Janeiro: Campus

Ramanathan R, He Q, Black A, Ghobadian A, Gallear D (2017) Environmental regulations, innovation and firm performance: a re-visit of the Porter hypothesis. J Clean Prod 155:79–92

Rassier DG, Earnhart D (2015) Effects of environmental regulation on actual and expected profitability. Ecol Econ 112(C):129–140

Ren S, Li X, Yuan B, Li D, Chen X (2018) The effects of three types of environmental regulation on eco-efficiency: a cross-region analysis in China. J Clean Prod 173:245–255

Rennings K, Rammer C (2011) The impact of regulation-driven environmental innovation on innovation success and firm performance. Ind Innov 18(03):255–283

Rubashkina Y, Galeotti M, Verdolini E (2015) Environmental regulation and competitiveness: empirical evidence on the Porter hypothesis from European manufacturing sectors. Energy Policy 83:288–300

Sáez-Martínez FJ, Díaz-García C, González-Moreno Á (2016) Factors promoting environmental responsibility in European SMEs: the effect on performance. Sustainability 8(9):898

Santin MFCL (2007). *Os impactos da demanda por crédito de carbono sobre o mercado de certificações de reduções de emissões no Brasil, no âmbito do protocolo de Quioto*. 2007. Masters dissertation - Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre

Schilke O (2018) A micro-institutional inquiry into resistance to environmental pressures. Acad Manag J 61(4):1431–1466. https://doi.org/10.5465/amj.2016.0762

Souto JE, Rodriguez A (2015) The problems of environmentally involved firms: innovation obstacles and essential issues in the achievement of environmental innovation. J Clean Prod 101:49–58

Stucki T, Woerter M (2016) Intra-firm diffusion of green energy technologies and the choice of policy instruments. J Clean Prod 131:545–560

Testa F, Iraldo F, Frey M (2011) The effect of environmental regulation on firms' competitive performance: the case of the building & construction sector in some EU regions. J Environ Manag 92(9):2136–2144. https://doi.org/10.1016/j.jenvman.2011.03.039

Tranfield D, Denyer D, Smart P (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br J Manag 14(3):207–222

Triguero A, Moreno-Mondéjar L, Davia MA (2013) Drivers of different types of eco-innovation in European SMEs. Ecol Econ 92:25–33

Triguero A, Moreno-Mondéjar L, Davia MA (2014) The influence of energy prices on adoption of clean technologies and recycling: evidence from European SMEs. Energy Econ 46:246–257

Van den Bergh JC (2013) Environmental and climate innovation: limitations, policies and prices. Technol Forecast Soc Chang 80(1):11–23

Van Leeuwen G, Mohnen P (2017) Revisiting the Porter hypothesis: an empirical analysis of green innovation for the Netherlands. Econ Innov New Technol 26(1-2):63–77

Wang Y, Shen N (2016a) Environmental regulation and environmental productivity: the case of China. Renew Sust Energ Rev 62:758–766

Wang Y, Shen N (2016b) Environmental regulation and environmental productivity: the case of China. Renew Sust Energ Rev 62:758–766

Wang Z, Zhang B, Zeng H (2016) The effect of environmental regulation on external trade: empirical evidences from Chinese economy. J Clean Prod 114:55–61

Wong SKS (2013) Environmental requirements, knowledge sharing and green innovation: empirical evidence from the electronics industry in China. Bus Strateg Environ 22(5):321–338

Xie RH, Yuan YJ, Huang JJ (2017) Different types of environmental regulations and heterogeneous influence on "green" productivity: evidence from China. Ecol Econ 132:104–112

Yabar H, Uwasu M, Hara K (2013) Tracking environmental innovations and policy regulations in Japan: case studies on dioxin emissions and electric home appliances recycling. J Clean Prod 44:152–158. https://doi.org/10.1016/j.jclepro.2012.10.045

Yarahmadi M, Higgins PG (2012) Motivations towards environmental innovation: a conceptual framework for multiparty cooperation. Eur J Innov Manag 15(4):400–420

Yuan B, Xiang Q (2018) Environmental regulation, industrial innovation and green development of Chinese manufacturing: based on an

extended CDM model. J Clean Prod 176:895–908. https://doi.org/10.1016/j.jclepro.2017.12.034

Zailani S, Govindan K, Iranmanesh M, Shaharudin MR, Chong YS (2015) Green innovation adoption in automotive supply chain: the Malaysian case. J Clean Prod 108:1115–1122

Zhang Y, Wang J, Xue Y, Yang J (2018) Impact of environmental regulations on green technological innovative behavior: an empirical study in China. J Clean Prod 188:763–773

Zhang J, Liang G, Feng T, Yuan C, Jiang W (2019) Green innovation to respond to environmental regulation: how external knowledge adoption and green absorptive capacity matter? Bus Strateg Environ 29(1):39–53

Zhao X, Sun B (2016) The influence of Chinese environmental regulation on corporation innovation and competitiveness. J Clean Prod 112: 1528–1536

Zhao X, Zhao Y, Zeng S, Zhang S (2015) Corporate behavior and competitiveness: impact of environmental regulation on Chinese firms. J Clean Prod 86:311–322

Jaffe AB, Newell RG, Stavins RN (2005) A tale of two market failures: Technology and environmental policy. Ecol Econ 54(2–3):164–174

Arenhardt DL, Battistella LF and Franchi TS (2012) A influência da inovação verde na busca de vantagem competitiva das empresas dos setores elétrico e eletrônico brasileiro. In: XXXVI Encontro da Anpad. Rio de Janeiro: Anpad.

Lanoie P, Laurent-Lucchetti J, Johnstone N, Ambec S (2011) Environmental policy, innovation and performance: new insights on the Porter hypothesis. J Econ Manag Strateg 20(3):803–842

Feng Z,Chen W (2018) Environmental regulation, green innovation, and industrial green development: An empirical analysis based on the Spatial Durbin model. Sustainability 10(1):223

Polzin F, von Flotow P, Klerkx L (2016) Addressing barriers to eco-innovation: Exploring the finance mobilisation functions of institutional innovation intermediaries. Technol Forecast Soc Chang 103: 34–46

Morandi MIWM and Camargo LFR(2015) Revisão sistemática da literatura. Design science research: método de pesquisa para avanço da ciência e tecnologia. Bookman, Porto Alegre pp 141–175

Mickwitz P (2003) A framework for evaluating environmental policy instruments: context and key concepts. Evaluation 9(4):415–436