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Green supply chain management and clean technology innovation: An empirical analysis of multinational enterprises in China

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ABSTRACT

This study identifies the impact of green supply chain management (GSCM) on clean technology innovation (CTI) by enterprises in China as well as compares the effects of forward and backward GSCM and the differences by industry and home country. The effect of CTI on GSCM is tested by 501 samples of mostly multinational enterprises in China from 2014 to 2016. The results indicate that CTI benefits from GSCM, which remains robust to a series of sensitivity test. And different management directions show great differences, where the backward GSCM has a stronger promotion effect on CTI than the forward GSCM. Moreover, light polluting industries and capital-intensive industries have stronger incentives to adopt GSCM than heavy-polluting industries and labour-intensive industries. And domestic companies perform better than foreign companies.

1. Introduction

In recent decades, China has relied on an extensive economic development model that promotes economic growth through increased investment. Although this type of development has driven rapid economic growth, it has also brought about serious environmental degradation. Therefore, how to achieve high-quality economic growth while still protecting the environment has become an urgent problem. Studies argue that technology plays a vital role in addressing the rise in pollution (Mizobuchi, 2015; Kogan et al., 2017). In particular, over the past decade, there has been renewed interest in clean technology innovation (CTI) (Acemoglu et al., 2012; Moser et al., 2013). Although studies have focused on the CTI effects of policy interventions (Gupta and Barua, 2018; Sun et al., 2019) and R&D subsidies (Veugelers, 2016; Polzin, 2017), they ignore the impact of supply chain management (SCM) by enterprises, especially the lack of CTI effects of green supply chain management (GSCM).

GSCM refers to the system that reduces environmental pollution and improves the efficiency of resource utilization during firms' procurement, production, and emissions. Research on GSCM focuses on the profitability and competitiveness of enterprises, showing that GSCM can improve resource efficiency, reduce environmental costs, expand market share, and provide companies with greater competitive advantage (Longoni and Cagliano, 2018; Cousins et al., 2019; Li et al., 2019). However, there is limited research on whether it can affect CTI. Researchers typically examine a certain subdivision of the green supply chain such as green supply (Geffen and Rothenberg, 2000; Vachon, 2007), green design (Gunasekaran and Spalanzani, 2012), and consumers' environmental demands (Christmann and Taylor, 2001; Vachon and Klassen, 2006) using comparative analysis, while a few obtain data through interviews or questionnaires, finding that green supply chain cooperation and GSCM have a significant effect on CTI (i.e. clean product and process innovation) (Chiou et al., 2011; Lee and Kim, 2011). Nonetheless, owing to the subjectivity of the questionnaire setting, such empirical evidence may be biased.

Although all these studies suggest that GSCM may play an important role in CTI, there is still a lack of convincing empirical analysis (Seman et al., 2012). To contribute to the debate on GSCM and CTI, this article draw data on GSCM by enterprises from the Green Supply Chain-CITI Index Annual Evaluation Report published by the Institute of Public and Environmental Affairs and Natural Resources Defense Council in China (the IPEA/NRDC report hereafter) to empirically test the CTI effect of GSCM at the firm level. This article also examine the impacts of forward and backward GSCM on CTI as well as possible industry and

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home country differences. This article find that GSCM can stimulate an enterprise's CTI. And compared with forward GSCM, backward GSCM has a stronger promotion effect on CTI. However, if the dimensions of forward GSCM are considered, the incentives for CTI show a decay effect with the deepening of GSCM. Additionally, this article show that different industries and countries restrict the CTI effect of enterprises' GSCM. Light polluting industries, capital-intensive industries, and domestic companies are more sensitive to GSCM incentives.

Our contributions are twofold. First, our findings on the effects of GSCM on CTI are likely to be central for developing optimal SCM in the future. Second, this article compare the differences across several industries and countries to explain why enterprises from different countries appear distinct in the same market.

2. Theoretical background and hypothesis development

The traditional literature pays attention to the extent to which both the external environment (Lesko et al., 2017) and the internal management (Ward and Forker, 2017; Ongena and Ravesteyn, 2019) influence the operations of enterprises. However, given the limitations of internal management and continuous improvement of management systems, relying solely on managers has been unable to solve the survival dilemma facing firms. Therefore, more studies have begun to incorporate firms' stakeholders such as suppliers, retailers, consumers, and the public into the management system to examine the impact on corporate behaviour (Dawkins and Fraas, 2011; Manetti and Toccafondi, 2011). Different stakeholders influence corporate governance by providing resources and investment to the enterprise. For example, a good supplier relationship will reduce the company's operating costs and economic risks, while consumers' perceptions will affect corporate image (McWilliams and Siegel, 2000), thereby changing the company's business model and objectives.

As the influence of stakeholders on enterprises has deepened, research has increasingly focused on SCM systems that include stakeholders (Alshboul et al., 2017). The early literature on SCM focused on supplier relationship quality and firm performance, showing that high-quality supplier relationships can promote the optimal allocation of resources and improve firm performance (Song et al., 2017). However, in the face of ever-increasing market competition and pressure on operating performance, how companies use internal mechanisms to promote innovation and sustainable competition has become crucial. For companies, process innovation and new product development are important forms of innovation, but they are not the only way. As pointed out in cutting-edge literature, external supplier collaboration and internal process optimization play an equally important role in innovation. Then, studies started to examine the supplier relationship quality–technological innovation relationship for two reasons. First, managers' investment in relationship management helps form good relationships among supply chain members and promotes innovative behaviour and the realization of innovation (Woo and Ennew, 2004; Lages et al., 2009). Second, harmonious relations among the upstream and downstream suppliers of the enterprise help the knowledge flow and knowledge sharing between supply chains, promote the formation of knowledge networks and knowledge integration, and create favourable conditions for the innovation and transformation of innovation results (Su et al., 2008; Bellamy et al., 2014).

Of course, business performance and market competition are not the only incentives for enterprises to innovate. The continuous deterioration of the environment and the enhancement of corporate social responsibility make enterprises continue to reduce environmental pollution through technological innovation. At the same time, in the face of the deteriorating natural environment, firms' stakeholders have also begun to question the rationality of companies pursuing only the maximization of commercial interests, reconsider the environmental impact of corporate behaviour (Rajeev et al., 2017) and speculate whether innovation can solve the paradox of raising both firm performance and environmental protection at the same time. However, as pointed out in frontier literature, innovation alone cannot completely eliminate the dilemma between environmental protection and business performance. Green technological innovation, including environmental governance, is the source of sustainable development for enterprises. Therefore, the introduction of green development into firms' innovation is likely to improve both their own interests and their environmental performance (Saunila et al., 2018).

Green technology refers to technology that can save resources and reduce environmental pollution during the production process. Green technology innovation mainly includes innovations in green product design, process optimization, and green recycling. In SCM, the increasing interest of stakeholders in environmental issues is forcing companies to work closely with them in product development and production to achieve environmental compliance (Chiou et al., 2011). Stakeholders' environmental orientation is also prompting enterprises to optimize their internal design and production processes as well as gradually replace traditional technologies with green technologies to reduce environmental pollution. Further, it may force companies to extend their environmental management to upstream suppliers (Krause et al., 2009), requiring external manufacturers to reduce pollution emissions.

GSCM, an extension of SCM, further incorporates environmental protection and ecological development. It includes management methods that can reduce environmental pollution such as green supply, ecological protection, green manufacturing, environmental management, and responsible recycling (Shi et al., 2012; Roehrich et al., 2017). That is, a green supply chain includes internal processes and external optimization (Gimenez et al., 2012; Wolf, 2014). The evolutionary approach (Nelson and Winter 1982) and innovation through co-creation model (Prahalad and Ramaswamy, 2004) state that to cope with the environmental pressure of government departments, internal process optimization and interaction among supply chain members are necessary to promote environmentally friendly technological progress.

Suppliers are important polluters in the production chain of enterprises (Fallahpour et al., 2020). With the strengthening of environmental protection legislation, the existence of external pressure has enabled enterprises and their suppliers to continuously reduce environmental pollution in the production of parts and product development. At the same time, as the core link of product production, companies often bear greater environmental pressure, forcing them to impose higher environmental protection requirements on upstream suppliers, thereby promoting CTI in the entire industry chain. In other words, green procurement can encourage technical cooperation between enterprises and upstream suppliers, induce firms to invest in environmental protection, and promote CTI (Lee and Kim, 2011). In addition to upstream suppliers, the components of the GSCM also include downstream consumers. As consumers' awareness of environmental protection continues to increase, they are often more inclined to buy green products, which further forces companies to carry out CTI to meet market demand. Consumers' environmental demands stimulate enterprises to improve production processes and technical levels, and force them to pursue CTI (Vachon and Klassen, 2006). That is, adopting sustainable development methods including GSCM can reduce the discharge of harmful substances and promote the recycling and reuse of waste (Tsoulfas and Pappis, 2006; Chien and Shih, 2007).

In general, incorporating environmental protection into internal production processes and external supplier materials, technologies, and transportation has contributed more to reducing environmental damage than management in other organizational areas (Carter and Rogers, 2008). At the same time, GSCM has become a path for managers of small and medium-sized enterprises to assume environmental responsibility and promote sustainable development (Ilyas et al., 2020). Therefore, GSCM is a driving force of CTI (Rao, 2002; Seman et al., 2019). This leads to the first hypothesis in the present study:

Hypothesis 1. A firm's GSCM is positively related to CTI. Moreover, the direction of GSCM (forward/backward) also has a different impact on CTI.

Companies in different industries do not behave the same when carrying out economic activities and inevitably have different coping methods when facing the same market scenario (Darnall et al., 2008). In the same industry, a similar market environment and degree of knowledge accumulation mean that enterprises have similar innovation strategies (Winter 1984). Generally speaking, labor-intensive and capital-intensive enterprises are quite different, and their management systems and system construction also have different preferences. In contrast, labor-intensive companies are often at the bottom of the production chain and rely more on large-scale manual labor for production. The construction of a GSCM system often requires higher costs, and labor-intensive companies are more sensitive to cost increases than capital-intensive companies, and lack the motivation for GSCM and innovation. The difference in the degree of corporate pollution is also an important factor that affects corporate decision-making. Compared with light-polluting companies, heavy-polluting companies have the characteristics of heavy assets and high emissions. The existence of industry characteristics makes heavy-polluting companies face greater internal obstacles in reducing emissions. And the construction of the green supply chain system also takes more time and cost. Therefore, the CTI effect of the GSCM of light-polluting enterprises is greater than that of the GSCM. In general, industry characteristics lead to the different effects of CTI on the GSCM of enterprises in different sectors.

Further, foreign companies are more willing to adopt environmentally friendly management systems than domestic companies when they first enter the market of a country as well as CTI (Eskeland and Harrison, 2003). However, enterprises are not independent individuals, and their production and operation often rely on the entire industrial chain including suppliers and consumers. Owing to the existence of an 'outsider disadvantage', foreign-funded enterprises face more institutional conflicts and cost disadvantages than domestic enterprises (Eden and Miller, 2004). In China, technical cooperation between supply chain members (Cheng and Shiu, 2012) and the maintenance of relationships are more susceptible to the influence of human relations. Compared with foreign-funded enterprises, it is easier for local enterprises to build a good relationship with upstream suppliers, and it is easier for the construction of a green supply chain system to obtain the understanding and cooperation of suppliers. At the same time, with the continuous development of China's economy, Chinese consumers' awareness of environmental protection has continued to increase. Similar cultural traditions have made it easier for local companies to perceive changes in consumer demand. Therefore, this outsider disadvantage may thus make foreign enterprises' GSCM effect inferior to that of domestic companies. In summary, the same environmental policy has different impacts on CTI in different industries (Alpay et al., 2002) and companies in different regions (Li and Zhang, 2016). This leads to our second hypothesis:

Hypothesis 2. The impact of GSCM on CTI depends on the industry characteristics of the company. Moreover, the CTI effect of the GSCM of domestic companies is greater than that of foreign companies.

3. Methodology

To analyse the impact of GSCM on CTI, this article adopt the following benchmark regression model: Eqn 1

$$CTI_{it} = \alpha_0 + \alpha_1 GSCM_{it} + \alpha_2 X_{it} + \alpha_3 Z_{it} + \alpha_4 C_{it} + \sigma_{it} \quad (1)$$

where CTI_{it} represents the clean technology innovation of enterprise i in year t, which is characterized by the number of clean technology patents; $GSCM_{it}$ is the level of the enterprise's green supply chain management; X_{it}, Z_{it}, and C_{it} are the control variables for enterprise, industry, and country, respectively; and σ_{it} is the random error.

In this study, the dependent variable is CTI. In the literature, there are three main ways to measure CTI. The first is to incorporate undesirable outputs such as SO_2, CO_2, and industrial waste into a stochastic frontier function or data envelopment analysis model and then characterize CTI by measuring green total factor productivity (Li et al., 2016). Under the second approach, CTI is divided into process innovation, product innovation, and end-of-line governance (Amores-Salvadó et al., 2014; Camisón and Villar-López, 2014). Third, CTI is represented by the number of clean technology patents (Chen et al., 2016).

Calculating green total factor productivity requires the accurate selection of green inputs and outputs. However, problems in the selection of the index could cause large errors in the measurement results. In addition, the companies selected in this study cover different countries and industries, and the availability of data makes it difficult to accurately distinguish between process and product innovation. Therefore, this study uses the clean technology patent codes in the IPC Green Inventory and matches the patent code of each company on the website of the National Intellectual Property Administration. This article then select the number of clean technology patents of each company to measure its CTI level.

The moderator variable is GSCM from the IPEA/NRDC report. Firms' GSCM is generally measured using questionnaires, which may make the empirical results less objective and credible. The IPEA/NRDC report provides an evaluation system for firms' GSCM based on the following five aspects: communication and response, compliance and rectification actions, green supply chain extension, data disclosure, and responsibility recovery. This evaluation system includes environmental violation records, supply chain pollution, supplier rectification, emission reduction data disclosure, and waste product recycling among other indicators. Communication and response is the company's response to environmental pollution from upstream suppliers. Compliance and rectification actions represent whether companies communicate with their upstream suppliers and require them to rectify environmental violations. Green supply chain extension represents whether companies recommend that upstream suppliers conduct GSCM to reduce environmental pollution. Data disclosure represents whether companies require suppliers to disclose environmental information. Responsible recycling represents whether the company recycles its products and reduces possible environmental pollution. This report collects environmental monitoring information on enterprises to dynamically evaluate their GSCM and finally obtain the CITI index. This makes the GSCM evaluation index highly objective and accurate.

There are eight control variables:

(1) Firm size (*sca*): Firm size is characterized by the annual total assets of each enterprise. The economies of scale and innovation hypotheses suggest that the fine-grained division of labour by industry and relatively comprehensive resource endowment of large-scale enterprises could enable them to reduce production costs, avoid market risks, and increase financing scale. This provides a guarantee for the company's continuous R&D investment and promotes CTI; however, Mansfield (1988) shows that raising firm size inhibits the development of technological innovation.
(2) Return on assets (*pro*): This is expressed by the annual net return on total assets.
(3) Firm profitability (*per*): Firm profitability is measured by the ratio of the annual net return of each enterprise to the income of the main business. Enterprises with stronger profitability and better performance invest more in R&D to enhance their green innovation capabilities, which may also inhibit their innovation motive because of higher profits.
(4) Debt structure (*debt*): This is measured by the ratio of the total annual debt of each enterprise to total assets. The debt structure represents the capital status that an enterprise can use for its production and operation activities and reflects the capital risk of

the enterprise. Excessive debt risk affects companies' investment in R&D innovation, thereby inhibiting their technological innovation.

(5) Firm maturity (*mat*): Firm maturity is represented by the time from the establishment of each enterprise. Enterprises with a long history have accumulated more technology and knowledge reserves, which is conducive to the success of firm-level innovation (Sorensen and Stuart, 2000). Further, more mature companies appear to have a higher sense of social responsibility, which offers more powerful incentives for CTI.

(6) Board governance (*ds*): This is represented by the number of boards members in each enterprise. Excellent board governance can effectively respond to changes in the business environment and continuously adjust to the business strategy of the company to promote CTI.

(7) Industry competition (*ind*): Competition is represented by the inverse of the number of companies in each industry. Industry competition has two distinct effects on CTI. First, the intensification of industry competition squeezes an enterprise's R&D investment, cutting CTI. Second, the intensification of competition stimulates enterprises to seize market share through technological innovation (Nesta et al., 2012).

(8) Environmental regulation (*enr*): This is expressed by total investment in regional environmental pollution treatment. Research on the impact of environmental regulation on CTI is mixed. Hanamoto (2006) and Horbach (2008) show that technological innovation promoted by moderate environmental regulation brings about higher revenue compensation to enterprises, which in turn raises the motivation to conduct CTI. Popp et al. (2009) argue that this compensation effect only works in the long term, however, and that the squeeze-out effect of environmental regulation in the short term is stronger, thus cutting CTI.

This study selects panel data of 501 groups of micro-enterprises operating in China. The sample spans from 2014 to 2016, of which 141 companies in 2014, 162 companies in 2015, and 198 companies in 2016; local companies accounted for 29% of the total sample. The GSCM data come from the China Market Green Supply Chain Index Report released by the IPEA/NRDC, a third-party organization. The CTI data is manually retrieved from the National Patent Network according to the International Green Innovation Patent Classification Code. The original data on firm size, return on assets, firm profitability, debt structure, firm maturity, and board governance come from the enterprise's annual report. The data on environmental regulation comes from the China Statistical Yearbook. Missing data are replaced using the mean method. Part of the data in this article comes from Li et al.(2019).

The descriptive statistics of each variable are shown in Table 1. The maximum value of CTI of an enterprise is 8.151 and the minimum value is 0, indicating that there are huge differences in CTI among different enterprises; the maximum value of GSCM is 4.394, and the minimum value is 0, which shows that the decision-making of the GSCM behaviour of the enterprise has obvious individual characteristics.

Table 1
Descriptive statistics.

Variable	Obs	Mean	Std.Dev.	Min	Max
Gti	501	1.594	2.138	0	8.151
Citi	501	2.158	1.309	0	4.394
Mat	501	68.754	44.504	4	191
Sca	501	8.205	3.183	2.167	22.249
Pro	501	0.073	0.064	−0.189	0.294
Per	501	0.058	0.052	−0.211	0.26
Debt	501	0.509	0.229	0	1.3
Ds	501	9.192	4.326	1	38
Enr	501	9.125	0.033	9.083	9.167
Ind	501	0.048	0.037	0.016	0.167

4. Estimation results

4.1. Benchmark regression

To measure the impact of GSCM on CTI, this article use the ordinary least squares method to perform the regression analysis based on the 501 samples of unbalanced panel data. Table 2 presents the results, showing that regardless of whether the company-, industry-, or country-level control variables are added, GSCM has a significantly positive impact on CTI at the 1% level; that is, GSCM significantly promotes CTI, consistent with the findings of Chiou et al. (2011) and Lee and Kim (2011). The enhanced competitiveness brought about by the enterprise's GSCM provides a superior market environment for CTI. Firm maturity (*mat*) and return on assets (*pro*) are positive at significance levels of 1% and 10%, respectively, which indicates that a strong economies of scale effect in CTI and enhanced asset returns provide more financial support for clean R&D. The impact of firm profitability (*per*) is negative at the significance level of 1%, which may be because the R&D inertia generated by companies with excellent profitability reduces R&D investment. The board governance (*ds*) coefficient is positive at a significance level of 1%, indicating that the business improvement and development prospects brought about by excellent board governance are effective (see Table 2).

4.2. Endogeneity tests

4.2.1. Influence of unobservable variables

Although the above benchmark regression and stability tests partially verify the CTI effect of GSCM, such empirical results may still have estimation errors, including whether omitted unobservable variables are considered. This article follow Altonji et al. (2005) and Nunn and Wantchekon (2011) by estimating the impact of unobservable variables on firms' CTI based on the effects of the observable variables in the benchmark regression. Specifically, this article construct two basic regressions: one considers only the constrained variables (coefficient = ν_1) and the other includes the control variable (coefficient = ν_2). The impact of unobservable variables is examined following $\beta = |\nu_2 / (\nu_1 - \nu_2)|$. If $\nu_1 - \nu_2$ is low, it indicates that the addition of observable control variables has a smaller impact on the GSCM coefficient. When some unobserved and unconsidered variables have a much greater impact on

Table 2
CTI effects of GSCM (1).

Variable	Model 1	Model 2	Model 3	Model 4
GSCM	0.368***	0.315***	0.323***	0.322***
	(0.0713)	(0.0759)	(0.0793)	(0.0795)
Mat		−0.000589	−0.0007	−0.000694
		(0.00215)	(0.00217)	(0.00218)
Sca		0.0999***	0.0995***	0.0995***
		(0.0312)	(0.0313)	(0.0313)
Pro		4.827**	4.881**	4.875**
		(2.316)	(2.323)	(2.326)
Per		−10.58***	−10.74***	−10.73***
		(2.948)	(2.984)	(2.988)
debt		−0.409	−0.424	−0.422
		(0.421)	(0.424)	(0.424)
Ds		0.0616***	0.0619***	0.0619***
		(0.0220)	(0.0220)	(0.0221)
ind			0.896	0.863
			(2.606)	(2.616)
enr				0.467
				(2.807)
_cons	0.800***	0.0417	0.00218	−4.256
	(0.180)	(0.403)	(0.419)	(25.60)
N	501	501	501	501
R^2	0.051	0.103	0.103	0.103

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

CTI than the control variables under consideration, the empirical results will have a large deviation.

This article construct three control regressions (see Table A1 in the Appendix) to investigate the effects of these unobservable variables. This article find that the values of β in the three groups of control regressions are 5.94, 7.18, and 7, which are all greater than 1. This means that if the unobservable variables make the benchmark regression result have a large deviation, its impact on CTI should be 5.94 times more than that of the control variables. Obviously, the CTI effect of GSCM cannot be more than 5.94 times the unobservable variables. Hence, according to Altonji et al. (2005) and Nunn and Wantchekon (2011), if the value of β is greater than 1, the effects of unobservable variables can be ignored.

4.2.2. Endogenous treatment

As GSCM promotes firms' CTI, the process optimization and industry collaboration brought about by CTI will also improve the GSCM of enterprises. Therefore, the relationship between GSCM and CTI may show reverse causality. To eliminate the possible negative effects of CTI, This article select the average level of GSCM in various industries as an instrumental variable of the company's GSCM to alleviate possible endogeneity problems.

Table A2 in the Appendix reports the empirical results using the average GSCM level of each industry and two-stage least squares method. Models 1 and 2 include only the core variables. Models 3 to 8 add the control variables as before. Model 1, Model 3, Model 5, and Model 7 are the first-stage regression results, while Model 2, Model 4, Model 6, and Model 8 are the second-stage regression results. They show that the influence of the instrumental variable on the green supply chain before and after adding the control variables in order is positive at a significance level of 1%. Further, the F value of each model is greater than 10, which excludes the possibility of weak instrumental variables. Hence, our empirical tests using instrumental variables to resolve the endogeneity issue again show that GSCM can significantly promote CTI. However, the coefficient of GSCM after mitigating endogeneity problems is much greater than the benchmark coefficient in Table 1 in other words, the potential reverse causality problem underestimates the incentive effect of GSCM on CTI.

4.3. Robustness checks

4.3.1. Lag one period

To test whether GSCM has an ongoing effect on CTI, this article conduct a first-order lag process. Table A3 shows the results. Model 1 is the baseline model and Model 2 add the firm-, industry-, and country-level control variables, respectively. This article find that regardless of whether the control variables are added, the GSCM coefficient is positive at a significance level of 1%, concurring with the results in Table 1. This means that the establishment of a strict GSCM system can continue to stimulate CTI.

4.3.2. Balanced panel data

To test the robustness of the impact of GSCM on CTI, this article filter the 501 samples to exclude the unbalanced panel data and test the remaining 423 samples of balanced panel data. Table A3 in the Appendix presents the results, showing that regardless of whether the control variables are added, the coefficients of the green supply chain (0.416 and 0.397) and benchmark regression coefficients (0.368 and 0.322) are positive at a significance level of 1%. That is, GSCM still plays an important role in promoting CTI.

4.3.3. Replacement explanatory variable

To further test the stability of the impact of GSCM, this article replace the GSCM variable value in the benchmark regression with binary variables (1 = company performs GSCM and 0 = otherwise). The results are shown in Table A3, where Model 5 is the baseline regression with only the core explanatory variables and Model 8 add the firm-, industry-, and country-level control variables, respectively. Again, regardless of whether the control variables are added, the coefficients remain positive at a significance level of 1%.

5. Heterogeneity tests

5.1. Forward and backward GSCM

As discussed earlier, in the IPEA/NRDC report, GSCM includes five aspects: communication and response, compliance and rectification actions, green supply chain extension, data disclosure, and responsibility recovery. Among these five dimensions, the first three represent forward GSCM, while data disclosure and responsibility recovery represent backward GSCM. This article next explore whether there are differences in the effects of forward and backward GSCM on CTI.

5.1.1. CTI effect of forward GSCM

Table 3, Models 1 and 2 represent communication and response, Models 3 and 4 represent compliance and rectification actions, and Models 5 and 6 represent green supply chain extension. Models 1, 3, and 5 are the results of the baseline regressions, while Models 2, 4, and 6 add the control variables. As before, regardless of whether the control variables are added, all the coefficients are significantly positive. The coefficient of green supply chain extension is the largest, followed by those of communication and response and compliance and rectification actions. This heterogeneous effect depends on the progressive nature of forward GSCM: the CTI effect of forward GSCM presents a 'decay effect', as it enables enterprises to communicate with and restrict upstream suppliers, thereby promoting the creation of green product and process innovation and ultimately achieving the coordinated development of clean technology.

5.1.2. CTI effect of backward GSCM

Here, Models 1 and 2 represent data disclosure and Models 3 and 4 responsibility recovery. Models 1 and 3 are again the baseline regressions and Models 2 and 4 include the control variables. The results in Table 4 show that the impact of responsible recycling is positive at a significance level of 1% (0.544 and 0.460), which means that responsible recycling can improve firms' CTI. The impact of data disclosure is positive but the significance level varies depending on the control variables. Responsible recycling saves firms raw materials, reduces product costs, increases product recyclability, and reduces environmental pollution, which forces companies to continuously improve their production processes and innovate in clean technology. Compared with forward GSCM, backward GSCM has a greater incentive to pursue CTI. The reason is that backward GSCM, such as responsibility recovery, can improve product utilization and directly reduce production costs, thus stimulating CTI.

5.2. Industry heterogeneity

Different industries have different market structures and development paths, which may affect GSCM differently. The industries in our sample are classified by polluting level (heavy and light) and intensity (capital-intensive and labour-intensive). First, following the classification of heavy polluting industries in the Guide to Environmental Information Disclosure of Listed Companies published by the Ministry of Environmental Protection in 2010, heavy polluting industries include textiles, chemicals, beer, paper products, and leather products, while light polluting industries include IT, food and beverage, and automotive. Table 5 shows the results. Models 1 and 2 represent heavy polluting industries and Models 3 and 4 light polluting industries. The results show that the GSCM coefficients in both are significantly positive (5% and 1%, respectively). Again, GSCM stimulates CTI. The CTI effect of GSCM in light polluting industries is greater than that in heavy polluting

Table 3
CTI effects of forward GSCM.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
gt	0.0754***	0.0481*				
	(0.0220)	(0.0250)				
hg			0.0475***	0.0382***		
			(0.0119)	(0.0142)		
ys					0.0883***	0.0579*
					(0.0275)	(0.0317)
mat		0.000400		0.000202		0.000805
		(0.00219)		(0.00218)		(0.00217)
sca		0.117***		0.103***		0.111***
		(0.0315)		(0.0324)		(0.0325)
pro		4.973**		5.229**		5.213**
		(2.358)		(2.345)		(2.355)
per		−9.846***		−10.23***		−10.13***
		(3.017)		(3.011)		(3.024)
debt		−0.432		−0.0988		−0.230
		(0.432)		(0.456)		(0.458)
ds		0.0665***		0.0687***		0.0677***
		(0.0223)		(0.0222)		(0.0223)
ind		−0.0497		0.307		−1.251
		(2.772)		(2.693)		(2.590)
enr		0.650		1.013		1.119
		(2.848)		(2.828)		(2.839)
_cons	1.229***	−5.738	1.309***	−9.117	1.421***	−9.939
	(0.143)	(25.98)	(0.118)	(25.80)	(0.109)	(25.91)
N	501	501	501	501	501	501
R^2	0.023	0.080	0.031	0.086	0.020	0.079

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

Table 4
CTI effects of backward GSCM.

Variable	Model 1	Model 2	Model 3	Model 4
sj	0.0549*	0.0275		
	(0.0303)	(0.0336)		
zr			0.544***	0.460***
			(0.0756)	(0.0807)
mat		0.000714		0.000445
		(0.00220)		(0.00211)
sca		0.123***		0.0874***
		(0.0323)		(0.0308)
pro		5.058**		4.294*
		(2.372)		(2.294)
per		−9.926***		−8.516***
		(3.032)		(2.941)
debt		−0.463		−0.0406
		(0.437)		(0.426)
ds		0.0708***		0.0473**
		(0.0223)		(0.0220)
ind		−2.081		−1.580
		(2.549)		(2.468)
enr		1.201		2.162
		(2.849)		(2.765)
_cons	1.494***	−10.58	1.293***	−19.29
	(0.110)	(26.00)	(0.100)	(25.23)
N	501	501	501	501
R^2	0.007	0.074	0.094	0.130

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

industries, suggesting that GSCM has a stronger incentive effect on CTI in light polluting industries, perhaps because of the lower environmental burden and because enterprise-level GSCM is conducive to faster production process transformation and technology upgrading.

Second, the sample enterprises are divided into capital-intensive and labour-intensive industries according to factor input standards. Capital-intensive industries include IT and automotive companies, whereas labour-intensive industries include the food and beverage, textiles, chemicals, beer, paper products, and leather products sectors. Models 5–8 of Table 5 show the results. The GSCM coefficients of capital-intensive industries are significant, while those of labour-intensive industries are not. This indicates that the incentives for CTI under GSCM only occur in capital-intensive industries, perhaps because labour-intensive industries are more dependent on a large labour force, firm performance is relatively weak, and companies lack sufficient funds or motivation for GSCM.

5.3. Home country heterogeneity

Different countries have their own factor endowments, market structures, and environmental regulations. When analysing the CTI effects of GSCM, the country of origin of enterprises should thus be fully considered. This article first divide the sample into domestic and foreign enterprises and then explore the different role of GSCM by foreign companies. Owing to the small number of enterprises in some countries, this article only consider samples with a large amount of data in their countries or regions. Specifically, only US and European companies are considered. Table 6 shows the results. Models 1 and 2 represent domestic and foreign companies, respectively, while Models 3 and 4 represent US and European companies, respectively. The GSCM coefficients of domestic and foreign companies are both positive at 1%, with domestic companies' GSCM providing a much greater incentive to pursue CTI than that of foreign companies. Compared with the high standard of environmental requirements in Europe, China is still in the process of transitioning from an extensive economy to an intensive economy and the high pollution emissions of domestic companies generally make GSCM more effective. The promotion of cleaner innovation is also greater. Meanwhile, among foreign companies, the coefficients of European companies are significant, while those of US companies are not.

6. Conclusion

This study investigateds the CTI effect of forward and backward GSCM as well as the differences by industry and home country, while previous studies focus on the effects of external policies and how they hamper CTI, paying limited attention to the internal effect of enterprises' GSCM. The results first show that GSCM can stimulate an enterprise's CTI; these results remain robust to using balanced panels,

Table 5
Heterogeneity test by industry.

	Heavy polluting industries		Light polluting industries		Capital-intensive industries		Labour-intensive industries	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
GSCM	0.0969**	0.152***	0.604***	0.738***	0.107**	0.146***	0.0940	0.188
	(0.0445)	(0.0496)	(0.132)	(0.169)	(0.0416)	(0.0456)	(0.154)	(0.193)
mat		−0.000181		0.000303		−0.00126		0.00146
		(0.00140)		(0.00389)		(0.00130)		(0.00428)
sca		−0.00432		−0.0616		−0.0124		−0.0513
		(0.0232)		(0.0548)		(0.0220)		(0.0535)
pro		6.399***		−2.951		5.301***		−7.408*
		(1.629)		(3.856)		(1.495)		(4.036)
per		−8.005***		−7.637		−5.694***		3.906
		(2.270)		(4.843)		(1.978)		(5.388)
debt		−0.580*		−0.811		−0.320		−0.388
		(0.336)		(0.706)		(0.281)		(0.734)
ds		−0.0294		−0.0395		−0.0147		−0.0601*
		(0.0183)		(0.0329)		(0.0164)		(0.0326)
ind		4.004***		13.41		3.373**		7.758
		(1.428)		(8.226)		(1.399)		(8.214)
enr		−0.200		−0.836		−1.072		1.138
		(1.847)		(4.629)		(1.701)		(5.016)
_cons	0.317***	2.393	1.609***	10.47	0.343***	10.30	3.805***	−5.560
	(0.110)	(16.84)	(0.343)	(42.20)	(0.0992)	(15.52)	(0.433)	(45.76)
N	284	284	217	217	352	352	149	149
R^2	0.017	0.116	0.088	0.161	0.019	0.081	0.003	0.067

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

Table 6
Heterogeneity tests by home country.

Country	Model 1	Model 2	Model 3	Model 4
	Domestic companies	Foreign companies	US companies	European companies
GSCM	0.430***	0.353***	0.182	0.292**
	(0.153)	(0.0960)	(0.127)	(0.128)
Mat	0.00171	0.00453*	−0.000828	0.00560*
	(0.00624)	(0.00265)	(0.00355)	(0.00311)
Sca	0.0308	0.137***	0.198***	−0.0439
	(0.0618)	(0.0358)	(0.0471)	(0.0644)
pro	2.457	6.829**	10.09***	3.745
	(4.146)	(2.763)	(3.631)	(3.836)
per	−11.73**	−13.26***	−14.31***	−11.59**
	(5.724)	(3.485)	(5.007)	(4.974)
debt	0.512	−1.222**	−1.259**	−1.585**
	(0.778)	(0.502)	(0.636)	(0.736)
ds	0.227***	0.0387*	0.0973**	0.0296
	(0.0637)	(0.0233)	(0.0470)	(0.0331)
ind	−10.97**	4.152	−0.0735	2.689
	(4.615)	(3.116)	(4.793)	(3.273)
enr	0.138	0.800	−2.113	2.810
	(4.882)	(3.287)	(4.054)	(4.043)
_cons	−1.544	−7.835	18.18	−24.71
	(44.55)	(29.98)	(36.98)	(36.89)
N	147	354	153	134
R^2	0.236	0.143	0.260	0.136

Note: Standard errors are in parentheses, and ***, **, and * indicate significant at the levels of 1%, 5%, and 10%, respectively.

different independent variables, unobservable variables, and instrumental variables. Second, this study finds that compared with forward GSCM, backward GSCM has a stronger promotion effect on CTI. However, if the dimensions of forward GSCM are considered, the incentives for CTI show a decay effect with the deepening of GSCM. Third, CTI affects enterprises' GSCM heterogeneously across different countries and industries. Light polluting industries, capital-intensive industries, and domestic companies are more sensitive to GSCM incentives. After further exploring the heterogeneity between domestic and foreign companies, this article concludes that the CTI effect on European companies is more sound.

Although empirical evidence shows that GSCM can improve CTI of enterprises, statistics show that more companies engaged in GSCM come from multinational companies with strong comprehensive strength, and more SMEs lack the awareness of GSCM. To guide more companies to optimize the supply training system and achieve full coverage of the green supply chain, this article puts forward the following policy recommendations: First, the dual role of the government and the market should be brought into full play, and the role of GSCM in achieving sustainable development should be promoted and popularized. Based on strengthening the communication and cooperation of industry associations, the government should establish a reward and punishment mechanism that is compatible with laws and regulations, forcing companies to reduce environmental pollution in the supply chain system. Second, pay attention to the differences in different management directions of the green supply chain, and accurately identify upstream supplies The difference between environmental protection demands of businesses and downstream consumers in promoting enterprises to conduct GSCM enables policy interventions to exert greater effects and more targeted. Third, adhere to the principle of "adjusting measures to production conditions and local conditions" and fully considering industry characteristics and differences, light pollution and heavy pollution, labor-intensive and capital-intensive, local and foreign-funded enterprises should carry out GSCM based on their circumstances, and make them develop in a direction conducive to CTI.

The research quantitatively examines the relationship between GSCM and CTI based on micro-enterprise data, and the conclusion improves the existing theories. First, the study confirm the stakeholder theory: as an important stakeholder in business decision-making, the behavioral patterns of upstream suppliers and downstream consumers will determine the business decision-making. In addition to relying on themselves, companies that want to achieve green transformation will need the joint actions of stakeholders. Secondly, the research in this article believes that local companies have better performance than foreign companies, which further verifies the existence of "outsiders' disadvantage". Therefore, in the process of attracting investment, especially foreign investment, the government should focus on the impact of the possible economic distance and legal system distance between the home country and the host country on the operation of foreign-funded enterprises.

The potential weakness of this study lies in sample selection. Due to the lack of data and the difficulty of obtaining it, this article only conducts empirical tests on micro-enterprises in the Chinese market. However, there are differences in the stage of economic development, the degree of government intervention, and the public's environmental protection demands between developed and developing countries, and even between different countries. Therefore, the basic conclusions of this article still need to be further tested in other countries and regions, and expanding the scope of research has become a direction of future research. In addition, the internal operating model of the enterprise and the role played by the management in the GSCM should not be ignored, and would become a fruitful area for future research.

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.

Appendix

Table A1
Impact of unobservable variables

Constrained variable	Contains control variables	β
Core explanatory variables	Core explanatory variables + firm control variables	5.94
Core explanatory variables	Core explanatory variables + firm and industry control variables	7.18
Core explanatory variables	Core explanatory variables + firm, industry, and country control variables	7

Table A2
Regression results of the instrumental variables

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Variable	*GSCM*	*CTI*	*GSCM*	*CTI*	*GSCM*	*CTI*	*GSCM*	*CTI*
GSCM-hpj	1***		0.991***		0.92***		0.918***	
	(0.09806)		(0.0937)		(0.115)		(0.117)	
GSCM		1.581***		1.441***		2.214***		2.259***
		(0.215)		(0.211)		(0.341)		(0.350)
mat			0.006***	−0.0057**	0.006***	−0.011***	0.006***	−0.011***
			(0.0011)	(0.00270)	(0.0011)	(0.00359)	(0.0011)	(0.00365)
Sca			0.072***	−0.0145	0.074***	−0.0850	0.074***	−0.0893
			(0.0164)	(0.0420)	(0.0165)	(0.0553)	(0.0165)	(0.0562)
Pro			−0.104	2.687	−0.094	2.660	−0.094	2.653
			(1.252)	(2.786)	(1.252)	(3.401)	(1.253)	(3.442)
Per			4.688**	−12.20***	4.732**	−16.29***	4.731**	−16.48***
			(1.607)	(3.527)	(1.608)	(4.443)	(1.609)	(4.504)
debt			−0.332	0.174	−0.309	0.189	−0.309	0.190
			(0.225)	(0.512)	(0.226)	(0.625)	(0.227)	(0.633)
Ds			0.0132	0.0263	0.0134	0.0141	0.0134	0.0136
			(0.0118)	(0.0269)	(0.0118)	(0.0331)	(0.0118)	(0.0335)
Ind					−1.749	18.69***	−1.76	19.30***
					(1.646)	(4.850)	(1.665)	(4.970)
Enr							0.0829	−3.371
							(1.519)	(4.180)
_cons	−4.31e-08	−1.818***	−1.177***	−0.821	−0.971**	−2.114***	−1.726	28.58
	(0.2183)	(0.479)	(0.2817)	(0.502)	(0.342)	(0.708)	(13.818)	(38.08)
N	501	501	501	501	501	501	501	501
F	103.99	.	32.06	.	28.2	.	25.02	.

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

Table A3
Robustness check

Variable	Model 1	Model 4	Model 3	Model 4	Model 5	Model 6
GSCM	0.387***	0.356***	0.416***	0.397***	1.164***	1.095***
	(0.0881)	(0.100)	(0.0790)	(0.0900)	(0.241)	(0.249)
Mat		−0.00193		−0.00053		−0.00002
		(0.00284)		(0.00244)		(0.00214)
Sca		0.0564		0.0674**		0.115***
		(0.0408)		(0.0337)		(0.0305)
Pro		2.645		4.244		5.111**
		(2.912)		(2.598)		(2.318)
Per		−5.239		−9.27***		−11.11***
		(3.784)		(3.282)		(2.986)
Debt		−0.457		−0.630		−0.786*
		(0.564)		(0.470)		(0.427)
Ds		0.0626**		0.0501**		0.061***
		(0.0285)		(0.0240)		(0.0220)
Ind		2.521		2.798		−0.544

(continued on next page)

Table A3 (*continued*)

Variable	Model 1	Model 4	Model 3	Model 4	Model 5	Model 6
		(4.167)		(2.872)		(2.525)
Enr		0.642		−0.423		1.265
		(5.309)		(3.005)		(2.795)
_cons	0.840***	−5.624	0.771***	4.086	0.644***	−11.65
	(0.223)	(48.38)	(0.207)	(27.42)	(0.218)	(25.50)
N	303	303	423	423	501	501
R^2	0.060	0.087	0.062	0.097	0.045	0.108

Note: Standard errors are in parentheses, and ***, **, and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

References

Acemoglu, D., Aghion, P., Bursztyn, L., 2012. The environment and directed technical change. Am. Econ. Rev. 102 (1), 131–166.

Alpay, E., Buccola, S., Kerkvlie, J., 2002. Productivity growth and environmental regulation in Mexican and US food manufacturing. Am. J. Agric. Econ. 84 (4), 887–901.

Alshboul, M.A., Barber, K.D., Garzareyes, J.A., Kumar, V., Abdi, M.R., 2017. The effect of supply chain management practices on supply chain and manufacturing firms' performance. J. Manuf. Technol. Manag. 28 (5), 577–609.

Altonji, J.G., Elder, T.E., Taber, C.R., 2005. Selection on observed and unobserved variables: assessing the effectiveness of catholic schools. J. Polit. Econ. 113 (1), 151–184.

Amores-Salvadó, J., Martín-de-Castro, G., Navas-López, J.E., 2014. Green corporate image: moderating the connection between environmental product innovation and firm performance. J. Clean. Prod. 83, 356–365.

Bellamy, M.A., Ghosh, S., Hora, M., 2014. The influence of supply network structure on firm innovation. J. Oper. Manag. 32 (6), 357–373.

Camisón, C., Villar-López, A., 2014. Organizational innovation as an enabler of technological innovation capabilities and firm performance. J. Bus. Res. 67 (1), 2891–2902.

Carter, C., Rogers, D., 2008. A framework of sustainable supply chain management: moving toward new theory. Int. J. Phys. Distrib. Logist. Manag. 38 (5), 360–387.

Chen, Y., Han, B., Liu, W., 2016. Green technology innovation and energy intensity in China. Nat. Hazards 84 (1), 317–332.

Cheng, C.C., Shiu, E.C., 2012. Validation of a proposed instrument for measuring eco-innovation: an implementation perspective. Technovation 32 (6), 329–344.

Chien, M., Shih, L.H., 2007. An empirical study of the implementation of green supply chain management practices in the electrical and electronic industry and their relation to organizational performances. Int. J. Environ. Sci. Te. 4, 1735-1472.

Chiou, T.Y., Chan, H.K., Lettice, F., Chung, S.H., 2011. The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. Transport. Res. E-Log. 47 (6), 822–836.

Christmann, P., Taylor, G., 2001. Globalization and the environment: determinants of firm self-regulation in China. J. Int. Bus. Stud. 32 (3), 439–458.

Cousins, P.D., Lawson, B., Petersen, K.J., Fugate, B., 2019. Investigating green supply chain management practices and performance: the moderating roles of supply chain ecocentricity and traceability. Int. J. Oper. Prod. Manag. 39 (5), 767–786.

Darnall, N., Henriques, I., Sadorsky, P., 2008. Do environmental management systems improve business performance in an international setting. J. Int. Manag. 14 (4), 364–376.

Dawkins, C., Fraas, J., 2011. Beyond acclamations and excuses: environmental performance, voluntary environmental disclosure and the role of visibility. J. Bus. Ethics 99, 383–397.

Eden, L., Miller, S.R., 2004. Distance matters? Liability of foreignness, institutional distance and ownership strategy. Adv. Int. Manag. 16 (3), 187–221.

Eskeland, G.S., Harrison, A.E., 2003. Moving to greener pastures? Multinationals and the pollution haven hypothesis. J. Dev. Econ. 70 (1), 1–23.

Fallahpour, A., Wong, K.Y., Rajoo, S., Mardani, A., 2020. An integrated fuzzy carbon management-based model for suppliers' performance evaluation and selection in green supply chain management. Int. J. Fuzzy Syst. 22 (2), 712–723.

Geffen, C., Rothenberg, S., 2000. Sustainable development across firm boundaries: the critical role of suppliers in environmental innovation. Int. J. Oper. Prod. Manag. 20 (2), 166–186.

Gimenez, C., Sierra, V., Rodon, J., 2012. Sustainable operations: their impact on the triple bottom line. Int. J. Prod. Econ. 140 (1), 149–159.

Gunasekaran, A., Spalanzani, A., 2012. Sustainability of manufacturing and services: investigations for research and applications. Int. J. Prod. Econ. 140 (1), 35–47.

Gupta, H., Barua, M.K., 2018. A grey DEMATEL-based approach for modeling enablers of green innovation in manufacturing organizations. Environ. Sci. Pollut. Res. 25 (1), 1–23.

Hanamoto, M., 2006. Environmental regulation and the productivity of Japanese manufacturing industries. Resour. Energy Econ. 28 (4), 299–312.

Horbach, J., 2008. Determinants of environmental innovation: new evidence from German panel data sources. Res. Pol. 37 (1), 163–173.

Ilyas, S., Hu, Z., Wiwattanakornwong, K., 2020. Unleashing the role of top management and government support in green supply chain management and sustainable development goals. Environ. Sci. Pollut. Res. 27 (4), 8210–8223.

Kogan, L., Papanikolaou, D., Seru, A., Stoffman, N., 2017. Technological innovation, resource allocation and growth. Q. J. Econ. 132 (2), 665–712.

Krause, D., Vachon, S., Klassen, R., 2009. Special topic forum on sustainable supply chain management: introduction and reflections on the role of purchasing management. J. Supply Chain Manag. 45 (4), 18–24.

Lages, L.F., Silva, G., Styles, C., 2009. Relationship capabilities, quality, and innovation as determinants of export performance. J. Int. Market. 17 (4), 47–70.

Lesko, O., Prychepa, I., Lesko, T., 2017. Development of approach to anticipatory risk management of the enterprise under uncertainty conditions. Technol. Audit Prod. Reserves 4 (36), 4–15.

Lee, K.H., Kim, J.W., 2011. Integrating suppliers into green product innovation development: an empirical case study in the semiconductor industry. Bus. Strat. Environ. 20 (8), 527–538.

Li, G., Shao, S., Zhang, L., 2019. Green supply chain behavior and business performance: evidence from China. Technol. Forecast. Soc. 144, 445–455.

Li, G.X., Zhang, W., 2016. Research on international capital and trade channels of green technology innovation under environmental regulation conditions. Res. Technol. Manag. 24, 15–20.

Longoni, A., Cagliano, R., 2018. Inclusive environmental disclosure practices and firm performance: the role of green supply chain management. Int. J. Oper. Prod. Manag. 38 (9), 1815–1835.

Manetti, G., Toccafondi, M., 2011. The role of stakeholders in sustainability reporting assurance. J. Bus. Ethics 107 (3), 363–377.

Mansfield, E., 1988. The speed and cost of industrial innovation in Japan and the United States: external vs. internal technology. Science 241 (4874), 1769–1774.

McWilliams, A., Siegel, D.S., 2000. Corporate social responsibility and financial performance: correlation or misspecification. Strat. Manag. J. 21 (5), 603–609.

Mizobuchi, H., 2015. Multiple directions for measuring biased technical change. CEPA Working Papers. No. WP09.

Moser, E., Prskawetz, A., Tragler, G., 2013. Environmental regulations, abatement and economic growth. Dynamic Modeling & Econometrics in Econ. & Finance 14 (4), 1–24.

Nelson, R., Winter, S., 1982. An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge MA.

Nesta, L., Vona, F., Nicolli, F., 2012. Environmental policies, product market regulation and innovation in renewable energy. Documents De Travail De Lofce 234 (6), 120–141.

Nunn, N., Wantchekon, L., 2011. The slave trade and the origins of mistrust in Africa. Am. Econ. Rev. 101 (7), 3221–3252.

Ongena, G., Ravesteyn, P., 2019. Business process management maturity and performance: a multi group analysis of sectors and organization sizes. Bus. Process Manag. J. 26 (1), 132–149.

Polzin, F., 2017. Mobilizing private finance for low-carbon innovation: a systematic review of barriers and solutions. Renew. Sustain. Energy Rev. 77, 525–535.

Popp, D., Newell, R.G., Jaffe, A.B., 2009. Energy, the environment, and technological Change. NBER Working Paper.

Prahalad, C., Ramaswamy, V., 2004. Cocreating unique value with customers. Strat. Leader. 32 (3), 4–9.

Rajeev, A., Pati, R.K., Padhi, S.S., Govindan, K., 2017. Evolution of sustainability in supply chain management: a literature review. J. Clean. Prod. 162, 299–314.

Rao, P., 2002. Greening the supply chain: a new initiative in South East Asia. Int. J. Oper. Prod. Manag. 22, 632–655.

Roehrich, J.K., Hoejmose, S.U., Overland, V., 2017. Driving green supply chain management performance through supplier selection and value internalization. Int. J. Oper. Prod. Manag. 37 (4), 489–509.

Saunila, M., Ukko, J., Rantala, T., 2018. Sustainability as a driver of green innovation investment and exploitation. J. Clean. Prod. 179 (1), 631–641.

Seman, N.A.A., Govindan, K., Mardani, A., Zakuan, N., Saman, M.Z., Hooker, R.E., Ozkul, S., 2019. The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. J. Clean. Prod. 229, 115–127.

Seman, N.A.A., Zakuan, N., Jusoh, A., Arif, M.S.M., Saman, M.Z.M., 2012. The relationship of green supply chain management and green innovation concept. Procedia Social Behav. Sci. 57, 453–457.

Shi, V.G., Koh, S.L., Baldwin, J., Cucchiella, F., 2012. Natural resource based green supply chain management. Supply Chain Manag. Int. J. 17 (1), 54–67.

Song, H., Turson, R., Ganguly, A., Yu, K., 2017. Evaluating the effects of supply chain quality management on food firm's performance: the mediating role of food certification and reputation. Int. J. Oper. Prod. Manag. 37 (10), 1541–1562.

Sorensen, J.B., Stuart, T.E., 2000. Aging, obsolescence and organizational innovation. Adm. Sci. Q. 45 (1), 81–112.

Su, Q., Song, Y., Li, Z., Dang, J., 2008. The impact of supply chain relationship quality on cooperative strategy. J. Purch. Supply Manag. 14 (4), 263–272.

Sun, Y., Du, J., Wang, S., 2019. Environmental regulations, enterprise productivity, and green technological progress: large-scale data analysis in China. Ann. Oper. Res. 1, 1–16.
Tsoulfas, G., Pappis, C., 2006. Environmental principles applicable to supply. J. Clean. Prod. 14, 1593–1602.
Vachon, S., 2007. Green supply chain practices and the selection of environmental technologies. Int. J. Prod. Res. 45 (18–19), 4357–4379.
Vachon, S., Klassen, R.D., 2006. Extending green practices across the supply chain: the impact of upstream and downstream integration. Int. J. Oper. Prod. Manag. 26 (7), 795–821.
Veugelers, R., 2016. Empowering the green innovation machine. Inter. econ. 51 (4), 205–208.
Ward, A.M., Forker, J., 2017. Financial management effectiveness and board gender diversity in member-governed, community financial institutions. J. Bus. Ethics 141, 1–16.
Winter, S.G., 1984. Schumpeterian competition in alternative technological regimes. J. Econ. Behav. Organ. 5, 287–320.
Wolf, J., 2014. The relationship between sustainable supply chain management, stakeholder pressure and corporate sustainability performance. J. Bus. Ethics 119 (3), 317–328.
Woo, K.S., Ennew, C.F., 2004. Business-to-business relationship quality: an IMP interaction-based conceptualization and measurement. Eur. J. Market. 39 (9), 1252–1271.