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RESEARCH ARTICLE

Environmental management, environmental innovation, and productivity growth: a global firm-level investigation

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Abstract

This paper empirically investigates the economic effects of environmental activities. To be specific, it investigates the interactive influence of firms' environmental management and environmental innovation on their productivity. We consider both internal and external environmental management practices of global firms observed from 41 countries between 2017 and 2019. We also consider both inputs and outputs of firms' innovation activities that aim to reduce environmental impacts. Multiple indices are constructed to comprehensively evaluate firms' environmental activities, and productivity is estimated with a semi-parametric method. We find that environmental management and environmental innovation are directly correlated to each other and both substantially promote productivity; however, they tend to substitute each other's positive effects on productivity. Other variables such as globalization, government, labor inputs, and informal competition strongly affect firm productivity too.

Keywords: environmental innovation; environmental management; firms; productivity

JEL classification: O12; O32; Q55

1. Introduction

It has long been widely acknowledged that innovation plays a crucial role in promoting productivity growth. Among all types of innovation, environmental innovation that endeavors to reduce environmental harm has recently received increasing attention. Environmental innovation differs from general innovation due to its specific evaluation methods and extra positive externality. As noted by Rennings (2000), in addition to the positive externality of knowledge spillovers as in any innovation activities, environmental damage could also be reduced by environmental innovation. De Marchi (2012) shows that the double externality of environmental innovation tends to reduce a firm's motivation to innovate because the associated knowledge spillover benefits its

competitors, leading to a situation in which the firm does not fully appropriate its created value. Jaffe *et al.* (2005) have also suggested that part of this created value is appropriated by society in terms of reduced environmental harms; thus, firms that engage in environmental innovation incur more costs than their polluting competitors do, discouraging them from adopting environmentally friendly technologies and processes. The literature always treats market demand and technology diffusions as the determinants of general innovation, while studies on environmental innovation also highlight the importance of institutional and regulatory factors.

We take major interest in the relationship between environmental innovation and environmental management – two frequently discussed green activities. More specifically, we investigate the interactive influence of both types of activities on firm productivity. Our research questions are straightforward. Do environmental innovation and environmental management complement or substitute each other's effect? How should each activity affect productivity, and do they augment or dampen each other's influence? To properly answer these questions, we acquire firm-level information from the latest Business Environment and Enterprise Performance Survey (BEEPS), which has produced a vast sample of more than 20,000 observations. We construct a rich cross-sectional dataset that allows us to examine the correlational evidence on firms' environmental activities and the effects thereof.

Then, we create multiple proxies to comprehensively evaluate firms' tendencies to environmentally manage and innovate. Environmental management is defined as managerial practices undertaken internally by firms or externally enforced by a government, market, or community to improve firms' energy efficiency and environmental friendliness. Environmental innovation is defined as production-related innovating activities for the same environmental concerns; both innovation inputs and outputs are considered to comprehensively evaluate their effect on productivity. Multiple tests are used to examine the determinants of productivity, which is estimated using a semi-parametric method. A two-step Heckman method is employed to mitigate potential endogeneity. Additionally, subsample analyses of firms with different management and innovation statuses are completed to address multicollinearity.

Our study reveals several interesting findings. Most importantly, in contrast to the common perception that environmental management and environmental innovation should work in tandem, we find otherwise. Echoing the extant literature, we identify a positive correlation between environmental management and environmental innovation and find that both activities improve firm productivity. Upon further tests, however, each activity proves to significantly enhance productivity only in the absence of the other. Environmental management significantly increases the productivity of firms that do not innovate, and environmental innovation significantly increases the productivity of firms that do not engage in environmental management.

This paper makes several novel contributions. First, we fill an important literature gap by undertaking a new empirical investigation based on the latest empirical evidence regarding firms' environmental management and environmental innovation, two commonly studied subjects. The relationship between both activities, as well as their respective influences, has been investigated in numerous works, but scant attention has been paid to their interactive influences. To this end, we focus on how they affect productivity, both simultaneously and separately, and we reveal new findings that stand in contrast to the public's common perceptions.

In addition, we create proxies to comprehensively assess firms' environmental management and environmental innovation. Prior studies treat both environmental activities

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as a set of discrete variables, and they make no special efforts to combine them for the purpose of a comprehensive overview. Instead, we use integrated indices to simultaneously capture various environmental management and innovation activities. These indices aid in constructing a thorough examination of the relationship among firms' environmental management, environmental innovation, and productivity growth.

Finally, this paper complements the literature by connecting different strands of studies. To date, many studies have deliberated over the benefits and costs, as well as the causes and consequences, of environmental management and innovation. This paper initiates a new perspective on the substitutability between these environmental activities. Furthermore, there are many controversies regarding the consequences of globalization and government power. This paper manages to reconcile these conflicting conclusions via firms' innovation. We find that a firm's connections with the international market (i.e., foreign-owned capital and exports) only significantly increase its productivity if it strives for environmental innovation. Besides, government-owned capital and contracts significantly promote a firm's productivity if and only if it innovates.

2. Literature review

Much attention has been paid to the environmental management strategies implemented by firms and governments worldwide. The major point of controversy surrounding this topic is whether environmental management can contribute to improved firm performance. As discussed in Guenther and Hoppe (2014), there have been debates on whether environmental management only serves to increase management costs and halt economic development or if it could benefit firms' sustainable growth. Since the 1970s, the beginning of the environmental movements, the contingent impact of environmental management has been the subject of many studies. The results have been inconclusive and even contradictory in some cases. Early studies – such as those conducted by Pethig (1976), Siebert (1977), and McGuire (1982) – all argue that environmental management, namely enforcement of environmental legislation, could compromise the comparative advantage of an economy. However, more recently, Delmas and Pekovic (2013) report that the voluntary adoption of international environmental management and product standards has a positive influence on French firms' labor productivity. Similarly, Lannelongue *et al.* (2017) use firm-level data from 23 European countries and detect a positive influence of environmental management on labor productivity. Using firm-level data from China, Ma *et al.* (2020) find that environmental management regulations negatively affected firms' labor productivity due to increased stringency, but this negative effect was moderated by product quality management.

There is also a rich body of literature on environmental innovation. Some works have focused on the causes of environmental innovation. For example, De Marchi (2012) emphasizes the importance of firms' cooperation with external partners. Meanwhile, Triguero *et al.* (2013) examine the driving forces of environmental innovation in small and medium European enterprises and find that supply-side factors – such as technology, management, research and development (R&D) projects, and resource prices – play more important roles than demand-side and regulatory factors. Noailly and Ryfisch (2015) examine the green innovation activities of worldwide multinational firms between 2004 and 2009, and they conclude that strong protection of intellectual property and low wages for scientists and engineers in a firm's home country increase the likelihood that the firm will offshore green innovation. More recently, Bai *et al.* (2019)

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investigate the impacts of Chinese government R&D subsidies on energy-intensive enterprises and find that these subsidies have significantly increased the likelihood of environmental innovation, especially for state-owned enterprises.

Other works focus on the consequences of environmental innovation. For instance, Lee and Min (2015) utilize a sample of Japanese manufacturers from the period of 2001–2010 to examine the impact of environmental innovation investment. As a result, they detect a positive relationship between innovation and financial performance but a negative relationship between innovation and carbon emissions. Based on empirical evidence from the European Union between 2001 and 2016, Beltrán-Esteve *et al.* (2019) argue that environmental productivity increases due to advanced environmental technologies. Meanwhile, Chen *et al.* (2019) theoretically analyze environmental R&D in a two-echelon supply chain model and conclude that improvement in a firm's performance is mainly determined by its own investment efficiency and technological spillover. Lin *et al.* (2019) argue that smaller firms engage in more innovation investment and thus generate higher profits. Putri and Soewarno (2020) conclude that Indonesian manufacturers have successfully improved their returns on assets through green innovation investments, whereas Fan *et al.* (2019) conclude that stricter environmental regulations in China have encouraged environmental efforts but also caused a sharp decline in firms' profits, capital, and labor input.

Studies have also investigated the correlation between environmental management and environmental innovation. Based on empirical evidence from German manufacturers, Wagner (2008) finds that an environmental management system (EMS) positively affects the likelihood that firms will pursue environmental process innovation but negatively affects the likelihood that firms will pursue general production innovation. More recently, Inoue *et al.* (2013) scrutinize Japanese facility-level data and how ISO14001 – a voluntary environmental management approach – has affected environment-related R&D activities. They find that facilities with improved ISO14001 were more likely to invest in environmental R&D. Amores-Salvadó *et al.* (2015) investigate 157 Spanish metal manufacturers and analyze the relationship between an EMS and environmental innovation as well as how they affect firm performance, which is measured by market shares and sales growth; they suggest EMS positively moderates the relationship between environmental innovation and firm performance. Dai *et al.* (2015) assert that firms will perceive their rivals' success in environmental management as competitive pressure, urging them to take supply chain actions to pursue environmental innovation. Meanwhile, Papagiannakis *et al.* (2019) argue that the relationship between environmental management and innovation is contingent upon a firm's engagement with its stakeholders. A better engagement with stakeholders such as suppliers, customers, and the local community creates optimal conditions for a firm to accomplish environmental innovation. Finally, Zhang and Ma (2021) suggest that environmental innovation has notably mediated the differentiated influences of environmental management and significantly improved returns on assets of Chinese firms. Nonetheless, these works have not paid any attention to the interactive influence between environmental management and environmental innovation on firm performance.

3. Variables

In this section, we introduce the variables. To properly understand the relationship between environmental management, environmental innovation, and productivity, multiple variables need to be estimated.

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3.1 Productivity

The first important task of our paper is to appropriately estimate firms' *productivity*. We adopt a semi-parametric method introduced by Olley and Pakes (1996) to address this question. This method mitigates the endogeneity problem caused by unobserved productivity shock. In business practices, a firm will analyze its current productivity before making profit-maximizing selections of labor and materials that are combined with the quasi-fixed input of capital. A more productive firm tends to hire more workers, acquire more materials and assets. Due to this endogeneity of the choices of production inputs, the estimation of the input coefficients is very likely to be biased. To mitigate this endogeneity problem, we use the investment decision as an intermediate input which increases monotonically with productivity, conditional on capital input. This method helps to obtain unbiased coefficients of production inputs, and hence deliver accurately estimated productivity.

3.2 Environmental management

The next important task is to properly define environmental management and innovation activities. Let us first focus on environmental management. In early studies such as Pethig (1976), Siebert (1977), and McGuire (1982), environmental management is perceived as stringent environmental legislation of the government. Recently it is considered as 'a complex process that requires cross-departmental coordination and major changes in present operational processes' (Ma *et al.*, 2020) – for example, a mandatory monitoring and reporting system on greenhouse gas (Nishitani *et al.*, 2014), international ISO14001 or organic certification (Delmas and Pekovic, 2013), or non-productive investments that aim to enforce environmental practices via renovating the organizational or human management of firms (Lannelongue *et al.*, 2017).

Following the literature, we define environmental management as the firms' managerial, non-productive measures to mitigate their environmental impacts. We further define two categories of management. One is *internal management*, which is undertaken by firms making changes to their internal managerial structure. Five measures are considered to pertain to this category. First, a firm monitors its own energy consumption including water usage, as well as its emissions of CO_2 and other pollutants. Second, a firm has strategic objectives that involve environmental or climate change issues. Third, a firm appoints a manager who is specifically responsible for environmental and climate change issues. Fourth, a firm sets targets for its energy consumption and emissions of CO_2 and other pollutants. Last, a firm aims to develop its own renewable energy such as solar, wind, hydro, biomass or geothermal energy. To sum up, internal management means that a firm incorporates environmental concerns into its managerial content.

The other is *external management*, which is enforced by external factors such as the government, the market, or the global community in terms of stringent environmental regulations. Another five measures are categorized under this type of management. First, a firm receives external audit of its energy consumption, water usage, and emissions of CO_2 as well as other pollutants. Second, a firm participates in an emission trading scheme such as the EU (for firms in EU countries only) or Kazakhstan (for Kazakhstan firms only) Emission Trading Schemes. Third, a firm is subject to energy taxation levied by the government. Fourth, a firm is subject to environmental standards set by the government. Last, a firm's customers require environmental certifications or adherence to certain environmental standards as a condition to do businesses with the firm. To

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sum up, external management captures the environmental awareness externally exerted by the government, the market, and the community.

A firm i is considered to implement internal management (internal management$_{it} = 1$) or external management (external management$_{it} = 1$) if it reports any internal or external management measures in year t; internal/external management$_{it} = 0$ if no environmental management is reported. We employ probit model equation (1) to examine the determinants of environmental management:

$$\text{Environmental management}_{it}^{j} = \begin{cases} 1 & \text{if } \gamma X_{it} + \delta_1 \theta_i + \delta_2 \theta_t + \varepsilon_{it} \geq 0 \\ 0 & \text{if otherwise} \end{cases} \quad (1)$$

where environmental management$_{it}^{j}$ = [internal management$_{it}^{j}$, external management$_{it}^{j}$]. j indicates each environmental management category, internal or external. X_{it} includes all explanatory variables for firm i at year t, including i's relationship with the international market and the government, labor input, and market condition. θ_i indicates industry and country fixed effects, which control for unobserved determinants of the outcomes and thus can account for the effects of a firm's difficult-to-quantify attributes, such as industry-specific policies, geographic features, and institutional services. θ_t is a year fixed effect that helps to control the time-specific attributes of the outcome. ε_{it} is the error term.

We use equation (1) to estimate the probability of each environmental management j.[1] We then create two integrated indices that respectively measure a firm's overall internal and external management. Specifically, we rank each estimated management probability from the lowest to the highest (five probabilities for internal management and another five for external management), sum up the ranks, and standardize the result to construct the management indices for each firm. Given this construction, a smaller index, or being top-ranked in our integration, means that a firm has a lower likelihood of environmental management.

3.3 Environmental innovation

The common feature shared by the environmental management practices is that they all directly affect a firm's managerial structure. Next, let us turn to environmental innovation. Rennings (2000: 322) defines environmental innovation as '…measures of relevant actors (firms, …, private households) which: (i) develop new ideas, behavior, products and processes, apply or introduce them, and (ii) which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets'. Following this definition, we consider the following activities that directly relate to the production process as environmental innovation: heating and cooling improvements; lighting system improvements; machinery and equipment upgrades; vehicle upgrades; climate-friendly energy generation on site; energy and water saving; pollution control, waste minimizing, and recycling during production. We then define two dummy variables that respectively represent two innovation statuses. *Environmental innovation inputs* equals 1 if a firm exhibits any of the above activities or 0 if no such activities have been reported.

[1] For test results on internal and external management measures, please refer to online appendix tables A6 and A7.

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At the same time, we are also interested in the outcome of a firm's environmental innovation. While environmental investments are supposed to lead to beneficial outcomes, economists and policy makers are also concerned about the possibility that the reduced costs and prices due to environmental innovation inputs, which are in terms of improved material and energy efficiency, will increase the consumption of the new efficient goods and cause a negative impact on the environment via a rebound effect (Binswanger, 2001; Jaffe *et al.*, 2005; Marin, 2014). Therefore, we define that *Environmental innovation outputs* equals 1 if a firm's environmental impacts[2] have been successfully reduced due to their innovation inputs, or 0 if otherwise.

$$\text{Environmental innovation}_{it}^{j} = \begin{cases} 1 & \text{if } \gamma X_{it} + \delta_1 \theta_i + \delta_2 \theta_t + \varepsilon_{it} \geq 0 \\ 0 & \text{if otherwise} \end{cases} \tag{2}$$

where $\text{environmental innovation}_{it}^{j} = [\text{environmental innovation inputs}_{it}^{j}, \text{environmental innovation outputs}_{it}^{j}]$. We then use probit model equation (2) to estimate the probabilities of both innovation inputs and outputs.[3]

3.4 Control variables

3.4.1 Relationship with the international market

Productivity has long been proved to be strongly subject to a firm's engagement on the international market (Melitz, 2003; De Loecker, 2013). After a firm enters the international market, it has access to worldwide advanced technology that helps to convert improved productivity into enhanced innovation capabilities. To comprehensively evaluate how closely a firm is connected to the international market, we consider two variables: percentage of foreign-owned capital and total exports as percentage of total sales.

3.4.2 Relationship with the government

It is also interesting and important to consider the role of government. Under the classic supply-side paradigm of productivity growth, government activities could integrate markets and provide public goods that facilitate growth; this positive effect of government expenditures and public investment were respectively confirmed in Peden (1991) and Ramirez (1998). In this study, we consider two variables assessing how closely a firm is related to the government. The first is the percentage of government-owned capital; the second is whether the firm secures or attempts to secure a contract to do business with the government.

3.4.3 Labor input

Following Lin *et al.* (2019), we consider a firm's employees – the total number of full-time, permanent workers – as an important variable that explains productivity. In addition, following Moretti (2004) and Fleisher *et al.* (2011), employees' education attainment strongly affects productivity as well. We hence use the percentages of permanent workers who have completed university education to represent the quality of labor inputs.

[2]A firm's environmental impact refers to the effect that its activities have on the environment. It includes air quality, biodiversity, climate change, landscape, noise and nuisance, waste, water quality, and flood risk.

[3]For test results on both environmental innovation statuses, please refer to online appendix table A8.

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Table 1. Data statistics

	Min.	1st Q	Median	Average	3rd Q	Max.
Productivity	−0.782	4.375	4.946	5.096	5.652	15.28
Foreign ownership (%)	0	0	0	6.72%	0	100%
Export (%)	0	0	0	17.43%	20%	100%
Government ownership (%)	0	0	0	0.84%	0	99%
Employees	1	10	24	98.65	79	64,000
Employees with university education (%)	0	0.1%	0.34%	11.79%	15%	100%

Source: Business Environment and Enterprise Performance Survey, EBRD, 2017–2019.

3.4.4 *Informal competition*

According to McCann and Bahl (2017) and Miocevic *et al.* (2022), firms' strategic behavior, such as whether and how much to innovate, is threatened by competition from informal, unregistered entities. As a result, we consider productivity as being subject to the influence of informal competition, and we include a dummy variable of whether a firm competed against unregistered or informal rivals.

4. Data description

We acquire firm-level data from the BEEPS[4] jointly conducted by the European Bank for Reconstruction and Development and the World Bank Group. The latest survey from 2017–2019 is studied to deliver the most up-to-date conclusions. In this survey, a Green Economy Module covering environmental management practices and green measures was included. Overall, 24,821 firms from 41 countries located in Europe, Central Asia, and North Africa have been effectively observed.[5]

Table 1 reports the descriptive statistics over all firms observed. The distribution of productivity, which is estimated by the semi-parametric method introduced in section 3.1, is slightly right-skewed.[6] Besides, with a 6.7 per cent foreign ownership on average, less than one quarter of the firms operate with any capital assets owned by foreigners. Most of the firms do not export any goods or services; on average, firms export 17 per cent of their total outputs. Hence, globalization has not affected the observed firms deeply. Government capital ownership is also very rarely observed in our sample, with an average of only 0.8 per cent. The distributions of employees and employees with university education are also very right-skewed, suggesting that the majority of the firms are relatively very small, hiring only a few educated employees. On average, the percentage of employees who have completed university education is only 12 per cent.[7]

[4]Data source: European Bank for Reconstruction and Development, https://www.beeps-ebrd.com/data/.

[5]For details on distribution of firms from all countries, please refer to online appendix table A1.

[6]Notice that our estimated productivity is in logarithmic form and its value can be negative.

[7]For more comparison statistics on firms with and without environmental management or innovation, please refer to online appendix table A2. Comparatively speaking, firms that engage in environmental innovation – either inputs or outputs – are significantly more productive than those that do not. In addition, innovating firms feature significantly closer relationships with the foreign market and with the government, and they were much larger with more educated employees. For more details on how many firms participated in each type of environmental management and innovation, please refer to online appendix tables A3, A4, and A5.

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4.1 Environmental management and environmental innovation

We further provide figure 1 to exhibit the percentages of firms with environmental management and innovation in all 41 countries. '% Innovation Inputs (Outputs)' indicates the percentage of firms with environmental innovation inputs (outputs) in each country; '% Internal (External) Management' indicates the percentage of firms with internal (external) environmental management in each country. It is straightforward that a positive correlation between environmental management and innovation, which are both direct reflections of strong environmental caution, exists in all countries. If a country has a large percentage of firms implementing environmental management, it is very likely to have many firms conducting environmental innovation at the same time. This positive correlation between environmental management and innovation has been firmly supported by the literature, as discussed in section 2. Relatively speaking, Mongolia, Latvia, and Uzbekistan are the three countries with most firms engaging in both environmental management and innovation. Belarus, Ukraine, Czechia, and Slovenia have the highest percentages of firms with environmental management; Malta and Cyprus are the two countries featuring the highest percentages of environmental innovators.

5. Tests and results

In this section we present our test methods as well as major findings. We will first explain the baseline regression, its potential problems, and how to properly address each of them. We will then present the results and demonstrate the substitutability between environmental management and environmental innovation.

5.1 Baseline tests

The main purpose of this study is to investigate the influences of environmental management and innovation on productivity. We therefore run a baseline regression using equation (3):

$$\begin{aligned} a_{it} = {} & \beta_0 + \beta_1 \widehat{\text{environmental management}}_{it} + \beta_2 \widehat{\text{environmental innovation}}_{it} \\ & + \beta_3 \widehat{\text{environmental management}}_{it} \times \widehat{\text{environmental innovation}}_{it} \\ & + \gamma X_{it} + \delta_1 \theta_i + \delta_2 \theta_t + \varepsilon_{it} \end{aligned} \tag{3}$$

where a_{it} represents the estimated productivity from section 3.1 and $\widehat{\text{environmental management}}_{it}$ includes the internal and external management indices estimated in section 3.2. $\widehat{\text{environmental innovation}}_{it}$ includes the probabilities of the two innovation statuses estimated in section 3.3. Interaction terms are also included to examine their interactive influence on productivity. X_{it} still includes the same explanatory variables for firm i at year t; industry, country, and year fixed effects are all included to address firms' heterogeneity.

Also notice that when estimating equation (3), an endogeneity problem arises. On the one hand, productive firms can overcome difficulties such as limited production conditions and exhibit active green managerial or innovating behavior. In other words, as shown in our statistics, productive firms self-select themselves to better manage and innovate; this sample selection bias leads to endogeneity. On the other hand, endogeneity may also occur because firms' management, innovation, and productivity are likely affected by the same elements of unobserved heterogeneity. For example, a firm's culture,

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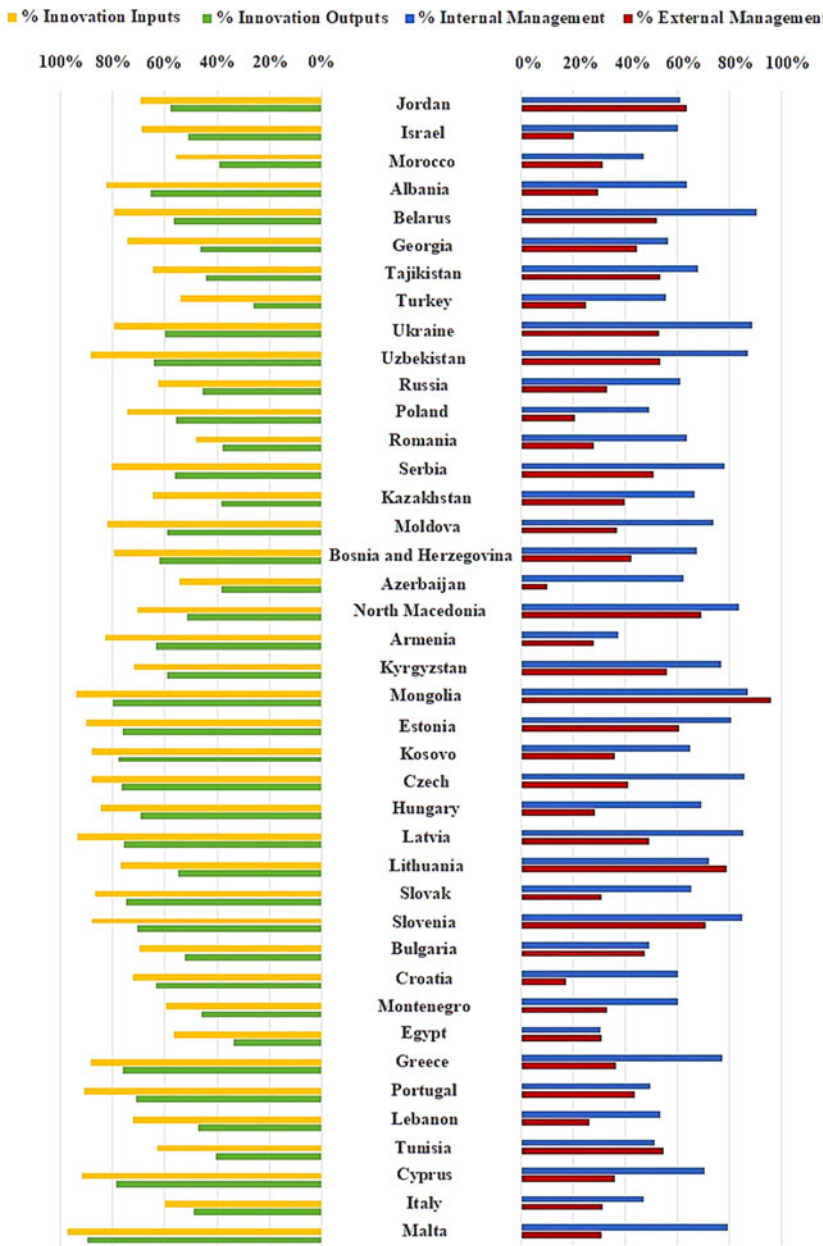

Figure 1. Percentages of firms with environmental management and innovation by countries.

history, or institutional structure that simultaneously affects its environmental awareness and productivity. For another example, the unpredictable outcomes and strategic confidentiality of innovation projects can create extra productivity shocks.

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To address this endogeneity problem, notice that we intentionally make all the major explanatory variables in equation (3) be either in forms of or derived from estimated probabilities. This method is adopted from the Heckman correction, a two-step estimation that corrects bias caused by non-randomly selected samples and the consequential endogeneity explained above. Instead of using dummies (for example, whether to environmentally manage or innovate) as explanatory variables, we predict the probability of these variables in the first step and apply the results into the second step, a linear regression shown by equation (3). Hussinger (2008) uses this two-step method to analyze the effect of government subsidies on German firms' private innovation inputs. Wang and Huynh (2014) also use this method and found that quality management played an important moderating role in how a firm's knowledge management affects its performance in Vietnam. We therefore follow the literature and adopt this two-step Heckman estimation on determinants of productivity.

5.2 Baseline results

Table 2 reports the results of equation (3), determinants of firms' productivity. The fact that a firm implements environmental management has a positive yet inconsistently significant effect on its productivity. This questionable influence of environmental management, therefore, requires further investigation, and we intend to look into how it interacts with innovation later in this study. In addition, environmental innovation, in terms of outputs or inputs or both, always promotes productivity.

A 1 per cent higher foreign ownership percentage brings up productivity by 0.2–0.3; foreign capital assets incorporate new knowledge and techniques from the global market, and therefore bring in technology spillover. However, the export percentage does not display significant coefficients. Firms' accession to the global market proves to help their productivity growth but only to a limited extent. Additionally, a closer relationship with the central government also features insignificant coefficients.

The more employees a firm has, the more productive it becomes. In addition, having more employees with an advanced education level exerts significantly positive influences on firm productivity; 1 per cent more employees with university degrees will significantly increase productivity by 0.3–0.4. Hence, a large employment size as well as a high-skilled workforce substantially promotes firm productivity. The existence of informal competition suggested a less regulated market; it significantly hinders firms' productivity growth.

Furthermore, interaction terms between environmental innovation and management reveal very important findings. These interaction terms all feature significantly negative coefficients, suggesting that environmental innovation and management are reducing each other's positive influence on productivity. Those firms that implemented environmental management will see a declining positive effect of its innovation on productivity; those that performed environmental innovation will also expect a diminishing positive effect of management. In other words, when it comes to promoting productivity, environmental management and innovation dilute each other's effect.

A potential problem with the results in table 2, however, is that the high correlation between environmental management and innovation may cause multicollinearity and hence bias the results. A firm is very likely to implement both environmental management and innovation at the same time. The positive correlation between both types of activities has been depicted in figure 1 and received abundant support from the literature.

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Table 2. Determinants of productivity

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Internal management	0.294 (0.294)	2.611 (0.503)	0.255 (0.269)	0.934 (0.346)	0.252 (0.269)	0.929 (0.346)
External management	0.734 (0.475)	0.253 (0.786)	0.360 (0.479)	0.259 (0.574)	0.359 (0.479)	0.259 (0.574)
Innovation inputs	0.886 (0.352)	1.494 (0.371)	–	–	–	–
Innovation outputs	–	–	2.480 (0.535)	3.266 (0.551)	–	–
Foreign ownership (%)	0.244 (0.058)	0.310 (0.060)	0.195 (0.059)	0.267 (0.063)	0.195 (0.059)	0.267 (0.063)
Export (%)	0.170 (0.067)	0.177 (0.071)	0.087 (0.078)	0.005 (0.083)	0.089 (0.078)	0.003 (0.083)
Government ownership (%)	0.394 (0.127)	0.416 (0.127)	0.129 (0.139)	0.254 (0.144)	0.128 (0.139)	0.252 (0.144)
Government contract	0.061 (0.062)	0.058 (0.068)	0.239 (0.077)	0.155 (0.082)	0.237 (0.076)	0.154 (0.082)
Employees	0.179 (0.012)	0.177 (0.116)	0.179 (0.116)	0.177 (0.116)	0.179 (0.116)	0.177 (0.012)
Employees with university education (%)	0.365 (0.046)	0.285 (0.051)	0.350 (0.045)	0.288 (0.048)	0.349 (0.045)	0.287 (0.048)
Informal competition	−0.198 (0.036)	−0.118 (0.042)	−0.275 (0.041)	−0.223 (0.044)	−0.276 (0.041)	−0.224 (0.045)
Innovation inputs × Internal management	–	−3.823 (0.629)	–	–	–	–
Innovation inputs × External management	–	−1.675 (0.655)	–	–	–	–
Innovation outputs × Internal management	–	–	–	−2.706 (0.458)	–	–
Innovation outputs × External management	–	–	–	−1.498 (0.453)	–	–
Adjust R^2 # Observations	0.361 13,734	0.362	0.361	0.363	0.361	0.363

Note: Standard errors are reported in parentheses.

To mitigate the multicollinearity problem and further study the relationship between environmental management and innovation, we conduct subsample studies on firms with different management or innovation statuses.[8]

[8]To examine the multicollinearity problem, we perform variance inflation factor (VIF) tests on our baseline results, which are reported in online appendix table A10. The VIF values of environmental management and innovation are concerningly high, suggesting the existence of multicollinearity due to the correlation between environmental management and innovation. For the correlation matrix on other explanatory variables, please refer to online appendix table A9.

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Table 3. Determinants of productivity – with versus without environmental innovation

	With innovation inputs	Without innovation inputs	With innovation outputs	Without innovation outputs
	(*i*)	(ii)	(iii)	(iv)
Internal management	0.154 (0.272)	2.359 (0.798)	0.161 (0.305)	1.334 (0.515)
External management	−0.253 (0.499)	4.884 (1.393)	−0.441 (0.549)	3.370 (0.934)
Foreign ownership (%)	0.300 (0.061)	−0.281 (0.183)	0.369 (0.066)	−0.096 (0.120)
Export (%)	0.212 (0.068)	−0.633 (0.204)	0.293 (0.074)	−0.365 (0.134)
Government ownership (%)	0.582 (0.133)	−1.002 (0.380)	0.669 (0.146)	−0.425 (0.251)
Government contract	0.054 (0.060)	−0.538 (0.188)	0.119 (0.065)	−0.353 (0.122)
Employees	0.162 (0.011)	1.170 (0.113)	0.149 (0.011)	1.150 (0.078)
Employees with university education (%)	0.338 (0.051)	0.397 (0.100)	0.340 (0.058)	0.331 (0.072)
Informal competition	−0.137 (0.034)	−0.428 (0.102)	−0.109 (0.037)	−0.307 (0.066)
Adjusted R^2	0.380	0.359	0.384	0.368
# Observations	10,233	3,501	7,646	6,088

Note: Standard errors are reported in parentheses.

5.3 With versus without environmental innovation

Table 3 reports the results of firms that have performed environmental innovation activities, and those that do not innovate. Columns (i) and (ii) respectively show firms with and without innovation inputs; columns (iii) and (iv) respectively show firms with and without innovation outputs. Interestingly, the coefficients of internal and external environmental management lose significance for innovators but remain significantly positive for non-innovators. This echoes the finding regarding the interaction terms in table 2. Among firms conducting innovation activities that enhance environmental friendliness, their environmental management does not affect productivity. We can only observe a positive influence of environmental management on productivity of firms not innovating. The substitutability instead of complementarity between environmental management and innovation is confirmed.

There is another interesting finding on firms' connection with the international market. A 1 per cent higher foreign ownership significantly raises innovators' productivity by over 0.3, but insignificantly reduces non-innovators' productivity. One per cent more exports significantly increases productivity of innovators by 0.2–0.3, but significantly decreases productivity of non-innovators. According to the learning-by-exporting theory, a firm's participation on the international market will allow access to worldwide state-of-the-art technologies and facilitate its growth due to technology

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spillover. Nonetheless, we find that foreign-owned capital assets and exports do not always promote firms' productivity growth, especially for those which do not innovate. Therefore, the learning-by-exporting effect is assured via innovation. Without innovation, globalization cannot effectively improve productivity.

A similar conclusion also applies to firms' relationship with the government. Operating with 1 per cent more capital assets owned by the government significantly increases innovators' productivity by 0.6–0.7 while it decreases non-innovators' productivity by 0.4–1. Securing a contract to do businesses with the government significantly increases innovators' productivity by 0.12 but decreases non-innovators' productivity by 0.4–0.5. Therefore, government influence promotes firm productivity if and only if innovation activities have been performed.

Echoing the baseline findings in table 2, the size and quality of the workforce strongly affect productivity no matter whether firms innovate or not. Hiring more employees significantly raises productivity of both innovators and non-innovators. One per cent more employees with university degrees significantly increases all firms' productivity by 0.3–0.4. Informal competition significantly decreases innovators' productivity by over 0.1 and non-innovators' productivity by 0.3–0.4.

5.4 With versus without environmental management

Next, we group firms by their environmental management statuses and report the results in table 4. Columns (i) and (ii) are results of firms with internal management; columns (iii) and (iv) are those of firms without internal management. Similarly, the next two columns are firms with external management while the last two columns are those without external management. Among firms with internal or external management, environmental innovation insignificantly affects productivity; among firms without internal management, innovation inputs increase productivity by 0.1 while outputs increase productivity by 0.15; among firms without external management, both innovation inputs and outputs increase productivity by 0.1.[9]

Combining the findings from tables 3 and 4, the substitutability between environmental innovation and management is reaffirmed. Although both environmental activities often occur together and positively affect firm productivity, they tend to offset each other's effect. Instead of the common understanding that environmental innovation and management may augment each other's effect on productivity, we prove otherwise. Among firms with environmental innovation, their environmental management does not encourage productivity growth; the positive influence of environmental management can only be observed among the non-innovating firms. Meanwhile, the positive influence of innovation can only be observed among firms without environmental management.

6. Discussions and policy implications

Environmental management and environmental innovation tend to occur simultaneously, as proven by the rich literature and our statistics above. Nonetheless, the most

[9]We also perform VIF tests for the subsample analyses. After firms are grouped by their environmental management or innovation statuses, the VIF values substantially decline, as shown in online appendix tables A11 and A12. This suggests that no more multicollinearity problems should be a concern in tables 3 and 4.

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Table 4. Determinants of productivity – with versus without environmental management

	With internal management		Without internal management		With external management		Without external management	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Innovation inputs	0.039 (0.027)	–	0.093 (0.027)	–	0.043 (0.034)	–	0.092 (0.021)	–
Innovation outputs	–	0.214 (0.832)	–	0.154 (0.028)	–	0.204 (0.532)	–	0.089 (0.020)
Foreign ownership (%)	0.347 (0.036)	0.346 (0.036)	0.403 (0.076)	0.402 (0.076)	0.296 (0.043)	0.293 (0.043)	0.355 (0.049)	0.357 (0.049)
Export (%)	0.211 (0.033)	0.208 (0.033)	0.239 (0.053)	0.235 (0.052)	0.223 (0.040)	0.216 (0.040)	0.170 (0.038)	0.170 (0.038)
Government ownership (%)	0.580 (0.101)	0.576 (0.101)	0.166 (0.393)	0.159 (0.392)	0.544 (0.120)	0.538 (0.120)	0.287 (0.169)	0.280 (0.169)
Government contract	0.107 (0.024)	0.103 (0.024)	0.089 (0.044)	0.077 (0.044)	0.144 (0.028)	0.137 (0.028)	0.044 (0.030)	0.042 (0.030)
Employees	0.157 (0.012)	0.157 (0.012)	1.101 (0.084)	1.087 (0.084)	0.136 (0.012)	0.134 (0.012)	0.980 (0.054)	0.977 (0.054)
Employees with university education (%)	0.245 (0.051)	0.242 (0.051)	0.386 (0.072)	0.383 (0.072)	0.276 (0.064)	0.273 (0.064)	0.330 (0.054)	0.326 (0.054)
Informal competition	−0.103 (0.020)	−0.104 (0.020)	−0.073 (0.028)	−0.075 (0.028)	−0.137 (0.024)	−0.142 (0.024)	−0.054 (0.021)	−0.051 (0.021)
Adjusted R^2	0.376	0.377	0.353	0.355	0.392	0.394	0.375	0.375
# Observations	8,893	8,893	4,841	4,841	5,731	5,731	8,003	8,003

Note: Standard errors are reported in parentheses.

important finding in this study is that firms' environmental management and environmental innovation play substitutable – not complementary – roles in promoting productivity. Firms performing managerial activities to reduce environmental impacts should not expect environmental innovation to effectively improve their productivity. Conversely, firms that innovate to enhance environmental friendliness should not expect environmental management to significantly increase their productivity.

To this end, by questioning the interactive influences of environmental management and environmental innovation, this paper challenges the conventional impression that these two activities complement each other's effects on productivity. Amores-Salvadó *et al.* (2015) and Zhang and Ma (2021) suggest that these activities play a complementary role in firm performance. More specifically, their findings indicated that environmental management and green innovation should augment each other's positive effects on firms' sales and returns on assets. However, we prove otherwise by focusing on firms' productivity. On the one hand, we find that environmental management and innovation typically coexist, as a firm incorporating environmental concerns into its managerial content is highly likely to simultaneously enforce green production technologies. On the other hand, we also show that environmental management and innovation dampen each other's beneficial influence on productivity. We interpret this finding as follows.

Environmental management and innovation activities feature the same purpose but divert firms' resources via different courses. Environmental management focuses on improving the managerial structure of a firm through either internal motivations or external enforcements, whereas innovation directly functions on the production process. These two activities compete for the limited production capacity and resources of a firm, causing distractions, redundancies, and inefficiencies in operation and production. Both environmental management and innovation represent vigilant environmental awareness, but the positive influence of each remains significant only in the absence of the other. Therefore, we conjecture that when a firm simultaneously pursues environmental management and innovation, it can only devote limited efforts to each aspect and thus achieves less productivity growth.

Furthermore, we suggest that to effectively promote productivity growth, a firm should focus on enhancing either the managerial structure or the production process. Paying special attention to either aspect should lead to greater proficiency and thus improve environmental friendliness further. A firm that efficiently manages its environmental impacts can quickly adapt to modern management ideology and enhance productivity. Meanwhile, a firm that actively mitigates environmental damages and controls energy usage during production can adapt to modern production conditions and thus better absorb state-of-the-art technologies.

Therefore, our recommendation for business owners and entrepreneurs is to enhance their firms' environmental awareness and specialize in a method to achieve this goal. We prove that both environmental management and innovation can increase firm productivity but that they only exert significant effects when applied separately instead of simultaneously. It is therefore advisable for firms to gain expertise in either managing environmental impacts or developing green production techniques to significantly grow their productivity.

We also reveal interesting findings regarding the contingent impact of globalization. Specifically, firms' exports and foreign-owned capital can only significantly improve productivity if they have environmental innovation. Non-innovating firms cannot expect productivity improvement due to their global connections. Interestingly, this dichotomous effect of globalization echoes the extant literature regarding the conflicted

findings on the learning-by-exporting theory (Arnold and Hussinger, 2005; Greenaway *et al.*, 2005; Topalova and Khandelwal, 2011; De Loecker, 2013). Our findings therefore explain the mixed evidence of the learning-by-exporting theory from the perspective of innovation, in close alignment with the literature. Previously, Cassiman and Golovko (2011) find that innovation affected firm productivity and induced small non-exporters to enter the export market. Both Yang and Chen (2012) and Wu and Chiou (2021) find that innovation exerts a positive impact on firms' productivity and exports. Innovation has thus been proven to play an important role in the realization of learning-by-exporting outcome.

Another dichotomous finding points to a firm's relationship with the government. We find that a closer relationship with the government, in terms of government ownership or contracts, helps raise productivity for innovating firms but not for non-innovating firms. Thus, to facilitate productivity growth, the most effective way is for the government to encourage firms' innovation activities. However, in spite of the strong emphasis that should be placed on innovation enforcement by governments, an excess of policy interventions will result in ill-designed regulations that distort firm behavior and cause firms to be unable to utilize their comparative advantages, and eventually impede economic growth (Ding and Li, 2015).

7. Conclusions

This paper empirically investigates the influence of firms' environmental management and innovation on productivity and how these activities interact in this context. We acquire the latest BEEPS data covering the period from 2017–2019, look into firms' management and innovation activities intended to enhance environmental friendliness, construct indices to simultaneously capture various management and innovation activities, and study these activities' effects on productivity that is estimated semi-parametrically. We find that overall, environmental management and innovation both increase firm productivity but substitute for each other's positive effects. Environmental management significantly increases productivity of firms that do not innovate, while environmental innovation significantly increases productivity of those without environmental management. This finding remains robust for different management and innovation statuses. Other variables, such as connections with the international market and government, labor inputs, and informal competition, also exert important effects on productivity.

The present study certainly has some limitations. Due to the cross-sectional nature of the dataset, the available time series information is insufficient for extensive analysis of firms' longitudinal productivity growth. If panel data were available, we could look more deeply into firms' environmental activities across the years, and more causal relationships with their performance could be detected. Moreover, due to limited data availability, we define firms' innovation inputs as whether any environmental efforts have been made, and we define innovation outputs as whether their environmental impacts have been reduced. The two dummy variables reveal limited information on firms' innovation activities; new definitions with greater details would be very helpful. Nonetheless, we believe this study provides not only important implications for global businesses and policymakers, but also insightful directions for the future.

To extend our current work, future studies should focus on the specific environmental impacts of the firms – for example, their carbon and pollutant emissions – which will be interesting indicators of enhanced firm environmental performance. How

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much effort has been made to enhance energy efficiency or environmental friendliness is another consideration regarding green investment and the returns. One more meaningful extension of this empirical work is to theoretically summarize how environmental management and innovation contingently affect firm growth and how firms should optimize their environmental activities under various circumstances such as financial or technical constraints.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1355770X23000049

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