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Global eco-innovation and its local impact in emerging economies: Boundary conditions of environmental regulations and pollution intensity

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Abstract

This paper examines the eco-innovation effects of foreign direct investment (FDI) by its economic agents, multinational enterprises (MNEs), in the context of emerging economies. It particularly focuses on environmental regulations and industrial pollution intensity as the key moderating mechanisms. We develop hypotheses by combining economic rationality of natural-resource-based view and institutional rationality of institution-based view. Our theoretical discussions highlight the importance of the intersection between the two theories in explaining the eco-innovation effects of foreign ownership and FDI spillovers, and in particular in allowing a nuanced consideration around the under-explored boundary conditions of FDI effects in the eco-innovation domain. Using the propensity score matching method to match domestically owned enterprises (DOEs) with foreign MNE-invested enterprises (FIEs) in China during the period of 2001–2013, we find clear evidence that FIEs outperform their domestic counterparts of similar characteristics in conducting eco-innovation. This superior performance is particularly pronounced in cities with higher levels of environmental regulation and industries with higher levels of pollution. Furthermore, we assess the local impact of MNEs on eco-innovation of DOEs and find evidence that the presence of FDI, in particular, that within cities, leads to increased eco-innovation in DOEs. FIEs′ eco-innovation spillover effects within a city are conditional on environmental regulation and pollution intensity. Thus, in China, MNEs are found to act as agents of change who not only conduct eco-innovation in the host country but also stimulate the eco-innovation of DOEs.

KEYWORDS

eco-innovation, environmental patent, environmental regulations, foreign direct investment (FDI), pollution intensity

1 | INTRODUCTION

Foreign direct investment (FDI) and its economic agents, multinational enterprises (MNEs), are an important driving force of eco-innovation[1] (Castellani et al., 2022; Marin & Zanfei, 2019). About 40% of global FDI carried out by MNEs was potentially relevant to environmental management (Golub et al., 2011). Additionally, MNEs conducted eco-innovation in host countries and about 17% of environmental patents owned by MNEs came from their overseas R&D activities (Kawai et al., 2018; Marin & Zanfei, 2019; Noailly & Ryfisch, 2015). However, the debates on the environmental impact of FDI and MNEs have largely centered on environmental pollution and much less attention has been paid to their role in eco-innovation (for reviews, see Demena & Afesorgbor, 2020; Wei et al., 2022). As highlighted by Marin and Zanfei (2019, p. 2089), there is "... sparse and largely anecdotal evidence that MNEs play a substantial role in the generation and diffusion of green innovation through their R&D facilities both in their home countries and in foreign locations." Recent research (Castellani et al., 2022) further notes that existing studies concerning the impact of MNEs on local eco-innovation are scant and mainly based on case studies and national surveys whose findings have limited generalizability.

To address this important research gap, our study explores the eco-innovation effects of FDI in a host emerging economy setting by examining whether MNEs' local subsidiaries (foreign-invested enterprises [FIEs]) outperform domestically-owned enterprises (DOEs) in eco-innovation and whether the eco-innovation of FIEs boosts that of DOEs. To add nuances to this line of enquiry, we further consider environmental regulations and pollution intensity as boundary conditions. This is due to their central role in the conflicting views on the environmental performance of FDI/MNEs (Bu & Wagner, 2016; Cheng et al., 2018; Dean et al., 2009). On the one hand, the "pollution haven" or "race to the bottom" hypothesis suggests that MNEs relocate their pollution-intensive activities to emerging economies to take advantage of their weaker environmental regulations. On the other, the "induced innovation" or "race to the top" hypothesis[2] proposes that tighter environmental requirements at home trigger MNEs to develop eco-innovation solutions which can be transferred to their subsidiaries, giving the latter competitive advantages enabling them to overcome the liability of foreignness in the host country.

[1]Eco-innovation, environmental innovation, and green innovation are often used interchangeably in the literature.

[2]This is also called the Porter hypothesis (Porter & van der Linde, 1995).

Practitioner points

- This study has important practical implications as the transition of China, the world's largest polluter and the second largest economy, to a green economy is a key concern for the world.
- Policies could continue with the encouragement of more FDI and their eco-innovation activities, further developing cities as the enabler of innovation and strengthening the formulation and implementation of the environmental policy instruments.
- Additionally, our finding of employment-based FDI spillovers having positive effects along both city and industry dimensions points to the importance of further liberalizing labor market.

We develop hypotheses by combining the economic rationality of the natural-resource-based view (NRBV) and the institutional rationality of the institution-based view (IBV; Hart, 1995; Oliver, 1997; Peng et al., 2008). Economic rationality explains the operation of the eco-innovation initiatives by FIEs and DOEs, allowing them to be conducted and to meet institutional requirements, while institutional rationality strengthens the economic value associated with the eco-innovation initiatives, contributing to the legitimacy of eco-innovation actions. Thus, we highlight the positive role of foreign ownership and FDI spillovers in eco-innovation. The complementary logic of NRBV and IBV further posits the positive moderating effects of environmental regulations and pollution intensity on the relationship between foreign ownership and firm eco-innovation, and that between FDI and the eco-innovation of DOEs, respectively.

The paper makes a theoretical contribution through framing the eco-innovation effects of FDI in a way that explores the complementarity of economic and institutional rationality. Our conceptual model bridges the eco-innovation literature, which has paid little attention to the role of FDI/MNEs and has mostly focused on institutional drivers (for systematic reviews and meta-analysis, see Barbieri et al., 2016; Bitencourt et al., 2020; Dangelico, 2016; del Río et al., 2016; He et al., 2018; Hojnik & Ruzzier, 2016; Liao et al., 2018; Meyer & Sinani, 2009), and the FDI spillovers literature, which has largely overlooked the institutional mechanisms underlying FDI spillovers (for systematic reviews and meta-analysis, see Perri & Peruffo, 2016; Rojec & Knell, 2018; Spencer, 2008). Portraying a more economic account of eco-innovation and a more institutional account of the FDI effects offers a novel attempt in theorizing the direct and indirect (spillover) eco-innovation effects of FDI.

Our empirical analysis is based on firms in China where significant environmental challenges are present, and environmental stringency varies among its regions (Bu & Wagner, 2016; Dean et al., 2009; Marquis et al., 2011). The salient role played by FDI in China has led to a large number of studies on FDI and environmental pollution and the meta-analysis by Wei et al. (2022) shows that FDI improves environmental performance through pollution abatement effects. However, there are few firm-level studies examining the eco-innovation effects of FDI.[3] Based on a large sample of firms in China from 2001 to 2013, we use an objective measure of eco-innovation, i.e., environmental patents, to explore the eco-innovation effects of FDI and find evidence to support our hypotheses.

2 | THEORETICAL BACKGROUND ON ECO-INNOVATION AND THE EMERGING ECONOMY CONTEXT

The eco-innovation research has simultaneously witnessed an increased theoretical pluralism, and the continued dominance of IBV (for reviews, see Barbieri et al., 2016; Bitencourt et al., 2020; Dangelico, 2016; del Río et al., 2016; He et al., 2018; Hojnik & Ruzzier, 2016; Liao et al., 2018). The resource-based view (RBV), although widely used in the broad innovation literature, is a less popular theoretical foundation in eco-innovation studies. The RBV recognizes the economic value of valuable, rare, imperfectly inimitable and non-substitutable organizational resources and asserts that firms leverage these resources to improve innovation performance and to gain competitive advantage (Barney, 1991; Prahalad & Hamel, 1990). Similar to conventional innovation, eco-innovation requires significant resource commitment to ensure success (Dangelico, 2016; Demirel & Kesidou, 2019; He et al., 2018; Liao & Liu, 2021). Eco-innovation, thus, like conventional innovation, should also be based on economic rationality concerning value-maximization through resource utilization. In the context of eco-innovation, the NRBV, which is an extended form of RBV, is particularly relevant. The NRBV recognizes the economic value of organizational resources, but more specifically its dependence on natural environmental constraints (Aragón-Correa & Sharma, 2003; Barney et al., 2011; Chan, 2005; Hart, 1995; Hart & Dowell, 2011). Thus, organizational resources should be tactfully managed to align with the natural environment and "... it is likely that strategy and competitive advantage in the coming years will be rooted in capabilities that facilitate environmentally sustainable economic activity" (p. 991).

Despite the examination of a wide range of resource factors, existing empirical studies often treat resource factors as control variables (see review papers, Barbieri et al., 2016; Dangelico, 2016; del Río et al., 2016). Two recent meta-analyses by Bitencourt et al. (2020) and Liao and Liu (2021) have indicated the small, positive effects of firm size and organizational resources/capabilities on eco-innovation.

By contrast, eco-innovation research has overtly emphasized the role of institutions. The argument is that the double externality problem[4] that differentiates eco-innovation and conventional innovation serves as a disincentive to potential eco-innovators. Therefore, institutional actions (e.g., environmental regulations and stakeholder demand) are called for to provide the impulse for eco-innovation (Berrone et al., 2013; Stojčić, 2021). According to the IBV, institutions greatly affect firm strategy and performance, including innovation performance (Peng et al., 2008). Institutions specify the rules for firms as a condition of conferring legitimacy and constraint. External stakeholders embedded in an institution can play a crucial role in the institutional processes. To protect their welfare against environmental

[3]Related to the topic of the FDI-eco-innovation nexus in China, our review identified only three studies. Chen et al. (2017) evaluate the link between FDI and eco-innovation at the province-level. Their eco-innovation measure based on a composite index constructed on four categories of green economy performance, ecological social performance, technological accumulation performance, and environmental protection performance is a very broad measure mixing both the antecedents and outcomes of eco-innovation with eco-innovation per se. Although Jin et al. (2019) and Qi et al. (2013) are both firm-level studies, they are about FIEs' eco-innovation behavior and FIEs' adoption of eco-innovation, respectively, not the development of eco-innovation. Eco-innovation behavior does not necessarily reflect internal R&D activities or imply outputs. They are likely to weakly represent innovative activities, at best. Qi et al. (2013) employ eco-labels to measure green product innovation. However, eco-labeling may be more of a reflection of marketing decision than innovation decisions. There may also be sector bias with eco-labeling. Additionally, both studies are based on questionnaire surveys. As argued by Berrone et al. (2013, p. 892), questionnaire surveys are likely to be biased "... as respondents tend to present a socially desirable image of themselves or their firms."

[4]Eco-innovation outputs cannot be fully appropriated by the innovators and their costs cannot be fully met by market demand because external stakeholders can benefit from the positive externalities associated with reduced environmental damage without incurring innovation costs and additional marketing costs that are required to educate and encourage consumers to accept green products (De Marchi, 2012; Kawai et al., 2018).

hazards, stakeholders interpret a firm's actions based on institutionalized norms, and exert pressures on firms to conduct eco-innovation (Kawai et al., 2018; Qi et al., 2013; Zhang & Zhu, 2019). Institutional rationality thus premises eco-innovation decisions as a response by firms to comply with regulative requirements and/or stakeholder demands (del Río et al., 2016; Hojnik & Ruzzier, 2016; Watson et al., 2018). While the eco-innovation effects of environmental regulations and stakeholder pressures have been widely examined, empirical findings are ambiguous (see review papers, del Río et al., 2016; He et al., 2018; Hojnik & Ruzzier, 2016). This indicates that firms' eco-innovation decisions cannot be fully justified by institutional rationality.

It is important to note here that empirical studies on eco-innovation have predominately focused on developed countries, as revealed by summary tables/figures in review papers (Barbieri et al., 2016; Dangelico, 2016; del Río et al., 2016; Liao & Liu, 2021). In general, firms in developed countries can more readily access the resources for innovation thanks to their developed institutional systems that can provide effective labor, financial, and business support markets. At the same time, environmental issues are evolving, so are environmental regulations and stakeholder pressures. This is probably why IBV is often at the center stage while RBV or NRBV has taken a backseat in theorizing about eco-innovation.

However, the influential role of resource factors needs to be explicated in combination with institutional factors in the emerging economy context. Their institutions are often underdeveloped, confronting firms with resource constraints for innovation in general and eco-innovation in particular, while institutional voids[5] further exacerbate the resource scarcity problem (Hoskisson et al., 2000). Eco-innovation is a relatively new concept and the dominant paradigm of eco-product and eco-process is underdeveloped in emerging economies. Firms can face difficulties in sensing and seizing technological and market opportunities and reconfiguring their organizational resources to capture these opportunities (Maksimov et al., 2019; Seebode et al., 2012). The development of green dynamic capabilities (i.e., the sensing, seizing, and reconfiguration capabilities) is also path-dependent and the required resources are organizationally embedded (Maksimov et al., 2019; Rugman & Verbeke, 1998b). Emerging economy firms with limited experience of eco-innovation thus have to commit to high upfront investments. Furthermore, firms may face organizational resistance to eco-innovation as the path-dependent nature of technological development locks firms into the old technological regime that is insensitive to environmental issues and/or even has detrimental environmental effects (Cecere et al., 2014; Kiefer et al., 2019; Rennings, 2000). In view of the critical role of firm resources and capabilities, combining economic rationality with institutional rationality helps provide a more complete picture of the drivers of eco-innovation in emerging economies. In the next section, we will draw upon NRBV and IBV to develop our hypotheses.

3 | HYPOTHESES DEVELOPMENT

There is a growing body of literature on foreign subsidiary innovation (also termed as R&D internationalization and innovation offshoring), but limited attention has been paid to FIEs' eco-innovation (for reviews, see Papanastassiou et al., 2020; Reilly & Sharkey Scott, 2014; Rosenbusch et al., 2019; Vrontis & Christofi, 2021). We also know little about whether FDI matters to local firms' eco-innovation in the host country. These are pertinent questions especially for emerging economies that, by and large, lag behind developed countries on the forefront of eco-innovation (Latupeirissa & Adhariani, 2020; Santos et al., 2019).[6] Recognizing the importance of eco-innovation for achieving sustainable development, they have placed eco-innovation in their policy agendas with various incentive schemes to attract green FDI in the hope of knowledge transfer from MNEs to their local subsidiaries, FIEs, and knowledge spillovers from FIEs to DOEs (Johnson, 2017; Noailly & Ryfisch, 2015). Below, we shall draw insights from NRBV and IBV to conceptually address our research questions. Specifically, we focus on environmental regulations and pollution intensity as boundary conditions as they can be critical junctures that influence the role of FDI in eco-innovation.

[5]Institutional voids refer to underdeveloped or missing institutions, for example, imperfect capital market, weak investor protection, and contract enforcement, that enable and support broad business activities and specific innovation activities (Khanna & Palepu, 1997). Institutional voids can lead to factor market distortion and resource misallocation (Ji, 2020).

[6]For example, the recently published dataset on Patents in Environment-related Technologies by the OECD Directorate for the Environment, in collaboration with the Directorate for Science, Technology, and Innovation, contains a number of patent-based innovation indicators (OECD, 2022). In terms of the total number of patents between 2010 and 2019, Japan and the United States were leading. Among developing economies, with the exception of China and India, most were behind OECD countries. China witnessed significant growth, with the number of environmental patents increasing from 1853 in 2010 to 5910 in 2019 and overtook Germany and South Korea to become the third leading innovator in recent years (2017–2019). India showed relatively steady growth in the number of environmental patents during 2010 (432) and 2015 (522), but has since seen the number fluctuate between 503 and 522.

3.1 | Research question 1: Do FIEs outperform DOEs in eco-innovation?

From the perspective of NRBV, FIEs enjoy resource advantages which present a necessary condition for eco-innovation in emerging economies, pointing to a positive relationship between foreign ownership and eco-innovation.

First, FIEs can access resources owned by MNEs, which is important in the emerging economy context where firms face imperfect factor markets, making external financing, hiring skilled labor embodying human capital, and acquiring advanced knowledge for eco-innovation a particular challenge (Hoskisson et al., 2000). Being members of MNEs provides FIEs with greater resources than DOEs for conducting eco-innovation and overcoming barriers (Liu et al., 2017; Un, 2016). The peculiarities of eco-innovation present more challenges for external financing than conventional innovation. For example, Polzin's (2017) systematic review of existing evidence reveals a combination of technological, economic, political, and institutional barriers to sub-optimal investment in eco-innovation. A more recent review (Emodi et al., 2022) of 45 studies has identified 36 barriers[7] to clean energy project finance. MNE membership gives FIEs financial advantages; they can access internal funds or secure external finance through signaling their credibility based on the reputation of MNEs who tend to enjoy superior visibility (Bu & Wagner, 2016; Tatoglu et al., 2014).

FIEs enjoy human capital advantages through tapping into the MNE's internal talent pool, being better positioned for talent recruitment, and taking advantage of employees' multicultural mindset which stimulates the ability to identify, integrate and use diversity of knowledge for innovation (Un, 2011). Eco-innovation can be understood as an integrated process of technological and social change that involves changes in culture, knowledge, practices, and governance (Bitencourt et al., 2020) and this requires human capital as an important input for sensing environmental issues and seizing opportunities, in addition to technological activities (Hart, 1995; Kiefer et al., 2019; Marzucchi & Montresor, 2017; Seebode et al., 2012). FIEs also benefit from MNEs being a knowledge integration system (Almeida & Phene, 2004; Maksimov et al., 2019). Combining the knowledge and technology owned by MNEs and embedded in their sustainability orientation[8] (Claudy et al., 2016) with local knowledge, FIEs are better placed than DOEs to transcend any limitations in the eco-technological trajectories in the emerging economy through broadening mental models and engaging in double-loop learning that can lead them to question and modify their underlying technological and social base (de Brentani et al., 2010; Figueiredo, 2011; Guimon, 2011; Luo & Rui, 2009).

Second, the multiembeddedness of MNEs in different contexts enables FIEs to access resources beyond their own networks, in addition to exposing them to multiple learning channels (Ding et al., 2021). Research on national innovation systems suggests that patterns of eco-innovation are country-specific, reflecting broader societal characteristics and cognition, and national institutional frameworks (Almeida & Phene, 2004; Chatzistamoulou & Koundouri, 2020; Phene et al., 2006). FIEs can benefit from the tacit knowledge elicited by MNEs from the "voice of the environment" or stakeholder perspectives in multiple contexts (Hart, 1995; Hart & Dowell, 2011) by integrated it into the eco-innovation design and development process. The enhanced richness and diversity of resource pools help FIEs to improve on existing eco-technological trajectories or shift to a new one (Watson et al., 2018). They also facilitate FIEs adopting a sustainability orientation which positively impacts on eco-innovation (Claudy et al., 2016; Kawai et al., 2018).

From the perspective of IBV, the combined institutional pressures from both home and host countries and global monitors constitute a sufficient condition for FIEs to undertake eco-innovation in emerging economies, indicating the positive role of foreign ownership in eco-innovation.

In the international context, although most environmental regulations are designed and implemented at the national level, international law has incorporated environmental elements to accommodate global climate challenges (Nyaberi, 2016). International government cooperation reduces opportunities for MNEs to arbitrage national differences in environmental regulations. MNEs are also increasingly subject to the scrutiny of global monitors and the media, which pressurizes MNEs to improve worldwide environmental performance (Crilly, 2011; Kolk & Pinkse, 2008).

In the local context, FIEs are often held to higher standards by stakeholders than DOEs (Kawai et al., 2018; Kim et al., 2016; King & Shaver, 2001). For example, in China, both the government and the public expect MNEs to "… contribute to China's development by bringing in advanced technology and higher standards of environmental protection, product quality, and treatment of labor" (Marquis et al., 2011, p. 56). MNEs seeking legitimacy may conduct eco-innovation in the host country, as this enables them to appear "local," to attune with local

[7] They fall into the broad groups of business/market; construction, technical, and operational; environmental; financial; legal and ownership rights; policy and regulatory; and political and social barriers.

[8] Sustainability orientation refers to firms' overall strategic stance in aligning strategies and operations with environmental concerns (Claudy et al., 2016).

institutions, manage dynamic and complex stakeholder relationships, gain reputation, and mitigate resource dependency (Ambec & Lanoie, 2008; Eiadat et al., 2008; Marquis et al., 2011).

NRBV and IBV point in the same direction with regard to the relationship between foreign ownership and eco-innovation.

> **Hypothesis 1.** Foreign ownership is positively related to eco-innovation such that FIEs conduct more eco-innovation than DOEs.

3.1.1 | Environmental regulations as boundary condition

Irrespective of ownership, the eco-innovation effects of environmental regulations can be ambiguous (for reviews, see Barbieri et al. (2016); Dangelico (2016); del Río et al. (2016); He et al. (2018); Hojnik and Ruzzier (2016)). Environmental regulations translate the concept of environmental protection into specific guidelines for firms and impose both coercive (resulting from power relationships and politics) and normative institutional pressures (pertaining to what is widely considered a proper course of action) on firms (Ding et al., 2016; Porter & van der Linde, 1995; Tsai & Liao, 2017). Complying with environmental regulations adds additional costs on firms, reducing the resources available for eco-innovation. But environmental regulations, although they are enacted by the government, they reflect the will of other stakeholders and therefore may serve as an incentive mechanism for firms engaging in eco-innovation to develop competitive advantages and to gain reputational benefits (Eiadat et al., 2008; Rugman & Verbeke, 1998a). Environmental regulations are one of the most widely investigated factors in eco-innovation research. Although there are studies showing a negative relationship (e.g., Eiadat et al. (2008) on chemical firms in Jordan), or an insignificant relationship between environmental regulations and firm eco-innovation (e.g., Demirel and Kesidou (2019) for the United Kingdom, Ha and Wei (2019) for Korea, and Qi et al. (2013) for China), two recent meta-analytical studies confirm the significant, positive effects of environmental regulations on eco-innovation, albeit the effect sizes are small to medium ($r = 0.124$ in Bitencourt et al. (2020); $r = 0.354$ in Liao and Liu (2021)).[9] This research stream has largely overlooked the role of foreign ownership.

Following the arguments related to IBV above, FIEs, in response to coercive international and local institutional pressures, proactively make eco-innovation decisions so as to gain legitimacy. Under a stringent regulatory regime, noncompliance can be very costly to FIEs, from financial penalties to reputational damage which may negatively impact on MNEs beyond the host country market (Berrone et al., 2013; Child & Tsai, 2005; Ding et al., 2016). In contrast, conducting eco-innovation helps to improve their corporate image and acquire new technological and commercial opportunities (Berrone et al., 2013; Eiadat et al., 2008). The benefits derived from eco-innovation may help to reduce or completely offset regulatory costs, achieve international technological leadership, and expand market share (Ambec & Lanoie, 2008; Cheng et al., 2018; Rugman & Verbeke, 1998a). Rugman and Verbeke (1998a) further posit that institutional pressures from environmental regulations may increase more rapidly than the MNEs' bargaining power, consequently they react positively to environmental regulations and engage in eco-innovation. Environmental regulations can also act as a source of normative isomorphism through channeling organizational practices to meet expectations, reducing information asymmetry between firms and stakeholders, and preventing socially undesirable underinvestment in eco-innovation (Ding et al., 2016; Porter & van der Linde, 1995; Stojčić, 2021). Given the liability of foreignness, MNEs/FIEs have greater incentives than DOEs to conduct eco-innovation locally so as to mitigate stakeholder pressures and satisfy their expectations.

FIEs also have the means to do so, as the above discussions in relation to NRBV have depicted. More stringent environmental regulations require more resources, that is, capital investment, skilled expertise, and information/knowledge, for firms to improve innovation capacity, processes, and practices to adapt to regulative requirements (García-Marco et al., 2020). Following from the “race to the top” argument, MNEs, with their superior green dynamic capabilities can meet stringent regulatory requirements and strict stakeholder demand at lower cost (Bu & Wagner, 2016; Maksimov et al., 2019). Environmental regulations compel MNEs to transfer more advanced resources and capabilities to FIEs to ensure the latter's competitiveness and their eco-innovation success (Bu & Wagner, 2016; Christmann & Taylor, 2001). Marin and Zanfei (2019) provide empirical evidence on the positive relationship between environmental regulations and the eco-innovation of foreign subsidiaries of MNEs.

In contrast, facing stringent regulative pressures, DOEs may not be as proactive as their foreign counterparts given their resource constraints. They may take a reactive approach by focusing mainly on compliance (He

[9]According to Cohen (1988), the thresholds for interpreting effect size are 0.1, 0.3, and 0.5 for small, medium, and large effect size, respectively.

et al., 2018; Liao et al., 2018) or even circumventing the enforcement of environmental regulations through their political connections (Zhang, 2021). For example, Fan et al.'s (2019, p. 32) comprehensive examination of Chinese firms between 2001 and 2010 reveals that more stringent environmental regulations induced firms to "… discharge less effluent, to consume less industrial water by recycling water, and to adopt devices that control pollution as well as expand their current pollution treatment abilities," but they are still reluctant in eco-innovation efforts.

Taken together, both IBV and NRBV suggest that stringent environmental regulations broaden the eco-innovation gap between FIEs and DOEs.

> **Hypothesis 1a.** The strength of the relationship between foreign ownership and eco-innovation depends on environmental regulation stringency such that the relationship is more pronounced under a higher level of environmental regulation stringency.

3.1.2 | Pollution intensity as boundary condition

Pollution intensity is another important factor to consider, as eco-innovation is more associated with pollution-intensive (or "dirty") industries (García-Marco et al., 2020; Kunapatarawong & Martínez-Ros, 2016). Dirty industries, represented by steel, cement, electrolytic aluminum, metallurgy, chemical, petrochemical, construction materials, paper and paper products, brewing, pharmaceuticals, textile, and other durable consumer goods (Ang et al., 2022), are often viewed as the main contributor to environmental problems. For example, in China, Fan et al. (2019) show that paper production alone accounted for 35.16% of the total chemical oxygen demand emissions, and Ang et al. (2022) find that dirty industries collectively account for more than half of the total energy consumption. Institutional pressures on firms to improve their environmental performance are stronger in dirty industries than in clean industries (Kunapatarawong & Martínez-Ros, 2016). A growing public concern with environmental issues in emerging economies has begun to command stakeholder attention to the environmental performance of firms in dirty industries (Child et al., 2007; Marquis et al., 2011; Marquis & Bird, 2018). Dissatisfaction with these firms' ineffective pollution control can lead to a surge of public complaints, protests, or boycotts, diminishing the value of their brand equity (Marquis & Bird, 2018; Yao et al., 2021). Furthermore, firms in dirty industries may be pro-active in eco-innovation as they face a great deal of "low-hanging fruits"—easy and inexpensive eco-innovation efforts that often see greater returns relative to development costs (Hart, 1995).[10] There are multiple sources of eco-innovation ideas in these industries including firms' "internal sensitivity to environmental issues," while the top management of these firms "may be more personally committed to sustainability," and these firms "may also have clearer and better-specified plans to deal with green innovations than cleaner industries" (Kunapatarawong & Martínez-Ros, 2016, p. 1224). Relative to the widespread examination of environmental regulations in eco-innovation research, only a few empirical studies have paid attention to pollution intensity and they generally suggest that dirty industries are more proactive in eco-innovation (e.g., Cainelli et al. (2012) and Mazzanti and Zoboli (2009) for Italy; and De Marchi (2012), del Río et al. (2015), and Garcia-Quevedo et al. (2020) for Spain). These studies have not considered the interactive effects of foreign ownership and pollution intensity.

MNEs operating in the dirty industries of emerging economies are particularly under international and local institutional pressures, in view of the "race to the bottom" concerns (Bu & Wagner, 2016; Kim et al., 2016; Rugman & Verbeke, 1998a). Their operations are typically more visible, and their actions are under greater scrutiny by stakeholders (Tatoglu et al., 2014). From the perspective of IBV, FIEs in dirty industries are disproportionally more motivated to engage in eco-innovation than DOEs so as to maintain legitimacy and protect their reputation, in addition to gaining competitive advantages (Aragón-Correa et al., 2016; Christmann & Taylor, 2001; Rugman & Verbeke, 1998b). Ambec and Lanoie (2008) also highlight the fact that a firm's environmental performance helps with external stakeholder relations, reducing the costs and risks associated with managing the relationships. Heavily regulated and scrutinized firms, which include MNEs in dirty industries, are more likely to benefit from such cost reductions. In the early stages of pollution prevention, firms can benefit from managing pollution; however, diminishing returns will set in with such an investment, and firms thus need eco-innovation to reach "zero emissions" (Hart, 1995). The economic rationality of NRBV offers a complementary perspective to FIEs' stronger commitment to eco-innovation in dirty industries. As argued above, FIEs' resource advantages over DOEs permit them to adopt sustainability orientation and deploy resources to realize their eco-innovation ambitions (Claudy et al., 2016).

In contrast, DOEs in emerging economies typically face resource constraints because the costs and risks involved in the adoption and implementation of

[10]We thank a reviewer for suggesting this point.

environmental technologies can be very high and the potential benefits of eco-innovation in terms of returns on investment and cost-saving are likely to be long-term. Those in dirty industries, therefore, are likely to focus mainly on pollution management than eco-innovation (García-Marco et al., 2020; Hart, 1995). At the early stages of managing environmental performance and focusing on sustainable development, they can benefit from "... easy and inexpensive behavioral and material changes that result in large emission reductions relative to costs" (Hart, 1995, p. 993), and therefore are less incentivized than FIEs to engage in eco-innovation. Their embeddedness in the local environment also provides them with resources, information, and bargaining power to manage institutional and stakeholder demand without engaging in eco-innovation. For example, Zhang (2021) finds that polluting firms navigate the institutional and stakeholder landscape by employing relational strategies (voluntary CSR disclosure and cooperation with NGOs) and through political connections.

Following the above rationale based on IBV and NRBV, we posit a greater eco-innovation gap between FIEs and DOEs in dirty industries than that in clean industries.

> **Hypothesis 1b.** The strength of the relationship between foreign ownership and eco-innovation depends on pollution intensity such that the relationship is more pronounced in dirty industries than in clean industries.

3.2 | Research question 2: Does the eco-innovation of FIEs boost that of DOEs?

FIEs would guard their eco-innovation against the appropriations by DOEs, for example, using patents. However, knowledge spillovers can still occur through studying patent documents (for reviews, see Neves & Sequeira, 2018). The FDI spillover literature has explored the performance effects of FDI/FIEs on DOEs (for reviews, see Perri & Peruffo, 2016; Spencer, 2008). The analysis is largely based on RBV in which FIEs are viewed as a source of new information/knowledge and expertise for innovation (Beamish & Chakravarty, 2021). Through demonstration effects, DOEs observe the globally competitive technology and practices of FIEs directly in the domestic market (Perri & Peruffo, 2016, Spencer, 2008). Transactional linkages with FIEs create learning opportunities for DOEs (ibid). Workers trained by FIEs/MNEs moving to DOEs, or establishing their own companies, offer another channel for DOEs to effectively learn for innovation (ibid). Notwithstanding the value of the FDI spillovers literature, it does not distinguish between eco-innovation and conventional innovation. Below we shall argue, based on the NRBV and the IBV, that the positive FDI spillover effects are particularly important to DOEs' eco-innovation in the context of emerging economies.

From the perspective of NRBV, FIEs/FDI offer DOEs a channel through which they acquire external information/knowledge to overcome barriers and build up internal resources and capabilities for eco-innovation. The demonstration, linkages, and labor turnover effects associated with FIEs expose DOEs to a new world of information/knowledge and expertise, and offer them opportunities to adopt a sustainability orientation and develop green dynamic capabilities to transcend internal limitations (Claudy et al., 2016; Demirel & Kesidou, 2019; Maksimov et al., 2019; Perri & Peruffo, 2016). They also help reduce uncertainty, tolerate ambiguity, and inform the DOEs of the value of eco-innovation, mitigating the barriers for DOEs to engage in eco-innovation (Ha & Wei, 2019). Overall, the NRBV rationale points to the positive FDI spillover effects on the eco-innovation of DOEs.

Although the NRBV perspective presents a necessary condition for FDI eco-innovation effects, it is insufficient in the sense that DOEs could leverage acquired resources from FIEs to improve environmental performance through pollution abatement rather than eco-innovation. IBV could provide additional contextual understanding, but the institutional mechanisms underlying FDI spillovers have received limited attention in the eco-innovation literature (Dangelico, 2016; Geng et al., 2017; Hojnik & Ruzzier, 2016).

Central to the IBV is that firms operating in a particular environment (e.g., city) or an organizational field (e.g., industry) tend to follow best practices, for example, eco-innovation, so as to maintain legitimacy (Cai & Li, 2018; Li et al., 2017; Liao, 2018b; Lin et al., 2014). FIEs are one of the stakeholder groups that set and maintain standards of corporate environmental responsibility (Rugman & Verbeke, 1998b) and can serve as catalysts for DOEs' engagement with eco-innovation through institutional isomorphism including mimetic isomorphism (arising primarily from uncertainty), coercive isomorphism, and normative isomorphism (DiMaggio & Powell, 1983).

First, FDI demonstration effects stimulate mimetic isomorphism. Socially valued goals associated with eco-innovation may be difficult for firms to implement due to the inherent complexity and ambiguity in means and ends (DiMaggio & Powell, 1983). To save search costs and overcome uncertainty, firms may benchmark best practices and imitate those who are perceived as especially legitimate or successful (Ha & Wei, 2019; Liao, 2018b). As argued above, FIEs tend to perform better than DOEs in eco-innovation; their leadership makes them a natural imitation target for domestic eco-innovators.

Second, FDI linkage effects exert coercive and normative environmental pressures on DOEs within their global value chain (Chiarvesio et al., 2015; Li, 2014; Wu & Ma, 2016). Domestic suppliers attend to the demand of FIEs/MNEs who often want to green their supply chain due to their own institutional pressures. FDI can act as a normative force by sending a clear signal of their endorsement of greener products and production processes, which stimulates their suppliers to conduct eco-innovation so as to meet FIEs/MNEs' standards, as failing to do so may lead FIEs/MNEs to terminate the transactional relationships and seek alternative suppliers (Wu & Ma, 2016). FIEs also exert normative influences on domestic customers through the effects of a shared cognitive base (Tatoglu et al., 2014). The interactions with FIEs stimulate domestic customers to adopt similar worldviews, which facilitates their eco-innovation.

Lastly, the labor turnover channel serves as a mimetic and/or normative process. This personnel flow within an institutional field, where MNEs are a core member, diffuses MNEs' strategies and practices and serves as an important vehicle for increasing the awareness of environmental issues, environmental practices, and the associated market and technical opportunities that MNEs have taken advantage of (Li et al., 2018). People are influenced by their past experience which creates a cognitive and normative frame shaping their perspectives on organizational goals and means to achieve them. On the basis of FIEs' higher eco-innovation tendency, their former employees, who possess the FIEs' organizational knowledge, may work as a conduit through which their new employers or their own companies imitate FIEs' practices (Spencer, 2008). Because of their understanding of the importance of eco-innovation beyond the economic rationale, these personnel can influence DOEs to engage in eco-innovation (Ha & Wei, 2019). They also serve as catalysts for improving the sustainability orientation and green dynamic capabilities of DOEs, helping them synthesize and integrate acquired information/knowledge with their existing resources (Claudy et al., 2016; Demirel & Kesidou, 2019; Spencer, 2008).

Combining NRBV and IBV, we expect positive FDI eco-innovation spillover effects on DOEs.

> **Hypothesis 2.** FIEs generate positive spillover effects on the eco-innovation of DOEs.

3.2.1 | Environmental regulations as boundary condition

We infer from the perspective of NRBV, environmental regulations would strengthen the eco-innovation FDI spillover effects on DOEs. As discussed in the section leading to Hypothesis 1a, stringent environmental regulations pressurize firms to improve environmental performance and proactively make eco-innovation decisions, but compliance with regulations requires significant resource inputs, particularly information and knowledge that are in short supply in emerging economies. Information and knowledge are important for eco-innovation too as revealed by recent meta-analysis research (Bitencourt et al., 2020; Liao & Liu, 2021).[11] So far, we have established that FDI increases knowledge and information stock that is available for DOEs to tap into for eco-innovation. We have also established that the more stringent local environmental regulations are, the more resources FIEs will receive from their MNE networks and the contexts within which MNEs operate. Taken together, under stringent environmental regulations, there is more scope for DOEs to benefit from FDI eco-innovation spillovers because of increased knowledge and information stock received by FIEs. Furthermore, environmental regulations prompt DOEs to innovate. Under stringent environmental regulations, they are therefore more proactive in searching for and absorbing FDI spillovers and engaging in eco-innovation activities. For example, Hansen and Hansen's (2020) case study of the catch-up of the Chinese biomass power plant industry reveals that the changes in the Chinese environmental regulatory framework, starting from the first renewable energy law in 2006, have created a window of opportunities for DOEs. This industry has evolved from a single firm being established by a Chinese-Swedish entrepreneur with a background in an MNE in 2004 to a large number of producers, making China one of the leading countries in terms of electricity generation from biomass in recent years (ranked 3rd in 2015, only behind the United States and Germany). Owing to knowledge spillovers, some of the DOEs have developed cutting-edge environmental technologies.

The institutional rationality advocated by IBV also suggests the positive moderating effects of environmental regulations on the relationship between FDI and the eco-innovation of DOEs. Institutional pressures triggered by environmental regulations spur FIEs to improve their environmental pollution performance (for reviews, see Demena & Afesorgbor, 2020; Wei et al., 2022), as well as eco-innovation, as argued in the section leading to Hypothesis 1a. The higher standards set by FIEs as a

[11]Bitencourt et al.'s (2020) meta-analysis shows the positive effects of information sources defined as good access to external knowledge and information on eco-innovation ($r = 0.228$). Liao and Liu's (2021) meta-analysis reveals the positive role of the breadth of knowledge defined as the number of knowledge sources of firms for innovation activities on eco-innovation ($r = 0.164$).

result of more stringent environmental regulations facilitate DOEs' adoption of the eco-innovation strategy through institutional isomorphism in line with the discussions proceeding Hypothesis 2. Environmental regulations also create normative consensus and a shared cognitive base between FIEs and DOEs in the same geography or organizational field. This helps to facilitate more interactions between the two groups of firms and lead to greater FDI spillovers to benefit the eco-innovation of DOEs (Child et al., 2007; Zhou et al., 2019). Thus, taking into account the mechanisms underlying environmental regulations, we expect that DOEs exposed to broader and more advanced eco-innovation resources and capabilities, benchmarked with the best practices of FIEs, are more likely to use these resources and capabilities to pursue eco-innovation.

Both NRBV and IBV indicate that environmental regulations strengthen FDI eco-innovation spillovers.

> **Hypothesis 2a.** The FDI spillover effects on the eco-innovation of DOEs depend on environmental regulation stringency in such a way that the strength of the relationship is more pronounced under a higher level of environmental regulation stringency.

3.2.2 | Pollution intensity as boundary condition

Through the theoretical lens of IBV, discussions in the section leading to Hypothesis 1b reveal that firms in dirty industries are under more institutional and stakeholder pressures to manage the interface between their business and the natural environment, and to improve their environmental performance. DOEs in these industries, therefore, have stronger intentions to conduct eco-innovation than their counterparts in clean industries so as to gain legitimacy. In view of the salient features of dirty industries and the common challenges that DOEs and FIEs face, the strong institutional pressures from FIEs' superior eco-innovation performance can channel DOEs' attention and commitment to eco-innovation activities (Marquis & Bird, 2018; Yao et al., 2021). On the other hand, proactively searching for and absorbing FDI spillovers for eco-innovation would enable DOEs to signal their green credibility and secure reputational benefits (Eiadat et al., 2008). Although resource constraints limit DOEs' ability in conducting eco-innovation in emerging economies, as argued in the section leading to Hypothesis 2, FIEs' superior pollution-abatement knowledge, skills, and principles constitute an important source from which DOEs can improve their resources and capabilities for eco-innovation so as to meet the institutional and stakeholder demand on dirty industries.

Taken together, the complementary logic of IBV and NRBV leads us to formulate the following hypothesis:

> **Hypothesis 2b.** The FDI spillover effects on the eco-innovation of DOEs depends on pollution intensity in such a way that the strength of the relationship is more pronounced in dirty industries than in clean industries.

4 | DATA AND METHODOLOGY

To address the two research questions, we collected and merged data from three sources, and employed the propensity score matching (PSM) method to investigate the link between foreign ownership and eco-innovation, then used the econometric technique to establish the impact of FIEs' eco-innovation on DOEs.

4.1 | Data and sample

We use environmental patent to measure eco-innovation. The literature has extensively debated the measures of innovation, with a range of measures being proposed, including input-based (e.g., R&D expenditure), intermediate output-based (e.g., patents), and final output-based (e.g., new product sales; for reviews, see Ding et al., 2021, Dziallas & Blind, 2019, Hagedoorn & Cloodt, 2003, Taques et al., 2021). They all have their own pros and cons and there is no general consensus on which measure/indicator is superior to others. As Chinese firms do not report green R&D expenditure and new green product sales, we follow existing studies, for example, Castellani et al. (2022), Marin and Zanfei (2019), Montresor and Quatraro (2020), Noailly and Ryfisch (2015), Santoalha and Boschma (2021), and Wagner (2007), and adopt the environmental patent count measure for eco-innovation of FIEs and DOEs, and eco-innovation related FDI spillover effects. Although this indicator has drawbacks, it is aligned to the new definition of innovation provided by the OECD's Oslo Manual (2018)—"... a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." This definition, unlike others that insist on the commercialization of innovation (which is phrased as "introduced to the market"), qualifies that "new or improved product or process" covered by patents as innovation. It also has the advantage of being continuous and objective, reflecting the technical success of innovation activities, and carrying cross-industry validity (Ding et al., 2021; Dziallas & Blind, 2019; Hagedoorn & Cloodt, 2003; Taques et al., 2021). Relative to input measures such as R&D investment, it is closer to market impact; and relative to output measures, such as new product sales, it is not subject to the issue of capturing marketing efforts. Existing studies have also shown that patent count indicator is highly correlated with other innovation indicators (e.g., Acs et al., 2002; Arundel & Kabla, 1998; Balasubramanian & Sivadasan, 2011; Kemp & Pearson, 2007).

To identify environmental patents, we use a detailed patent search strategy developed by Haščič and Migotto (2015), combined with the "IPC Environmental Inventory" provided by the World Intellectual Property Organization (WIPO).[12] Patents data were collected from the database of China's National Intellectual Property Administration (CNIPA), formerly China's State Intellectual Property Office (SIPO). Since 1994, China has been a signatory of the Patent Cooperation Treaty which makes it possible for innovating firms to seek worldwide patent protection by filing a single application in one country instead of filing separate applications in multiple countries. Thus, the CNIPA patent data are likely to be associated with DOEs' and FIEs' local R&D activities. Keupp et al. (2012, p. 1422) also argue that "… the exponential growth of foreign firms' patents in China is unlikely to constitute a mere 'replication' of firms' existing patent stocks outside of China." The database contains detailed information on patents (Dang & Motohashi, 2015), including application number, application date, IPC classification, patent type (invention, utility model, or design), applicants' names and addresses, inventors' names, and patent attorneys' names and addresses. However, it has no information on patent citations. CNIPA defines environmental patents as inventions, utility models, and appearance designs with environmental technologies that can improve energy efficiency, reduce air pollution, and achieve sustainable development. They include alternative energy, environmental protection materials, energy conservation and emissions reduction, pollution control, and recycling technologies.

We merged patent data with the Annual Industrial Enterprises Survey (AIES) database compiled by the National Bureau of Statistics (NBS). The AIES covers all Chinese enterprises with an annual turnover of more than RMB 5 million during the period of 2001–2013. It contains detailed information on enterprises, including name, ownership, location, industry, assets, revenue, investment, profit, export, employment, and cash flow. Due to its comprehensive coverage of DOEs and FIEs in China, it has been widely used in existing studies including those published recently in leading journals—*European Economic Review* (e.g., Lai et al., 2020), *Journal of International Business Studies* (e.g., Zhong et al., 2019), *Journal of World Business* (Zhu et al., 2019), and *Research Policy* (e.g., Wu et al., 2021).

Shares of sample enterprises in each province are proportional to their shares in provincial GDP. Thus, the data do not have a severe regional bias. Due to entry and exit and ownership restructuring, the number of enterprises in the database changes over time. The data were cleaned via extensive checks for nonsense observations, outliers, coding mistakes, and the like. In particular, we dropped observations if they had missing values for key financial variables (such as total assets, fixed assets, and industrial output) and if the number of employees was reported to be <10.

The patent and enterprise-level data were then merged with the city-level data obtained from the CEIC database[13] which contains economic, institutional, and geographic information for Chinese cities. Table 1 presents a sample profile by two-digit industry. Table 2 summarizes variable definitions and measurements.

4.2 | Propensity score matching method

To address research question 1, we use the propensity score matching (PSM) method (Li, 2012; Rosenbaum & Rubin, 1983). It is likely that FIEs exhibit characteristics that are systematically different from DOEs. For example, if foreign investors are more likely to invest in innovative firms, then FIEs may have more environmental patents because of certain firm-specific characteristics, not because of foreign ownership per se. This implies that estimates on the outcome variable (eco-innovation) become biased if non-randomness is overlooked. The PSM method is suitable to alleviate this possible selection bias. It has two advantages over alternative approaches: (1) it does not require assumptions about the functional form of the outcome equation and the distribution of error terms; (2) it does not involve the use of instrumental variables which are arguably difficult to identify here given most variables that affect foreign firm ownership are also likely to be determinants of innovation.

The basic idea of PSM is to identify the conditional probability of assignment to a particular treatment given the pre-treatment factors:

$$p(x) \equiv \Pr(z=1|x) = E(z|x) \qquad (1)$$

[12] http://www.wipo.int/classifications/ipc/en/green_inventory/

[13] https://www.ceicdata.com/en

TABLE 1 Sample profile by two-digit industry.

Two-digit industry code	Name	Number of firms	Number of observations
6	Coal mining and washing	13,716	37,682
7	Petroleum and natural gas extraction	386	1108
8	Ferrous metal mining	5429	15,546
9	Non-ferrous mining	3881	9715
10	Non-metallic minerals mining	6589	17,140
11	Other mining	91	91
13	Food processing	36,094	108,955
14	Food manufacturing	13,628	40,151
15	Beverage manufacturing	8626	25,942
16	Tobacco	352	1240
17	Textile	50,605	168,733
18	Clothing, shoes, and hats	32,223	97,230
19	Leather, fur, feather, and related products	15,462	49,682
20	Wood processing and manufacturing of wood, bamboo, rattan, palm, and straw-made articles	15,491	43,322
21	Furniture	8943	25,561
22	Paper and paper products	8943	53,117
23	Printing and reproduction of recording media	9974	31,615
24	Culture, education, and sports goods	10,413	28,760
25	Petroleum processing, coking, and nuclear fuel	4442	12,922
26	Chemical raw material and chemical products	43,749	144,787
27	Pharmaceutical	10,386	33,450
28	Chemical fiber	3826	11,084
29	Rubber	16,109	32,376
30	Plastic	45,663	103,499
31	Non-metallic minerals product	52,000	141,005
32	Ferrous metal smelting and extrusion	16,513	42,069
33	Non-ferrous smelting and extrusion	24,439	41,916
34	Metalwork	51,204	120,254
35	General-purpose equipment manufacturing	60,182	167,180
36	Specialized equipment manufacturing	36,094	84,947
37	Transport and communication equipment manufacturing	28,011	78,963
39	Electric machinery and equipment manufacturing	45,415	116,561
40	Communication equipment, computers, and other electronic equipment	30,603	69,923
41	Instruments and meters, and machinery for culture and office machinery manufacturing	13,172	30,521
42	Artwork and related	14,406	36,264
43	Waste resources and waste materials recycling and processing	5570	9198
44	Production and supply of electric power and heat power	8628	30,643
45	Gas production and supply	133	200
46	Water production and supply	2389	8314

TABLE 2 Variable definitions and summary statistics.

Variables	Definition and measurement	Minimum	Maximum	Mean	SD
FIE	A binary dummy variable taking the value of one if a firm is a FIE, 0 otherwise	0	1		
Eco-innovation	Environmental patents granted to a firm added by one in logarithm	0 (0)	5.617 (274)	0.012 (0.033)	0.131 (0.730)
Environmental levies	Environmental levy imposed on a firm added by one in logarithm	0 (0)	10.945 (56,645)	0.879 (33.081)	1.583 (418.48)
Size	Firm size, measured by total assets in logarithm	7.302 (1484)	14.445 (1,876,922)	9.922 (78,134)	1.444 (231,402)
Age	Firm age, measured by the number of years since its establishment in logarithm	0.693 (1)	3.912 (49)	2.039 (9.229)	0.74 (9.093)
Capital intensity	Firm's total fixed capital scaled by total employees in logarithm	1.295 (0.612)	5.972 (1376.9)	3.696 (97.663)	1.237 (182.95)
Export propensity	The export propensity dummy variable taking the value of 1 for exporters and 0 for non-exporters	0	1	0.257	0.437
Productivity	Firm's labor productivity measured by total sales revenue divided by the number of employees	3.447 (31.403)	8.481 (4823.6)	5.649 (496.69)	1.007 (707.22)
Human capital	Firm's wage bill divided by the number of employees in logarithm	0.757 (2.131)	5.072 (159.45)	2.544 (17.675)	0.736 (21.009)
FDI_Eco-innovation (City)	FDI spillovers measured by eco-innovation at the city level, i.e., the share of environmental patents owned by FIEs in a city's total environmental patents	0.005	0.923	0.339	0.286
FDI_Employment (City)	FDI spillovers measured by employment at the city level, i.e., the share of employment of FIEs in a city's total employment	0.001	0.996	0.159	0.179
FDI_Output (City)	FDI spillovers measured by industrial output at the city level, i.e., the share of gross industrial output of FIEs in a city's total industrial output	0.0003	0.998	0.176	0.187
FDI_Sales (City)	FDI spillovers measured by sales at the city level, i.e., the share of output sales of FIEs in a city's total output sales	0.0005	0.997	0.177	0.189
FDI_Assets (City)	FDI spillovers measured by assets at the city level, i.e., the share of assets of FIEs in a city's total assets	0.0001	0.998	0.173	0.184
FDI_Eco-innovation (Industry)	FDI spillovers measured by environmental innovation at the industry level, i.e., the ratio of environmental patents owned by FIEs to total environmental patents of a 4-digit industry	0.0001	0.996	0.231	0.318

(Continues)

TABLE 2 (Continued)

Variables	Definition and measurement	Minimum	Maximum	Mean	SD
FDI_Employment (Industry)	FDI spillovers measured by employment at the industry level, i.e., the ratio of employment of FIEs to total employment of a 4-digit industry	0.0002	0.954	0.266	0.203
FDI_Output (Industry)	FDI spillovers measured by industrial output at the industry level, i.e., the ratio of industrial output of FIEs to total industrial output of a 4-digit industry	0.0002	0.979	0.303	0.215
FDI_Sales (Industry)	FDI spillovers measured by sales at the industry level, i.e., the ratio of sales of FIEs to total sales of a 4-digit industry	0.0002	0.997	0.306	0.216
FDI_Assets (Industry)	FDI spillovers measured by sales at the industry level, i.e., the ratio of sales of FIEs to total sales of a 4-digit industry	0.0001	0.998	0.322	0.214
GDP per capita	GDP per capita of a city in logarithm	4.181 (65.461)	12.190 (196,728)	9.747 (24,110)	0.848 (21,660)
Government spending	The ratio of local government fiscal expenditure to GDP of the city	0.031	0.858	0.145	0.089
ER	The level of environment regulations proxied by the sulfur dioxide removal rate at the city level	0.001	0.981	0.385	0.275
Heavy	A dummy variable taking the value of one for heavy industries and 0 for light industries. Heavy industries produce capital goods, such as heavy equipment and large machine tools, that are used by other industries of the economy. Light industries refer to those that mainly produce consumer goods. We follow China's Industry Classification for National Economic Activities (GB/T4754-2017) to classify industries into heavy and light industries.	0	1		
Capital-intensive	A dummy variable taking the value of one for capital-intensive industries and 0 for labor-intensive industries. The division of industries into the category of capital-intensive and labor-intensive is based on the median value of capital intensity at the industry level.	0	1		

Note: Summary statistics of variables not in logarithm form are reported in the parenthesis.
Abbreviation: SD, standard deviation.

where $p(x)$ is the propensity score, $z = (0, 1)$ is the indicator of receiving the treatment (i.e., foreign ownership) and x is a vector of observed pre-treatment factors. We focus on firm characteristics between foreign ownership variables (FIEs) (the treatment group) and DOEs (the control group). For each treatment case i, the average treatment effect on the treated (ATT_i) can be estimated as follows,

$$\text{ATT}_i = E(\Delta i|\text{FIE}_i = 1) = E(Y_{1i}|\text{FIE}_i = 1) - E(Y_{0i}|\text{FIE}_i = 1) \tag{2}$$

where Y_{1i} and Y_{0i} denote the potential outcome (i.e., the number of environmental patents) in the two counterfactual situations of treatment and no treatment, respectively, and $\Delta i = Y_{1i} - Y_{0i}$. As the counterfactual expected value for those being treated, $E(Y_{0i}|\text{FIE}_i = 1)$, is unobservable, the propensity score is obtained from a Logit model of FIE. Similar to Kim et al. (2016) and Wang and Wang (2015), we chose a set of firm-level factors including *Size*, *Age*, *Export propensity*, *Capital intensity*, *Productivity*, and *Human capital*, in addition to firm-, industry-, province-, and year-fixed effects.

We apply the nearest neighbor matching method suggested by Li (2012) to estimate the difference in eco-innovation between FIEs and DOEs and conduct the propensity score density distribution and variables balance test to check the matching effects. For robustness check, we also perform Kernel matching method. In general, the matching results are considered to be acceptable when the absolute value of the standard bias of each covariate is <20%. Further, we perform a *t*-test on the mean values of the matching variables between the treatment group and the control group to assess whether there is a significant difference between the two groups after matching.

To assess environmental regulations and pollution intensity as boundary conditions, we conduct split-sample analysis. China, as a large country, has high intra-country variation in environmental regulations (Bu & Wagner, 2016). We thus divide the full sample based on the median value of the environmental regulations (*ER*) variable. Heavy industries tend to have higher levels of pollution than light industries, while capital-intensive industries tend to have higher levels of pollution than labor-intensive industries (Cole & Elliott, 2005). We thus identify heavy and light industries following China's Industry Classification for National Economic Activities (GB/T4754-2017). Capital-intensive and labor-intensive industries are separated based on the median value of the industry-level capital intensity.

4.3 | Econometric analysis

To address research question 2, we model a knowledge production function for DOEs with dependent variable, *Eco-innovation*. Specifically, we use the following specification for estimation:

$$\begin{aligned} Eco-innovation_{ijkt} = & \beta_0 FDI\_Eco-innovation_{jk,t-1} \\ & + \beta_1 ER_{k,t-1} + \beta_2 FDI\_Eco \\ & - innovation_{jk,t-1} \times ER_{k,t-1} \\ & + \gamma_i \boldsymbol{X}_{ijk,t-1} + \eta_j + \varphi_k + \mu_t + \varepsilon_{ijkt} \end{aligned}$$

where *Eco-innovation*$_{it}$ is eco-innovation of DOE i in industry j, province k, at time t and *FDI_Eco-innovation* is measured at the city (*FDI_Eco-innovation* (*City*)) or the industrial level (*FDI_Eco-innovation* (*Industry*)). $\boldsymbol{X}$ is a vector of control variables. We lagged all the explanatory variables by one year to allow for some time in the realization of their effects on the eco-innovation of DOEs and to account for endogeneity, an issue we will come back later. η_j, φ_k, and μ_t capture industry-, province-, and year-fixed effects, respectively. ε is the error term.

Consistent with previous studies, we measure FDI spillovers using the presence of FIEs (Liu et al., 2010). Although this is a widely accepted measure (for systematic review and meta-analysis, see Meyer & Sinani, 2009; Perri & Peruffo, 2016; Rojec & Knell, 2018), we recognize that this is an imperfect measure. As Rojec and Knell (2018, p. 582) said, it is a second-best measure and does not directly tackle "the question of how … spillovers actually take place," instead "focuses on the simpler issue of whether the presence and magnitude of MNEs affect … domestic firms." Perri and Peruffo (2016) also argue that it mainly focuses on the attribute of "magnitude" and overlooks the attributes of "scope" (the sectoral scope, the geographical scope, and the technological scope), and "speed" (the temporal patterns). Despite these limitations, such a measure provides us with a starting point to estimate the eco-innovation spillovers of FDI.

We assess both the geographical and the industrial dimension of FDI spillovers. The former is measured by the concentration of FDI activities undertaken by FIEs in the specific geographical territory of China where the DOE's headquarters is located. We identify city as the relevant territorial unit of analysis. In China's attempt to become an innovative country, cities are the country's innovation hubs, where almost all innovation activities take place and innovative firms and innovative people reside (Fang et al., 2014; Ning et al., 2016). Cities are considered the frontline of innovation because of their advanced producer services, production and innovation infrastructures (including the local pool of human assets), dense knowledge networks, and international connectivity. Cities provide geographic proximity and co-location of FIEs and DOEs. It is in cities where foreign and domestic firms interact with each other and share information, knowledge and a common space for business transactions and for factor mobility, which enables the occurrence of FDI spillovers.

FDI spillovers considered along the industrial dimension are captured by the share of FDI activities undertaken by FIEs in the specific industry in which the DOE competes, given that industry reflects technological regimes (e.g., cycle time of technology, fluidity of technological trajectories, and modularity) and market regimes (e.g., market segmentation) (Lee et al., 2017). Changes in technological and market regimes create "windows of opportunity" for innovation. DOEs, thus may exploit intra-industry FDI spillovers from FIEs. We use China's

TABLE 3 Treatment effect of environmental innovation and environmental performance based on nearest neighbor matching.

	N	Mean		ATT	SD	*t*
		Treatment group	Control group			
Eco-innovation						
Panel A: Full sample	1,546,768 (552,638)	0.013	0.009	0.004	0.0003	13.64
Panel B: Regional heterogeneity						
High stringency of environmental regulations	735,376 (386,729)	0.017	0.011	0.006	0.0005	11.95
Low stringency of environmental regulations	811,392 (352,442)	0.009	0.006	0.003	0.0003	7.16
Panel C: Industrial heterogeneity						
Light industries	969,980 (361,008)	0.007	0.005	0.002	0.0002	8.19
Heavy industries	576,587 (221,070)	0.026	0.017	0.009	0.0008	10.80
Labor-intensive industries	1,119,204 (449,892)	0.010	0.006	0.004	0.0003	12.55
Capital-intensive industries	427,564 (205,018)	0.019	0.014	0.005	0.0006	6.66
Environmental levies						
Panel D: Sample (year 2004)	185,499	0.790	1.222	−0.432	0.0141	−30.65

4-digit industry classification code to categorizes industries. For a robustness check, we used 3-digit industry classification and the results are qualitatively similar.

We first deduce FDI spillovers from FIEs' eco-innovation in either the geographical (*FDI_Eco-innovation* (*City*)) or the industrial dimension (*FDI_Eco-innovation* (*Industry*)). This implies, in relation to Hypothesis 2, the channels of resource transmission and institutional pressures are embedded in FIEs' eco-innovation activities. However, this may be too restrictive to measure FDI spillovers. The benefits of DOEs may derive from the broad FIEs activities which manifest the global innovation efforts of MNEs beyond local innovative activities. As argued by Tian (2007) and Wei and Liu (2006), different measures of FDI may capture different channels of spillovers. We thus follow these studies and take a multidimensional approach to measure global knowledge spillovers using employment, output, sales, and assets. The measure of employment-based FDI spillovers might be better associated with spillover effects linked to labor turnover. Output-based and sales-based measures might capture more of the channels through products, whereas an assets-based measure is likely to reflect the spillovers accrued to broad business activities.

To control for firm-level effects, we use *Size* and *Human capital* and firm-fixed effects. Additionally, we manage the potential confounding factors that underline both FDI spillovers and the eco-innovation of DOEs using *GDP* per capita and *Government spending* at the city-level as control variables and a set of industry-, province-, and year-fixed effects. The industry-fixed/province-fixed effects control for all time-invariant industry-specific/province-specific factors that could influence the level of inward FDI activities in the industry/province and the innovation path of DOEs in that industry/province. The year-fixed effects capture time-variant factors such as unobservable changes in the business environment or in the business cycle.

To further control for the potential endogeneity issue between FDI spillovers and eco-innovation of DOEs, we employ an instrumental-variable (IV) approach. The IVs for FDI spillovers variables at the city level are the distance from shoreline (*Distance*) and lagged FDI spillovers variables. In terms of the IVs for FDI spillovers variables at the industry level, we followed Park et al. (2010) and employed exchange rate weighted industry-level wage rate (*Erindex*) and lagged FDI spillovers variables. To check the validity of IVs, we report Kleibergen–Paap rank LM test for under-identification, Kleibergen–Paap rank Wald *F* test for weak-identification and Hansen-J statistics for over-identification. These tests confirm the validity of the instruments.

5 | RESULTS AND DISCUSSION

5.1 | Research question 1: Do MNEs' local subsidiaries, FIEs, outperform DOEs in eco-innovation?

The PSM method is carried out with results presented in Appendix A. Following the satisfactory matching results, we address research question 1 by estimating the ATT. Table 3 depicts the comparison of eco-innovation of FIEs and DOEs, controlling for firm-specific factors susceptible to impact on foreign ownership. Panel A shows that the difference in eco-innovation between the treatment group and the control group (ATT) is positive and the associated *t*-statistic is statistically significant. The number of environmental patents of FIEs is significantly more than that of DOEs. Hypothesis 1 is supported, indicating FIEs engage in more eco-innovation than DOEs. This finding is in line with the findings of empirical studies that verify the positive effects of foreign ownership on a firm's general innovation in the context of China (Chen & Zhang, 2019; Choi et al., 2011; Hu & Jefferson, 2009).

We further assess whether the estimated treatment effect on eco-innovation is contingent on environmental regulations and pollution intensity. We proceed with subsample analysis, focusing on environmental regulations at the city level and pollution intensity at the industry level. The results are shown in Panels B and C. ATT is shown to be statistically significant and positive, indicating that under the same level of environmental regulative stringency, FIEs engage in more eco-innovation than their DOE counterparts. This is again in line with Hypothesis 1. But the magnitude of ATT is larger under the condition of high stringency of environmental regulations than under the condition of low stringency, indicating a support for Hypothesis 1a. A comparison of mean values of the treatment group and the control group further reveals that (1) both FIEs and DOEs have more environmental patents in cities with higher levels of environmental regulation stringency than those in cities with lower levels of environmental regulation stringency; (2) comparable DOEs in cities with higher level of environmental regulation stringency have a higher number of environmental patents than FIEs in cities with lower level of environmental regulation stringency. This is an interesting finding, indicating that environmental regulations are an important antecedent for eco-innovation, not only through its direct effects, but also its joint effects with FDI.

We then compare heavy industries with light industries and capital-intensive industries with labor-intensive industries. ATT is shown to be statistically significant and positive for all industry types (light industries, heavy industries, labor-intensive industries, and capital-intensive industries), indicating that FIEs engage in more eco-innovation than their DOE counterparts in the respective industries. This again supports Hypothesis 1. The magnitude of ATT is larger when comparing heavy industries to light industries and when comparing capital-intensive industries to labor-intensive industries. Both provide support for Hypothesis 1b. A comparison of mean values of the treatment group and the control group further reveals that DOEs in heavy industries have more environmental patents than FIEs in light industries. DOEs in capital-intensive industries have more environmental patents than FIEs in labor-intensive industries. This evidence suggests that pollution intensity is an important context for the FDI-eco-innovation relationship.

5.2 | Research question 2: Does the global eco-innovation of MNEs boost that of DOEs?

Table 4 presents the correlation coefficients for variables used in econometric analysis. Correlation coefficients are low. The variance-inflation factors are low, ranging from 1.00 to 1.30. Both indicate that multicollinearity is not a major concern.

Table 5 reports regression results. All models include control variables, but Model (1) only includes city-level FDI eco-innovation spillovers (*FDI_Eco-innovation* (*City*)), Model (2) industry-level FDI eco-innovation spillovers (*FDI_Eco-innovation* (*Industry*)), and Model (3) both FDI eco-innovation spillovers at the city and the industry level. The bottom of the table reports a battery of diagnostic tests. The Kleibergen–Paap LM statistics and the Kleibergen–Paap F statistics suggest the rejection of the null of under-identification and weak-identification, respectively. The Hansen test of overidentifying restrictions indicates that the orthogonality of conditions cannot be rejected at the 10% level. Together, these tests give us the confidence in the results of IV estimation.

Due to missing values, the number of observations in Model (3) is substantially less than that in Models (1) and (2). Nevertheless, the qualitative findings of Model (3) are broadly in line with those of Models (1) and (2). The main findings are (1) *FDI_Eco-innovation* (*City*) is positive and statistically significant; (2) *FDI_Eco-innovation* (*Industry*) is positive but statistically insignificant. Thus Hypothesis 2 is supported at the city level, but not at the industry level. The FDI spillover effects are economically meaningful,[14] with a unit of change in FDI eco-innovation spillovers at the city level leading to a 10% increase in the number of environmental patents in DOEs (or a 1 standard deviation [henceforth, SD] increase in *FDI_Eco-innovation* (*City*) being associated with a 0.223 SD increase in *Eco-innovation* of DOEs). The first finding is in line with some of the studies on general innovation in China. For example, Ning et al. (2016) employ the spatial econometric framework to estimate FDI spillover effects on urban innovation and find that the effects are confined to the cities where MNEs have made the investment. As widely recognized in the

[14]According to Acock (2008), the standardized regression coefficients ($\widehat{\beta}$), is considered a weak effect if $\widehat{\beta} < 0.2$, a moderate effect $0.2 < \widehat{\beta} < 0.5$, and a strong effect if $\widehat{\beta} > 0.5$.

TABLE 4 Correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Eco-innovation															
2. Size	0.167														
3. Human capital	0.112	0.402													
4. FDI_Eco-innovation (City)	0.024	0.120	0.025												
5. FDI_Employment (City)	0.022	0.076	0.086	0.445											
6. FDI_Output (City)	0.021	0.069	0.081	0.430	0.938										
7. FDI_Sales (City)	0.021	0.068	0.081	0.429	0.938	0.931									
8. FDI_Assets (City)	0.012	0.080	0.066	0.468	0.922	0.930	0.930								
9. FDI_Eco-innovation (Industry)	0.008	0.061	0.005	0.043	0.074	0.068	0.068	0.065							
10. FDI_Employment (Industry)	0.029	0.103	0.042	0.105	0.220	0.194	0.195	0.181	0.352						
11. FDI_Output (Industry)	0.024	0.113	0.025	0.118	0.215	0.200	0.201	0.176	0.336	0.914					
12. FDI_Sales (Industry)	0.025	0.114	0.025	0.118	0.215	0.200	0.200	0.176	0.335	0.914	0.932				
13. FDI_Assets (industry)	0.007	0.141	0.008	0.113	0.202	0.183	0.183	0.167	0.364	0.885	0.948	0.948			
14. GDP per capita	0.077	0.275	0.216	0.079	0.342	0.349	0.350	0.331	0.025	0.033	−0.047	−0.047	−0.036		
15. Government spending	0.038	0.194	0.074	0.131	0.084	0.014	0.015	0.104	0.054	0.084	0.110	0.110	0.109	0.058	
16. ER	0.044	0.200	0.097	0.168	0.133	−0.137	0.136	0.117	0.037	0.057	0.097	0.097	0.086	0.334	0.060

economic geography and knowledge spillovers literature, knowledge spillovers more readily occur within close geographical proximity (Filatotchev et al., 2011), and, within cities, inter-industry spillovers are as important as intra-industry spillovers, if not more so (Jacobs, 1969). This is because effectively gaining and utilizing knowledge requires geographic co-location so as to access information that tends to be localized, engage in dense communication, and break down barriers to knowledge exchanges (Tallman & Chacar, 2011). City is, therefore, a more relevant unit of analysis for spillover effects. In contrast, the second finding on national intra-industry FDI spillover effects is likely to capture the net effects of both positive eco-innovation spillovers and the crowding-out effects from FDI (Spencer, 2008), as well as the negligible benefits that DOEs can derive from the eco-innovation activities of FIEs located beyond their shared geographical sphere.

To assess the boundary condition of environmental regulations and pollution intensity, we conduct additional analysis and present the results in Table 6. As *FDI_Eco-innovation* (*Industry*) is shown to be statistically insignificant in Table 5, here we focus on *FDI_Eco-innovation* (*City*). In Model (1), three variables that are of our main concern, *FDI_Eco-innovation*, *ER*, and their interaction, are positive and statistically significant. This shows that not only DOEs benefit from co-location with FIEs who conduct eco-innovation locally, such benefits are also stronger in cities with more stringent environmental regulations than in those with less stringent environmental regulations, supporting Hypothesis 2a.

Models (2) and (3) include two industry dummies (*Heavy* and *Capital-intensive*) and their interaction terms with *FDI_Eco-innovation*. *Heavy* is positive and statistically significant, indicating that DOEs in heavy industries conduct more eco-innovation than those in light industries. *Capital-intensive* is positive but statistically insignificant, indicating that eco-innovation of DOEs in capital-intensive industries is not different from their counterparts in labor-intensive industries. *FDI_Eco-innovation* and its interaction with the two industry dummies are positive and statistically significant, indicating that, on average, FDI stimulates DOEs' eco-innovation more in heavy industries than in light industries, and more in capital-intensive industries than in labor-intensive industries. Taken together, we can see that FDI spillover effects are stronger in dirty industries than in clean industries, supporting Hypothesis 2b.

5.3 | Robustness checks

When addressing research question 1, we also performed PSM based on Kernel matching. The results are presented in Table B3 and are similar to those in Table 3: (1) FIEs have more environmental patents than DOEs of similar

TABLE 5 FDI eco-innovation spillovers on environmental innovation of DOEs (Dependent variable = environmental patent of DOEs).

Second stage	**(1)**	**(2)**	**(3)**
FDI_Eco-innovation (City)	0.102** (0.043)		0.098* (0.059)
FDI_Eco-innovation (Industry)		0.002 (0.014)	0.002 (0.023)
ER	0.014*** (0.002)	0.018*** (0.006)	0.052*** (0.016)
Size	0.005*** (0.001)	0.003 (0.002)	0.002 (0.004)
Human capital	0.001 (0.001)	0.003** (0.002)	0.007** (0.003)
GDP per capita	0.037*** (0.008)	0.014*** (0.004)	0.027*** (0.010)
Government spending	0.009 (0.075)	0.266*** (0.066)	0.595*** (0.194)
Kleibergen–Paap rank LM statistic	248.962***	1529.982***	262.602***
Kleibergen–Paap rank Wald *F* statistic	124.733***	788.044***	66.256***
Hansen-J statistic	0.510	1.380	0.439
N	135,118	78,270	36,236
First stage			
L2.FDI_Eco-innovation (City)	0.046*** (0.003)		0.101*** (0.006)
Distance	−0.0002*** (0.0001)		−0.0002** (0.0001)
L2.FDI_Eco-innovation (Industry)		0.159*** (0.004)	0.171*** (0.006)
Erindex		0.0002* (0.0001)	0.0002* (0.0001)

Note: Standard errors in parentheses. Firm-, industry-, province-, and year-fixed effects are included.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

characteristics, supporting Hypothesis 1; (2) the magnitude of ATT is larger under the condition of high stringency of environmental regulations than under the condition of low stringency of environmental regulations, supporting Hypothesis 1a; (3) the magnitude of ATT is larger for heavy industries when compared to light industries and for capital-intensive industries when comparing to labor-intensive industries, supporting Hypothesis 1b.

Environmental levies are charged on polluters based on their discharge of sewage, waste gas, solid waste and hazardous waste[15] and is directly linked to emissions (Chen et al., 2014; Ding et al., 2016; Maung et al., 2016). The PSM results are presented in Appendix B and the results for the comparison of FIEs and DOEs using nearest neighbor matching are presented in Panel D of Table 3. The difference in environmental levies between the treatment group and the control group (ATT) is negative and the *t*-statistic is statistically significant. For a robustness check, we also performed PSM based on Kernel matching and the results are similar. That is, FIEs incurred significantly less environmental levies than DOEs, a result in line with Maung et al. (2016) who applied a regression technique, but not accounting for the endogeneity of FDI. This finding indicates the importance of looking at FDI spillovers beyond local eco-innovation. As argued above, although the local eco-innovation of FIEs may be more relevant, more observable to DOEs, MNEs often conduct eco-innovation globally and transfer eco-innovation outcomes to host countries which could also be spilled over to DOEs. We performed PSM on environmental levies, a measure of environmental pollution.

Moving onto research question 2, we assess FDI spillover effects by using alternative measures and present the results in Table 7. Models (1)–(4) include each measurement of spillovers variables by employment, output, sales, and assets at the city and the industry level. In Model (1), FDI spillovers measured by employment at the city level and at the industry level are both positive and statistically significant, albeit the degree of impact is more pronounced at the city level. Models (2), (3), and (4) show the coefficients on output-based, sales-based and assets-based FDI spillovers are positive but only statistically significant at the city level. Taken together, these findings further confirm the importance of co-location in the same cities of the FIEs to DOEs' eco-innovation. Both the economic and institutional rationale associated with FDI spillover effects are applicable at the city level. In terms of the level of economic significance, based on the standardized regression coefficient ($\widehat{\beta}$), it

[15]The charge of environmental levies is according to the "Administrative Regulations on Pollution Discharge Fee" (http://www.gov.cn/gongbao/content/2003/content_62565.htm) issued by the State Council, which covers >100 various pollutants. The calculation method and collection process are comprehensive.

TABLE 6 FDI eco-innovation spillovers (City) moderated by environmental regulations and pollution intensity.

Dependent variable	Environmental patent of DOEs			New product sales weighted by environmental innovation intensity of DOEs		
	(1)	(2)	(3)	(4)	(5)	(6)
FDI_Eco-innovation (City)	0.103** (0.042)	0.102** (0.042)	0.208** (0.087)	0.303** (0.140)	0.726** (0.326)	0.326* (0.185)
ER	0.072*** (0.023)	0.013*** (0.002)	0.013*** (0.002)	0.163** (0.083)	0.024 (0.024)	0.138 (0.094)
FDI_Eco-innovation (City) × ER	0.159** (0.064)			0.492** (0.212)		
FDI_Eco-innovation (City) × Heavy		0.079** (0.034)			0.573** (0.252)	
FDI_Eco-innovation (City) × Capital-intensive			0.207** (0.085)			0.309* (0.175)
Heavy		0.031** (0.012)			0.201** (0.089)	
Capital-intensive			0.037 (0.107)			0.294 (0.647)
Control variables	Included	Included	Included	Included	Included	Included
Kleibergen–Paap rank LM statistic	657.494***	332.693***	105.556***	1149.708***	116.257***	175.225***
Kleibergen–Paap rank Wald *F* statistic	330.898***	166.834***	52.801***	583.120***	58.166***	87.739***
Hansen-J statistic	0.130	0.303	0.391	0.059	0.001	0.002
N	135,118	135,118	135,118	118,240	118,240	118,240

Note: Standard errors in parentheses. Control variables, and firm-, industry-, province-, and year-fixed effects are included.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

appears that *FDI_Eco-innovation* (*City*) ($\widehat{\beta} = 0.223$) has the largest effect size, followed by *FDI_Sales* (*City*) ($\widehat{\beta} = 0.105$), *FDI_Employment* (*City*) ($\widehat{\beta} = 0.093$), *FDI_Assets* (*City*) ($\widehat{\beta} = 0.090$), and *FDI_Output* (*City*) ($\widehat{\beta} = 0.054$). Thus, the eco-innovation of FIEs have moderate effects, and FIEs' other non-eco-innovation all have small effects on the eco-innovation of DOEs.

At the national level, the only relevant mechanism is labor turnover. Innovation is human capital-intensive, with a 1 SD increase in *FDI_Employment* (*Industry*) being associated with a 0.107 SD increase in *Eco-innovation* of DOEs, thus showing weak effects. The availability of highly qualified skilled labor is crucial in R&D decisions (Papanastassiou et al., 2020) and has a significant impact on the DOE's general innovation performance (Liu et al., 2010). Complex, tacit knowledge, an essential ingredient for innovation, is best transmitted through human interactions (Tallman & Chacar, 2011). The geographical and the industrial dimension of FDI spillovers through labor mobility from FIEs to DOEs therefore play an important role in the eco-innovation of DOEs. In contrast, the eco-innovation of DOEs that benefit from resource acquisition and institutional isomorphism associated with the broad FDI activities, is largely geographically confined to the city level.

Our final robustness check is to focus on the eco-innovation measure for DOEs. As patent does not cover the commercialization aspect of innovation activities, we used an alternative measure, that is, new product sales weighted by eco-innovation intensity (i.e., the ratio of environmental patents in total patents). This measure is aligned with the Schumpeter view of innovation that "… innovation is only accomplished with the entry of a new product or process into commercial use" (Kemp & Pearson, 2007) and based on empirical observations of a positive association between the introduction of new products and the time of patenting (Balasubramanian & Sivadasan, 2011). The results are presented in Models (4)–(6) of Table 6. They are similar to those based on the patent-measured dependent variable except that *ER* becomes statistically insignificant in Models (5) and (6), although the coefficients remain positive.

6 | CONCLUSIONS AND FUTURE WORK

This paper explores the global eco-innovation of MNEs and its local impact. It is placed at the intersection of three strands of the existing literature. The first is on the determinants of eco-innovation, though much of it focuses on domestic firms in a single country setting (for recent reviews, see Dangelico, 2016; Hojnik & Ruzzier, 2016). The second is on the environmental performance and environmental management of MNEs based on the

TABLE 7 FDI spillovers on environmental innovation of DOEs by alternative measure of FDI spillovers variable (Dependent variable = environmental patent of DOEs).

	(1)	(2)	(3)	(4)
FDI_Employment (City)	0.068*** (0.024)			
FDI_Employment (Industry)	0.069* (0.036)			
FDI_Output (City)		0.038* (0.020)		
FDI_Output (Industry)		0.005 (0.017)		
FDI_Sales (City)			0.073*** (0.024)	
FDI_Sales (Industry)			0.042 (0.035)	
FDI_Assets (City)				0.064* (0.037)
FDI_Assets (Industry)				0.012 (0.032)
ER	0.006*** (0.002)	0.007* (0.004)	0.003 (0.004)	0.007*** (0.002)
Size	0.003*** (0.001)	0.005*** (0.001)	0.004*** (0.001)	0.003*** (0.001)
Human capital	0.002*** (0.001)	0.003** (0.001)	0.003*** (0.001)	0.002*** (0.001)
GDP per capital	0.004** (0.002)	0.007*** (0.003)	0.015*** (0.003)	0.004* (0.002)
Government intervention	0.103*** (0.026)	0.143*** (0.050)	0.052 (0.060)	0.118*** (0.026)
Kleibergen–Paap rank LM statistic	1903.383***	7937.656***	1399.583***	1587.138***
Kleibergen–Paap rank Wald *F* statistic	481.7492***	2307.700***	353.043***	400.851***
Hansen-J statistic	1.718	1.801	2.225	2.054
N	223,139	102,729	222,702	223,139
First stage				
L2.FDI_Eco-innovation (City)	0.25*** (0.002)	0.324*** (0.004)	0.081*** (0.002)	0.119*** (0.002)
Distance	−0.0001*** (6.38e-06)	−0.0002** (0.00001)	−0.0001** (8.14e-06)	−0.00008** (8.23e-06)
L2.FDI_Eco-innovation (Industry)	0.104*** (0.002)	0.384*** (0.004)	0.092*** (0.002)	0.094*** (0.002)
Erindex	0.00002* (0.00001)	0.00003* (0.00002)	0.00007*** (0.00002)	0.0001*** (0.00002)

Note: Standard errors in parentheses. Firm-, industry-, province-, and year-fixed effects are included.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

overarching theoretical framework of IBV (Aragón-Correa et al., 2016; Holtbrügge & Dögl, 2012; Kolk & Pinkse, 2008; Maksimov et al., 2019; Tatoglu et al., 2014). The third is on the innovation effects of inward FDI which focus on innovation in general without distinguishing eco-innovation and conventional innovation (Liu et al., 2017; Papanastassiou et al., 2020; Un, 2011). Building on these research streams, our conceptual model brings together the economic rationality underpinning NRBV and the institutional rationality of IBV as complementary perspectives in theorizing FDI as drivers of eco-innovation in emerging economies. Drawing on NRBV and IBV further advances our understanding of environmental regulations and pollution intensity as boundary conditions of the FDI effects in the domain of eco-innovation.

Our main theoretical contribution is in adopting a pluralistic theoretical approach by combining insights from NRBV and IBV to examine the eco-innovation effects FDI/MNEs (foreign ownership and FDI spillovers) and those being contingent on environmental regulations and pollution intensity (Thatcher & Fisher, 2022). Due to the diverse theoretical assumptions of these two perspectives, NRBV and IBV have progressed along separate, parallel paths, although RBV and IBV have been brought together to form a conceptual framework in international business strategy research (Peng et al., 2008, 2009). Our theoretical discussions highlight the importance of the intersection between the two theories in explaining the eco-innovation effects of FDI, and in particular in allowing a nuanced consideration around the under-explored boundary conditions of FDI effects in the eco-innovation domain.

Our study also makes an important empirical contribution. As the world's largest polluter and the second largest economy, China's transition to a green economy is a key concern for the world (Marquis et al., 2011). Since its 11th Five-Year Plan for National Economic and Social Development, the Chinese government has shifted its priorities from an exclusive focus on economic growth to longer-term, more balanced economic and social development. Furthermore, China pledged to reach carbon neutrality before 2060 at the virtual UN General Assembly meeting. This begs a big question regarding how China can achieve the goal. Given that China is a leading recipient of FDI and that it aims to enhance international competitiveness via innovation, this research provides fresh evidence and a route forward on how to stimulate eco-innovation to ease environmental tension and improve environmental performance alongside economic development.

First, we find that FIEs conduct more eco-innovation than their domestic counterparts with similar characteristics. Following from this result, we assess whether MNEs' global eco-innovation generates spillover effects to DOEs in China. We find that MNEs' global eco-innovation significantly contributes to the eco-innovation of DOEs, not only through their FIEs' co-location of eco-innovation activities with DOEs in the same city, but also FIEs' broad business activities that are in the presence of DOEs' local business environment. Additionally, labor mobility seems to offer a channel, facilitating intra-industry FDI spillovers at the national level. Although, in general, the role of FDI in eco-innovation activities in China is positive, there are differential effects determined by environmental regulations and pollution intensity. Both FIEs and DOEs conduct more eco-innovation in cities with more stringent environmental regulations than their counterparts in cities with less stringent environmental regulations. However, DOEs in cities with more stringent environmental regulations outperform FIEs in cities with less stringent environmental regulations. This shows the important role of environmental regulations in eco-innovation. We also find the positive FDI eco-innovation spillover effects vary according to the pollution level of an industry. They are stronger in heavy and capital-intensive industries. These new findings significantly enhance our understanding of eco-innovation in China, more specifically, the role of FDI in promoting eco-innovation.

In summary, this paper provides important contributions concerning international strategy and innovation in emerging markets. The theorization based on NRBV and IBV takes an important step toward rounding out our understanding of the role of FDI in eco-innovation and the associated boundary conditions. In so doing, we contribute novel insights on the theoretical validity of the "induced innovation" or "race to the top" hypothesis (Bu & Wagner, 2016). MNEs face a unique institutional environment in which regulative requirements on and stakeholder demands of their actions on sustainability in general, and eco-innovation in particular, are becoming increasingly strong and diverse. There is, therefore, a need for MNEs to have international sustainability strategy with a focus on eco-innovation. Our findings are indicative of the primary environmental benefits that MNEs have on offer. Under institutional pressures, organizational resource capacity and green dynamic capabilities enable them to conduct and diffuse eco-innovation in the host, emerging economies, and these are more likely to occur in high-salience cities with more stringent environmental regulations and industries with higher levels of pollution whereby environmental challenges are of a major concern.

6.1 | Practical implications

Emerging economies including China often have policies attracting FDI in the hope that FDI will lead to knowledge transfer which will help with the country's economic development and catch-up. However, there have been concerns on FDI impact. On the innovation front, debates focus on whether MNEs transfer advanced technologies and whether the technologies transferred help improve the country's innovative capabilities. For example, Nam's (2011) case study of China's automotive industry reveals that there was limited technology transfer from VW to their Chinese joint ventures until the Chinese government and SAIC signed up to a joint venture agreement with GM. Although the technologies transferred over time helped Chinese firms' catch-up, they strengthened only the production capabilities of Chinese firms (both joint ventures and local suppliers) but not their innovation capabilities. Our study, using more recent data and focusing on eco-innovation based on a very large dataset, reveals not only the higher innovation capabilities of FIEs over DOEs, but also the spillovers from FIEs leading to eco-innovation within DOEs. Therefore, the government should recognize that MNEs taking the responsibility for sustainability could act as agents of change, not only conducting eco-innovation in the host country but also stimulating the eco-innovation of DOEs. Policies could be designed to encourage more FDI and their eco-innovation activities in China through national economic diplomacy (e.g., bilateral trade and investment treaties and FDI promotion agencies). Additionally, our evidence on the significant role of FDI in cities also corroborates Côté et al.'s (2020) suggestions of city diplomacy[16] and the coordination of national and city diplomacy. For managers of DOEs, there should be more collaboration with FIEs. In view of the lessons from the automotive industry, which has an oligopolistic market structure and market protection of firms from import competition, we recommend a

[16]City diplomacy is defined as "the ways in which cities can represent their interests internationally, both with other cities and with other relevant organizations" (Côté et al., 2020, p. 201).

policy of more competition in order to maximize the potential benefits from FDI.

Second, the benefits of eco-innovation for DOEs from FDI are largely localized, and this highlights the need to further develop cities as the enablers of innovation. Cities are the center of innovation through bringing together economic agents and assets. China has made significant progress in urbanization since economic reforms of the late 1970s, transforming to an urban country from a largely agricultural country, increasing the geographical built-up areas of cities, improving infrastructure and public services, and promoting urban agglomerations (Guan et al., 2018). However, the rapid evolution of cities does not go by without challenges. The most noticeable issues include high resource consumption, high levels of pollution, and deteriorating living conditions for some. Governments, therefore, should coordinate urbanization strategies in order to take advantage of FDI spillovers, transforming the urbanization model from resource-driven to eco-innovation-driven. For managers of DOEs, their aim should be to co-locate with FIEs to gain access to knowledge spillovers from industry leaders and to take advantage of any "windows of opportunity."

Third, our finding of employment-based FDI spillovers having positive effects along both city and industry dimensions indicates the important role of human mobility in facilitating resource acquisition and exerting institutional pressures in driving forward the eco-innovation of DOEs. Since economic reform, the rigid "Hukou system" in China that used to limit human mobility across cities has been gradually eased. Our research indicates that for DOEs to take advantage of FDI spillover effects for their eco-innovation activities, there is a need for government actions to further liberalize the labor market. This could take the form of migration at the subnational and the national levels and together with corporate actions to attract highly skilled labor from MNEs.

Finally, the evidence in relation to environmental regulations confirms its important role in the eco-innovation of FIEs and DOEs. However, as claimed by Liao (2018a, p. 50), following their content analysis of China's environmental instruments for promoting corporate eco-innovation, the policy instruments "lacked authority" and were missing "comprehensive application of different environmental policy instruments." Our research suggests that China needs to further strengthen the formulation and implementation of the environmental policy instruments. Filling institutional voids in government regulations will encourage more eco-innovation by DOEs directly and indirectly through leveraging the effects of FDI eco-innovation spillovers. This is particularly important for the eco-innovation activities in dirty industries.

6.2 | Limitations and suggestions for future research

Our study has several limitations. First, it tests hypotheses based on only one emerging economy—China. This may not be representative of broad emerging economies given its large size, and our study was also of the period 2001–2013 when the globalization movement was at its peak (Maksimov et al., 2019). Although China shares similar characteristics with other emerging economies (e.g., imperfect factor markets and institutional voids) future research examining other countries would help to verify the hypotheses. Furthermore, more recent events such as Brexit, trade conflicts between the United States and China, the COVID-19 pandemic, and China's intensified efforts on the policy and eco-innovation fronts to meet climate ambitions (Carlson et al., 2021), may impact on future research findings. Future research therefore could use more recent data and look at boundary conditions of the eco-innovation effects of FDI in relation to the recent more volatile economic and political environment.

Our second limitation is related to variable measurements for eco-innovation and FDI spillovers. We have used patent-based measures for eco-innovation and FDI eco-innovation spillovers variables. Patent represents new technologies and has been shown to correlate with innovation activities and so is a popular measure used in innovation studies (Ding et al., 2021; Dziallas & Blind, 2019). Knowledge spillovers literature has also largely used patent-based measures for spillovers because new knowledge can be acquired through studying patent documents (for reviews, see Nelson, 2009; Neves & Sequeira, 2018). More specific to eco-innovation, according to Wagner (2007, p. 1590), "... patented environmental innovations are in many ways the most desirable measure of environmental innovation activities." However, as is rightly pointed out by Dziallas and Blind (2019), such measures do not capture the commercialization aspect of innovation. They tend to under-estimate eco-innovations as not all eco-innovations are patented, and firms may choose to use a strategy of secrecy instead of patenting their innovation to protect it. Firms' patenting propensity can be related to their size and the sectors within which they operate, thus, patent might understate eco-innovation. Additionally, the extant literature has compared patent counts and patent citations, arguing that the latter better accounts for the quality of patents (Nelson, 2009). Unfortunately, patent citation data are not available. In relation to other measures of the FDI spillovers variable (i.e., those are based on employment, output, sales, and assets), as mentioned above, they are imperfect measures. More direct measures may be labor turnover and direct business transactions from FIEs to

DOEs.[17] We therefore need to be cautious in interpreting our findings.

Third, as summarized in review papers on product innovation (Evanschitzky et al., 2012) and eco-innovation (Hojnik & Ruzzier, 2016), an extensive set of factors/drivers behind successful product or eco-innovation has been covered in the literature. Despite our best efforts in controlling for firm-, industry-, province-, and city-level factors or fixed effects, due to data availability, we have not looked into, for example, specific effects of organizational climate (Evanschitzky et al., 2012), management capabilities (Watson et al., 2018), and top management support as well as the personal commitment of managers (Hojnik & Ruzzier, 2016). Future research could explore these internal factors and how they interact with foreign ownership and the presence of FDI in their business environment.

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ETHICS STATEMENT

The authors have read and agreed to the Committee on Publication Ethics (COPE) international standards for authors.

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APPENDIX A

A.1 | Results of PSM method for eco-innovation

TABLE A1 PSM estimates and balance property based on Nearest Neighbor matching, full sample covering 2001–2013.

Variables	Logit regression (dependent variable = FIE)	Treatment	Mean: Treatment group	Mean: Control group	Standardized bias (SB) (%)	SB reduction (%)	*p*-value for *t*-test
Size	0.377*** (174.05)	Before matching	10.675	9.938	50.4	85.6	0.000
		After matching	10.675	10.569	7.3		0.178
Age	−0.289*** (−81.38)	Before matching	2.029	2.024	0.7	2.5	0.001
		After matching	2.029	2.025	0.7		0.006
Export propensity	1.450*** (281.74)	Before matching	0.649	0.287	77.9	84.4	0.000
		After matching	0.649	0.593	12.1		0.134
Capital intensity	0.036*** (14.39)	Before matching	3.766	3.617	11.7	81.1	0.000
		After matching	3.766	3.738	2.2		0.119
Productivity	0.194*** (62.12)	Before matching	5.629	5.565	6.1	93.7	0.000
		After matching	5.629	5.625	0.4		0.138
Human Capital	0.530*** (125.71)	Before matching	2.901	2.544	47.8	87.3	0.000
		After matching	2.901	2.856	6.1		0.105
Constant	−5.914*** (−176.23)						
χ^2	363,842.03						
Pseudo R^2	0.235						

Note: $N = 1{,}546{,}768$. t value in parentheses in the Logit regression results. Industry-, province-, and year-fixed effects are included in the Logit model. Treatment group = FIEs; Control group = DOEs. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

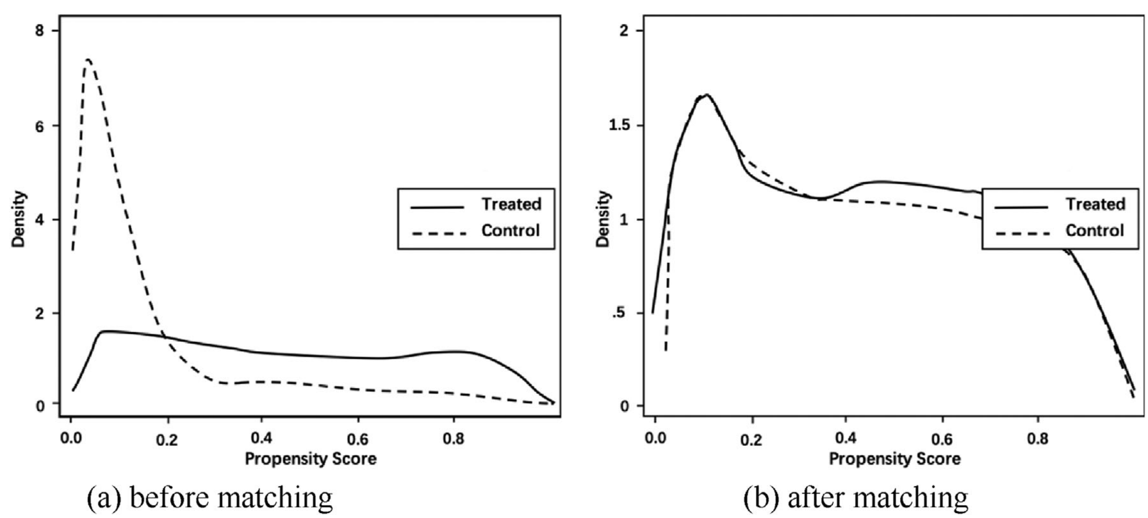

FIGURE A1 Distribution of propensity score density before and after matching (based on nearest neighbor matching).

Table A1 (on the left side) reports the results of the Logit model with dependent variable FIE differentiating FIEs and DOEs for the whole sample period. The coefficient estimates suggest that FIEs tend to be firms that are larger in size, younger in age, more export-oriented and have a higher level of capital-intensity, productivity, and

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TABLE A2 PSM estimates and balance property based on Kernel matching, full sample covering 2001–2013.

Variables	Logit regression (dependent variable = FIE)	Treatment	Mean: Treatment group	Mean: Control group	Standardized bias (SB) (%)	SB reduction (%)	*p*-value for *t*-test
Size	0.377*** (174.05)	Before matching	10.675	9.939	50.4	86.4	0.000
		After matching	10.675	10.775	−6.8		0.170
Age	−0.289*** (−81.38)	Before matching	2.029	2.024	0.7	−172.8	0.001
		After matching	2.029	2.043	−1.9		0.106
Export propensity	1.450*** (281.74)	Before matching	0.649	0.287	77.9	99.4	0.000
		After matching	0.649	0.647	0.5		0.165
Capital intensity	0.036*** (14.39)	Before matching	3.766	3.617	11.7	86.5	0.000
		After matching	3.766	3.786	−1.6		0.114
Productivity	0.194*** (62.12)	Before matching	5.629	5.565	6.1	62.2	0.000
		After matching	5.629	5.653	−2.3		0.112
Human Capital	0.530*** (125.71)	Before matching	2.901	2.544	47.8	96.5	0.000
		After matching	2.901	2.914	−1.8		0.115
Constant	−5.914*** (−176.23)						
χ^2	363,842.03						
Pseudo R^2	0.235						

Note: $N = 1{,}546{,}768$. *t* value in parentheses in the Logit regression results. Industry-, province-, and year-fixed effects are included in the Logit model. Treatment group = FIEs; Control group = DOEs. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

human capital. Our results are in line with the findings of Wang and Wang (2015) whose study is based on the same database but covers a shorter time period (2001–2005) than our study (2001–2013).

To examine the performance of the PSM method, we compare distribution of propensity score density before and after nearest neighbor matching (see Figure A1) and conduct balance tests of matching covariates. Figure A1 shows that there is a significant difference in the distribution of propensity score density between the control group (DOEs) and the treatment group (FIEs) before matching, and the degree of fitting is optimized after matching.

The balance test results on the right side of Table A1 show that the absolute values of standardized bias (SB) after matching are <10% for all variables except *Export propensity*. This is a substantial improvement over the absolute SB values before using PSM. Furthermore, the *t*-test was conducted to examine the balance of each variable; *p*-values of *t*-tests for all variables except *Age* are very small before matching. After matching, these *p*-values, bar that for *Age*, are >0.1. Thus, there is strong evidence that the covariates are balanced for the treatment and the control groups. The results of these tests indicate that our matching results are acceptable and the treatment group (FIEs) and the control group (DOEs) do not significantly differ from each other with regard to the set of covariates employed in the matching exercise.

To check for robustness, we also conducted PSM based on Kernel matching. The results are presented in Table A2. They are qualitatively similar to those of Table A1. The balance test results show that the absolute values of SB after matching are <10% for all variables, much improved over the absolute SB values before using PSM. In addition, *p*-values of *t*-tests for all variables are very small before matching. After matching, *p*-values are >0.1.

APPENDIX B

B.1 | Results of PSM method for environmental levies

Table B1 (on the left side) reports the estimation results of the Logit model with dependent variable FIE for 2004 because environmental levies are only available for 2004 (Maung et al., 2016). The estimation results are qualitatively similar to the full-sample results. Comparing the distribution of propensity score density before and after matching (see Figure B1) and conducting the balance tests of matching covariates, we again confirm the validity of the matching results. To check for robustness, we also conducted PSM based on Kernel matching. The results are presented in Table B2. They are qualitatively similar to those of Table B1.

TABLE B1 PSM estimates and balance property based on nearest neighbor matching, sample for 2004.

Variables	Logit regression (dependent variable = FIE)	Treatment	Mean: Treatment group	Mean: Control group	Standardized bias (SB) (%)	SB reduction (%)	*p*-value for *t*-test
Size	0.306*** (48.37)	Before matching	10.257	9.439	58.6	68.1	0.000
		After matching	10.257	9.996	18.7		0.175
Age	−0.296*** (−31.64)	Before matching	1.824	1.817	0.9	−266.6	0.160
		After matching	1.824	1.799	3.2		0.117
Export propensity	1.878*** (121.47)	Before matching	0.684	0.198	112.1	86.3	0.106
		After matching	0.684	0.617	15.4		0.121
Capital intensity	0.098*** (12.88)	Before matching	3.690	3.497	15.0	36.5	0.000
		After matching	3.690	3.568	9.5		0.134
Productivity	0.060*** (6.27)	Before matching	5.438	5.307	13.4	42.7	0.000
		After matching	5.438	5.363	7.7		0.143
Human Capital	0.952*** (61.11)	Before matching	2.673	2.348	59.7	68.4	0.000
		After matching	2.673	2.570	18.9		0.118
Constant	−9.125*** (−56.51)						
χ^2	54,366.97						
Pseudo R^2	0.291						

Note: $N = 185{,}499$. t value in parentheses in the Logit regression results. Industry-, province-, and year-fixed effects are included in the Logit model. Treatment group = FIEs; Control group = DOEs. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

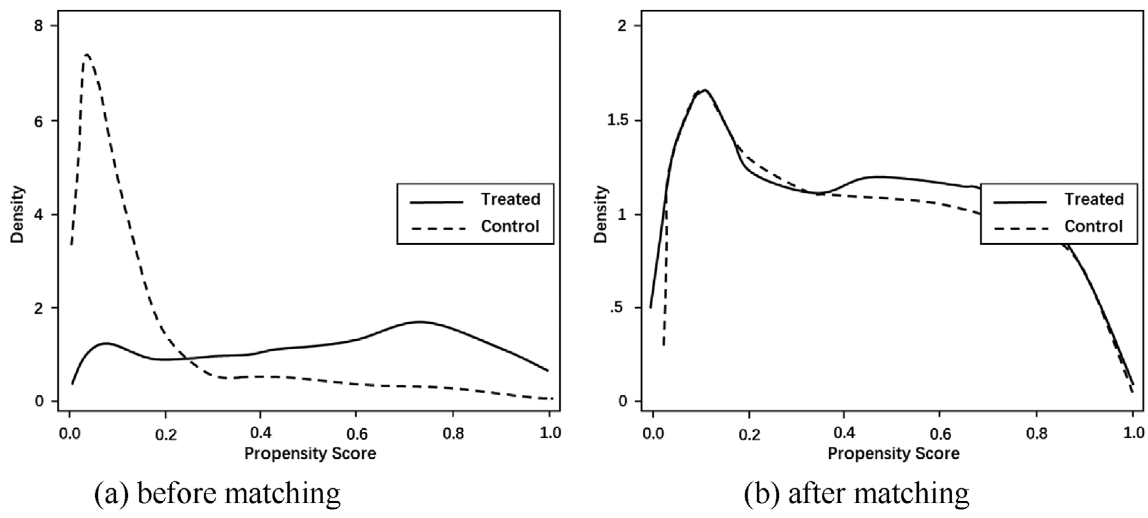

FIGURE B1 Distribution of propensity score density before and after matching (based on nearest neighbor matching).

TABLE B2 PSM estimates and balance property based on Kernel matching, sample for 2004.

Variables	Logit regression (dependent variable = FIE)	Treatment	Mean: Treatment group	Mean: Control group	Standardized bias (SB) (%)	SB reduction (%)	*p*-value for *t*-test
Size	0.306*** (48.37)	Before matching	10.257	9.439	58.6	84.5	0.000
		After matching	10.257	10.384	−9.1		0.156
Age	−0.296*** (−31.64)	Before matching	1.824	1.817	0.9	71.2	0.160
		After matching	1.824	1.826	−0.3		0.730
Export propensity	1.878*** (121.47)	Before matching	0.684	0.198	112.1	99.6	0.000
		After matching	0.684	0.682	0.4		0.596
Capital intensity	0.098*** (12.88)	Before matching	3.690	3.497	15.0	89.7	0.000
		After matching	3.690	3.710	−1.5		0.147
Productivity	0.060*** (6.27)	Before matching	5.438	5.307	13.4	93.0	0.000
		After matching	5.438	5.447	−0.9		0.209
Human Capital	0.952*** (61.11)	Before matching	2.673	2.348	59.7	97.2	0.000
		After matching	2.673	2.682	−1.7		0.140
Constant	−9.125*** (−56.51)						
χ^2	54,366.97						
Pseudo R^2	0.291						

Note: $N = 185{,}499$. *t* value in parentheses in the Logit regression results. Industry-, province-, and year-fixed effects are included in the Logit model. Treatment group = FIEs; Control group = DOEs. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE B3 Treatment effect of environmental innovation and environmental performance based on Kernel matching.

	N	Mean: Treatment group	Mean: Control group	ATT	SD	*t*
Eco-innovation						
Panel A: Full sample	1,546,768 (552,638)	0.013	0.012	0.001	0.0003	1.80
Panel B: Environmental regulations						
High stringency of environmental regulations	735,376 (386,729)	0.017	0.014	0.003	0.0005	6.20
Low stringency of environmental regulations	811,392 (352,442)	0.009	0.008	0.001	0.0003	4.01
Panel C: Pollution intensity						
Light industries	969,980 (361,008)	0.007	0.006	0.001	0.0003	4.53
Heavy industries	576,587 (221,070)	0.026	0.023	0.003	0.0008	4.06
Labor-intensive industries	1,119,204 (449,892)	0.010	0.008	0.002	0.0003	5.31
Capital-intensive industries	427,564 (205,018)	0.019	0.017	0.002	0.0005	3.73
Environmental levies						
Panel D: Sample (year 2004)	185,499	0.790	1.223	−0.433	0.0156	−27.78

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