Environmental Practices, Digitalization, and Green Innovation in Multinational Firms

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ABSTRACT

This study examines the diverse environmental practices of multinational firms, the degree of digitalization among parent firms, and green innovation. Using data from multinational listed firms from 2007 to 2018 as a sample, this article uses regression analysis to show that the more widely distributed the subsidiaries of multinational firms, the more heterogeneous the environmental knowledge acquired by the parent firm. The more diverse the environmental practices, the worse the green innovation performance of the parent firm. The degree of digitalization of the parent firm can effectively mitigate this negative effect. The more digital the parent company is, the more quickly it can process the large amount of complex information that helps the parent firm to achieve green innovation. These findings provide a new perspective on innovation in firms.

KEYWORDS
Digitalization, Environmental Practice, Green Innovation, Knowledge, Multinational Firms

INTRODUCTION

It is increasingly recognized that global climate change will bring many problems that will seriously affect the sustainable development of human beings. Green innovation, a key initiative to sustain environmental stewardship (Arenhardt et al., 2016; Chen, 2008; Chen et al., 2012; Yang et al., 2016), can help build a more resilient and sustainable world (Usman et al., 2020). However, environmental regulations and priorities vary between countries, which poses considerable challenges for international firms (Bansal, 2005; Christmann, 2004; Christmann & Taylor, 2001, 2006; Rugman & Verbeke, 1998).

An important stream of research related to international business and corporate environmental management lies in how multinational firms adapt to the environmental policies of their host countries and develop environmental strategies accordingly. The concept of environmental protection may be more institutionalized and more of a social norm in some countries. In turn, corporate behavior can align with national behaviors, facilitating green innovation (Quan et al., 2023). The corporate values...
of the foreign subsidiary should align with the environmental policies of the host country (Scott, 1995). Once the subsidiary has gained this legitimacy, it can access better resources from the host country and compete more effectively (Oliver, 1991).

Two hypotheses, namely the pollution halo hypothesis and the pollution haven hypothesis, describe the relationship between multinational corporations and their surrounding environment. The pollution halo hypothesis occurs when multinational firms with advanced technology and management skills encounter strict environmental laws and standards in host countries (Zarsky, 1999). This logic has been supported by several scholars who argue that strict environmental regulation will promote green development (Elliott & Zhou, 2013) and innovation in greener directions rather than pollution haven (Letchumanan & Kodama, 2000). In contrast, capital spent on the production of pollution-intensive goods yields higher returns in countries where firms bear lower environmental compliance costs. Developing countries have relatively weak environmental institutional regulations and low environmental standards; therefore, it is not surprising that these countries will deteriorate the environment in the search for higher economic growth (Liu et al., 2020; Singhania & Saini, 2021; Yao et al., 2023). This will encourage the flow of low-tech polluting industries to developing countries (Antweiler et al., 2001; Copeland & Taylor, 2004; Markusen et al., 1993; Pething, 1976), making it easier for multinational firms to become pollution havens (Cole et al., 2007). Host countries with lenient environmental regulations will use this as a strategy to attract high-tech firms to invest. Such firms will also change their business strategies to suit the environmental regime of the host country during their operations. Meanwhile, if the host country’s environmental regulations are slightly stricter, pollution havens may not emerge (Zeng & Zhao, 2009).

Another important school of thought focuses on how multinational firms acquire knowledge from the host country and transfer it to the home country to stimulate environmental innovation in the parent firm. Knowledge has been recognized as the most important part of the relevant resources that influence a firm’s strategy (Rabbiosi & Santangelo, 2013). For developing country firms learning from developed markets, the gap between the advanced resources available and the limited ability of developing country firms to use this knowledge at home is so large that such firms need to devote more time to knowledge acquisition, thereby slowing down parent firms’ innovation (Tsang & Yip, 2007). Differences in environmental regulations between countries can affect the country’s innovation in relation to environmental practices. In turn, firms in the country are more likely to generate new environmentally relevant technologies and knowledge, becoming exporters of new environmental technologies (Jaffe & Palmer, 1997). The researchers argue that MNCs can cross-use the new knowledge learned from such an exchange (Almeida & Phene, 2004).

Firms can access knowledge and resources from local sources by expanding internationally (Li et al., 2004; Nachum & Zaheer, 2005; Petersen et al., 2008). These firms learn from diversification (Johanson & Vahlne, 2003) and attempt to identify, collate, and assimilate new and advanced knowledge from foreign markets, providing extensions or refinements to existing knowledge (Benner & Tushman, 2003). Through transnational behavior, they can acquire the knowledge needed for green innovation and use it for their own innovations (Nair et al., 2016). According to the literature, MNCs not only develop environmental strategies and innovation in host countries through market activities. They also acquire nonmarket relevant knowledge by adapting to local environmental institutional requirements. How the acquisition of nonmarket relevant knowledge by parent companies influences their own environmental innovation remains under-researched.

Based on this literature review and the research gaps, this study addresses how the complexity of the environmental knowledge fed to the parent firm by the subsidiary affect the parent firm’s green innovation. It also considers how this relates to the parent firm’s digitalization process. Based on the Knowledge-based View (KBV), the researchers argue that parent firms can absorb and utilize knowledge to achieve their own competitive advantage. In particular, the complexity of new environmental knowledge perceived by the parent firm influences its uptake of knowledge. Thus,
the greater the diversity of environmental knowledge received by the parent firm, the more difficult it is to innovate.

China, as the largest emerging economy, provides a good environment for the current research (Wu et al., 2015). First, domestically listed firms open many overseas subsidiaries every year. These subsidiaries bring certain environmental knowledge back to China through their overseas operations. Second, the Chinese government has recognized the serious environmental problems caused by economic growth. Thus, they have put forward new requirements for environmental innovation by firms.

Using panel data from 266 Chinese listed firms across 12 years, the researchers examine the distribution of firms’ overseas subsidiaries by country and number to analyze the knowledge diversity endured by parent firms due to the environmental practice gap between countries. Previous literature has suggested that environmental performance gaps help firms innovate environmentally to enhance the legitimacy of their subsidiaries’ operations in the respective countries. This study goes a step further, arguing that the absorption of knowledge by MNCs cannot be achieved without information technology. For example, the effectiveness of communication between multinationals is influenced by the development of information technology between the host and home countries. This affects the cost-effectiveness of the parent firm (Lee et al., 2023; Li et al., 2022). Green innovation in firms requires significant financial support (Berrone et al., 2017). Therefore, the researchers propose that the degree of digitalization of a firm influences the efficiency and accuracy of knowledge transfer in multinational firms. This can significantly affect their green innovation activities. A more digital firm can process the acquired knowledge efficiently, which can help the firm use external knowledge for green innovation. In addition, the researchers chose the word “frequency” related to digitalization of a firm as the moderating variable in this study. It describes the relationship between corporate green knowledge and corporate green innovation more accurately.

This study provides two key perspectives on the existing literature. First, according to previous literature, this study is one of the few that investigates the relationship between firms’ environmental knowledge and corporate green innovation from a KBV. More specifically, this study empirically confirms the relationship between firms’ diversity of knowledge of environmental practices and corporate green innovation due to the existence of overseas subsidiaries. Therefore, this study provides a new perspective on the analysis of corporate green innovation, broadening the scope of research to include the relationship between experiential learning of corporate knowledge and corporate green innovation. The researchers link two important streams of research in international business studies. First, the study explores how multinational firms adapt to host country environmental regulations and develop corresponding environmental strategies. Second, the researchers will study how knowledge transfer through host countries leads to environmental innovation. The article develops an important research question on how parent firms adapt to host country environmental strategies through subsidiaries, transferring and absorbing this knowledge for their own environmental innovation. This pushes the boundaries of further discussion between these two streams of literature.

Second, the researchers will calculate that the digital experience of firms (the frequency of the keyword “digital” in the firm’s annual report) plays an important role in the study of corporate green innovation. The emphasis on digitalization as a key mechanism for improving the transfer of information and knowledge in the internationalization of firms enriches the mechanisms for exploring this aspect of the topic. The key argument for digitalization as an internal key strength of firms also enriches the research on a KBV.

The remainder of this study is organized as follows. The next section details the theoretical framework of the article and sets two hypotheses for this study. The third section describes the data and main regression analysis methods. Then, the empirical results are presented, followed by discussions and limitations. Conclusions are outlined in the final section.
THEORETICAL BACKGROUND AND HYPOTHESES

The KBV emphasizes knowledge as the most important intangible asset of firms. In addition, the heterogeneous knowledge of different firms is an important factor in determining the competitive advantage of firms (DeCarolis & Deeds, 1999). In multinational enterprises, the integration and transfer of knowledge are important aspects of a firm’s strategic decision making. By learning and operating in a nondomestic environment, multinational firms can accumulate and transfer new knowledge rapidly (Gassmann & Keupp, 2007). In this context, knowledge-based resources contribute more to the firm than property-based resources (Miller & Shamsie, 1996). Therefore, the researchers take the KBV as the theoretical anchor because it analyzes the behavior of firms from the perspective of their internal, self-generated knowledge resources (Grant, 1996). Knowledge is expressed in the form of technology (Kogut & Zander, 1992). Thus, the presence of knowledge helps firms deal with complex problems, giving them a competitive advantage and enabling them to exist (Blome et al., 2014).

This article refers to corporate environmental practices abroad as an activity in which multinational firms change their environmental strategies to adapt to local environmental policies. According to previous studies, there is knowledge transfer between sub-parent firms. Knowledge transfer is the process by which one unit is influenced by the experience of another unit (Argote & Ingram, 2000). Organizations can learn directly from their own experiences and indirectly from the experiences of other organizations (Argote & Epple, 1990). There is a consensus among both practitioners and scholars that knowledge creation and transfer are the foundation of a firm’s competitive advantage (Argote & Ingram, 2000).

Organizations that are successful in knowledge transfer are more productive and more likely to survive (Baum & Ingram, 1998). According to KBV, firms create, transfer, store, and apply knowledge (Argote et al., 2003). Parent firms use this kind of knowledge to make decisions that affect their own green innovation performance (Barney, 1991). Subsidiaries can transfer the knowledge they acquire in the host country back to the parent firm; therefore, it can be argued that the responses of subsidiaries when faced with environmental regulations are also a source of knowledge. Moreover, the subsidiaries of MNCs face different environmental regulations depending on the country where they are located. The strategic feedback by the subsidiaries also differs. As a result, the parent firm is exposed to a range of overseas environmental practices.

This diversity of environmental practices makes the knowledge acquired by the parent firm complex. Firms need a certain amount of time to translate knowledge. Due to the difference in environmental regulations in each country, the learning costs of the enterprise’s subsidiaries to meet the legality of the host country are also diversified. This results in a gap in environmental practices. In general, the absorption of knowledge by firms can help them conduct better operations and improve their performance.

However, as the diversity of knowledge increases, the sunk cost of knowledge absorption through learning transformation by firms becomes higher. Environmental innovations require better capital investment and face higher risks. Such returns are usually long-term; therefore, firms will bear higher costs when they engage in green innovation (Berrone et al., 2013; Wu et al., 2021). Firms must consider whether the cost of green innovation is within the acceptable range of the firm. At the same time, the large amount of knowledge acquired by firms through internationalization turns from an advantage to a disadvantage. In turn, it becomes a burden and high costs make firms slow down or become reluctant to innovate.

In summary:

H1: The higher the diversity of environmental practice gaps faced by the parent firm, the less likely it is to engage in green innovation.
In today’s digital economy, digital transformation offers a new direction for firms. As a key driver of sustainable development, green innovation in firms is limited by the development of digital technology (Liu et al., 2022). Digitalization is not simply the conversion of corporate resources and paper materials into electronic materials. It is the deep integration of various production factors of firms with digital technologies and digital operations at the level of knowledge acquisition, processing, and application. As technology penetration increases, digital technologies can enable more complex business ecological scenarios (Boland et al., 2007). It can facilitate green innovation in firms through, for example, the development of the internet and increasing media coverage (Chen et al., 2018; Luo et al., 2022; Wu et al., 2021). Digitalization means that firms use digital technologies to improve the generation, analysis, use of data (Björkdahl, 2020), internal systems (Appio et al., 2021; Scott et al., 2017), and internal management efficiency (Xu et al., 2022). On the contrary, some scholars argue that the enhancement of digitalization is limited and only useful for some firms (Ekata, 2012; Hajli, 2015). However, it is necessary to acknowledge that digital technologies optimize the productive resources of firms (Acemoglu, 2003), help firms explore and mine data, and greatly improve the efficiency of information processing and circulation (Balakrishnan et al., 2014).

Digital technologies are seen as an important contributor to knowledge transfer (Antonova, 2011; Xu et al., 2023), helping transform tacit knowledge into explicit knowledge (Sambamurthy, 2003). Multinational firms with many subsidiaries are inevitably confronted with the massive and repetitive knowledge transferred to them by subsidiaries. Digitalization changes the scope and speed of access of information (Lema, 2017), as well as its analysis and use (Jing & Sun, 2019). When multinational firms are less digitized, they are slower to filter, integrate, and process information relative to firms that are more digitized. That is, when faced with complex information, digitalization helps firms analyze data intelligently, improves the integration of data resources, and makes it possible to rearrange and process internal knowledge to generate new knowledge (Martínez-Caro, 2020).

It is reasonable to infer that digitalization can help firms integrate information related to green innovation and improve their innovation decision-making capabilities when they face an increased diversity of knowledge about overseas environmental practices. Therefore:

H2: The more digitalized a firm is, the more capable it is of green innovation.

METHOD

Sample and Data Collection

This study used a database of Chinese listed firms to:

1. Investigate the impact of the gap between the environmental practices of the country where the parent firm is located (i.e., China) and the country where its subsidiaries are located on the green innovation of the parent firm.
2. Measure the gap in environmental practices between countries, the degree of digitalization of the parent firm, and whether the firm has engaged in green innovation.

The data consisted of Chinese firms listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange in China with overseas subsidiaries from 2007 to 2018. It excluded ST and ST* firms, firms that were delisted, and firms that conducted initial public offerings (IPOs). Further, firms with many missing variables were removed; only firms with observed variables for five consecutive years were retained. In the end, the study used 548 firm-year observations from 266 firms as the final sample.
The sources of panel data are diverse. First, basic corporate data (i.e., financial data, environmental data, executive data, and digital data) were collected from the China Stock Market and Accounting Research (CSMAR) database. This is a major database with information on the Chinese stock market and listed firms (Liu et al., 2021a; Wang & Qian, 2011). In particular, the data on corporate patents were obtained from the Green Patent Research Database (GPRD), a sub-database of the CSMAR database. GPRD is a professional database developed by combining Chinese patent data with the green patent classification number standard published by the World Intellectual Property Office. It can reflect the degree of green innovation in various regions and listed firms more objectively. In addition, data on environmental practices among sub-parent firms were obtained from the Environmental Performance Index of Yale University and Columbia University. These data cover the environmental performance of countries from 1950 to 2020. Finally, the gross domestic product (GDP) data for each province were taken from the China Statistical Yearbook.

Measures

Firm_Green_Innovation

The green innovation of firms, named Firm_Green_Innovation, is the dependent variable of this study. The number of green patents can indicate a firm’s ability to carry out high-level green activities (Wurlod & Noailly, 2018). Green patents can be divided into those independently acquired and those jointly acquired by firms in the current year. They, in turn, are divided into the number of green inventions and green utility model patents. Based on previous literature (Chen et al., 2018), this study intends to use the sum of the number of green inventions and green utility model patents independently applied for by listed firms after going public. The number of green utility model patents independently applied for by listed firms in the year after listing is proposed for the ROBUST test. Furthermore, the logarithmic treatment is not used because the number of corporate green patents is small.

Firm_EPI_Entropy

The diversity of gaps due to differences in environmental practices in the countries where the sub-parent firms are located is used as the independent variable. The researchers believe that overseas subsidiaries learn from the knowledge and technology of the host country. Thus, they transform it into their own management experience. The parent firm will set up numerous subsidiaries in different countries every year. Then, the feedback from these subsidiaries will differ for the parent firm. There is a certain diversity of knowledge and experience in environmental practices acquired from the different systems in the host countries. The impact of this diversity must be considered in the process of green innovation in firms. Therefore, this study calculates the environmental practice gap index between the country of the sub-parent firms and compares it with the environmental practice index (Kim et al., 2021) of the country of the parent firm. Then, the study obtains the percentage of the environmental practice gap between the two countries. The parent firm has many subsidiaries in different countries each year. Thus, the percentage is weighted with the subsidiaries under each parent firm. Finally, the study performs an entropy calculation to calculate the diversity of each parent firm’s annual environmental practice gap index with foreign countries.

Firm_Digital_Frequency

The degree of digitalization of the firm is used as a moderating variable, which presents the frequency of the firm’s use of digitalization during a total of 12 years (2007 – 2018). The degree of digitalization is defined as the use of high-tech processes with the goal of improving the efficiency and quality of corporate production management. This study reflects the extent of the implementation of digital strategy within enterprises. Thus, it adopts the word “frequency data,” involving “enterprise digital transformation” in the annual reports of listed firms. The specific measurement is extracted from the annual report of the listed firms about the firm’s employees. The five major fields and positive
sentiment statements include: (1) artificial intelligence; (2) big data; (3) blockchain; (4) cloud computing; and (5) digital technology applications. Finally, the word frequencies of these five directions are summarized to form the “degree of enterprise digitalization.” Based on the data, no logarithmic treatment was performed in this study.

**Control Variables**

In this article, the control variables are selected from the following three levels. First, at the entrepreneurial level, the CEO’s personal shareholding (named CEO_ownshare) and whether the CEO serves as a corporate director (named Duality) are considered two of the control variables because whether a firm’s innovation decisions are implemented is influenced by the firm’s CEO (Zheng et al., 2021).

Second, there are several aspects to consider within firms. The longer and larger the firm has been in business, the more comfortable it is perceived to be with environmental innovation, and the more socially relevant and proactive it is when faced with corporate environmental innovation (Hojnik & Ruzzier, 2016). Therefore, the study added the age of the firm, named Firm age, measured as the number of years from a firm’s foundation until the end of 2018. The size of the firm, named “Firm size,” is measured as the logarithm of a firm’s total assets (Chen et al., 2018). At the same time, a firm’s operating conditions and cash flow affluence greatly influence its decisions because the green innovation process is time-consuming and relatively slow to pay off. The researchers believe that firms are more likely to engage in green innovation when they have sufficient internal idle resources. Thus, the study uses corporate financial performance (named TobinQ a) measured according to the method of Tobin-Q (Kim et al., 2021) and corporate net cash flow situation (named Net_Cash_Flow) measured as the amount of net cash to control for the firm’s performance. Moreover, due to the high-risk, high-investment, and low-return nature of green innovation, many firms do not have sufficient financial support to carry out innovative activities. Therefore, depending on the amount of external support the firm receives, the ease of financing constraints needs to be considered. The study uses government grants received by the firm, named Government_grants, measured as the logarithm of government subsidies received by the firm, and the degree of financing constraints of the firm, named Financial_slack, measured as the logarithm of the degree of financing constraints, to control for the variables (Benner et al., 2003).

Lastly, at the regional level, the level of economic development of the Chinese provinces and the importance attached to green innovation will affect the level of green innovation of firms. Therefore, the value of the GDP of the province where the parent firm is located, named Province_GDP, measured as the logarithm of the GDP of the province as well as the rate of green utility patents filed in that province in that year named, Province_green_ugrantapplyratio, are included. The study also introduces a year dummy, an industry dummy, and a province dummy into the regression.

**Estimation Model**

The final sample comprises 548 firm-year observations involving 266 unique firms, which illustrates a panel data structure. The dependent variable, a count number of patents, is the nonnegative integer. Therefore, the researchers followed previous similar studies and conducted the panel data negative binomial regression model for the analysis, using the command “xtnbreg” in Stata software.

**EMPIRICAL RESULTS**

**Descriptive Statistics and Correlation**

Table 1 reports the sample characteristics, including the sample size, mean, and standard deviation of each variable. The sample observations are 548 firm-year data, where the average number of green
innovations per firm per year is 10.651. The mean and standard deviation of each variable are in the acceptable range interval.

Table 2 summarizes the results of the Pearson correlation analysis for all variables in this study. The diversity of gaps in the environmental practices of the subsidiaries is correlated with the green innovation of the firm (0.02), which is in line with expectations. Most of the correlation between the two variables

**Table 1. Descriptive statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>S. D.</th>
<th>P1</th>
<th>P99</th>
</tr>
</thead>
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<tr>
<td>Firm_Green_Innovation</td>
<td>548</td>
<td>10.651</td>
<td>31.955</td>
<td>0</td>
<td>131</td>
</tr>
<tr>
<td>Firm_EPI_Entropy</td>
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<td>0.654</td>
<td>0</td>
<td>3.119</td>
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<td>Firm_Digital_Frequency</td>
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<td>2.057</td>
<td>1.125</td>
<td>0.693</td>
<td>4.564</td>
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<td>Duality</td>
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<td>0.466</td>
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<td>1</td>
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<td>Firm_age</td>
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<td>15.403</td>
<td>4.990</td>
<td>4</td>
<td>27</td>
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<td>0.116</td>
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<td>0.505</td>
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<tr>
<td>Net_Cash_Flow</td>
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<td>19.728</td>
<td>1.773</td>
<td>15.932</td>
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</tr>
<tr>
<td>Government_grants</td>
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<td>17.451</td>
<td>2.159</td>
<td>13.101</td>
<td>21.06</td>
</tr>
<tr>
<td>Firm_size</td>
<td>548</td>
<td>22.8</td>
<td>1.394</td>
<td>20.488</td>
<td>26.958</td>
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<td>TobinQ_a</td>
<td>548</td>
<td>2.196</td>
<td>1.772</td>
<td>0.235</td>
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<td>Financial_slack</td>
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<td>Province_GDP</td>
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<td>10.48</td>
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<td>Province_green_ugrantapplyratio</td>
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<td>0.098</td>
<td>0.021</td>
<td>0.066</td>
<td>0.157</td>
</tr>
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</table>

Table 2. Correlation matrix

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<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
<th>(12)</th>
<th>(13)</th>
</tr>
</thead>
<tbody>
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<td>(1) Firm_Green_Innovation</td>
<td>1.000</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Firm_EPI_Entropy</td>
<td>0.020</td>
<td>1.000</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Firm_Digital_Frequency</td>
<td>0.046</td>
<td>0.116</td>
<td>1.000</td>
<td></td>
<td></td>
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<tr>
<td>(4) CEO_ownshare</td>
<td>0.074</td>
<td>0.092</td>
<td>0.220</td>
<td>1.000</td>
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<tr>
<td>(5) Duality</td>
<td>0.056</td>
<td>-0.071</td>
<td>0.048</td>
<td>0.295</td>
<td>1.000</td>
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<tr>
<td>(6) Firm_age</td>
<td>0.164</td>
<td>0.009</td>
<td>-0.057</td>
<td>-0.121</td>
<td>-0.036</td>
<td>1.000</td>
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<td>(7) State_ownership_share</td>
<td>-0.006</td>
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<td>-0.069</td>
<td>-0.172</td>
<td>-0.137</td>
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<tr>
<td>(8) Net_Cash_Flow</td>
<td>0.312</td>
<td>0.108</td>
<td>-0.113</td>
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<td>-0.180</td>
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<td>0.072</td>
<td>1.000</td>
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<tr>
<td>(9) Government_grants</td>
<td>0.095</td>
<td>0.167</td>
<td>-0.065</td>
<td>-0.058</td>
<td>-0.085</td>
<td>0.105</td>
<td>0.099</td>
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<td>(10) Firm_size</td>
<td>0.369</td>
<td>0.239</td>
<td>-0.158</td>
<td>-0.234</td>
<td>-0.209</td>
<td>0.209</td>
<td>0.069</td>
<td>0.807</td>
<td>0.430</td>
<td>1.000</td>
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<tr>
<td>(11) TobinQ_a</td>
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<td>-0.101</td>
<td>0.293</td>
<td>0.271</td>
<td>0.219</td>
<td>-0.320</td>
<td>-0.054</td>
<td>-0.397</td>
<td>-0.189</td>
<td>-0.559</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(12) Financial_slack</td>
<td>-0.094</td>
<td>-0.097</td>
<td>0.171</td>
<td>0.178</td>
<td>0.158</td>
<td>-0.275</td>
<td>-0.025</td>
<td>-0.297</td>
<td>-0.117</td>
<td>-0.361</td>
<td>0.275</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>(13) Province_GDP</td>
<td>0.079</td>
<td>-0.005</td>
<td>0.070</td>
<td>0.218</td>
<td>0.224</td>
<td>0.092</td>
<td>-0.254</td>
<td>-0.143</td>
<td>-0.189</td>
<td>-0.202</td>
<td>0.138</td>
<td>0.016</td>
<td>1.000</td>
</tr>
<tr>
<td>(14) Province_green_ugrantapplyratio</td>
<td>0.017</td>
<td>0.094</td>
<td>0.146</td>
<td>-0.017</td>
<td>-0.066</td>
<td>-0.017</td>
<td>-0.013</td>
<td>0.028</td>
<td>0.110</td>
<td>0.111</td>
<td>0.058</td>
<td>0.039</td>
<td>-0.360</td>
</tr>
</tbody>
</table>
is not higher than 0.5; thus, the concern of a high correlation between the variables is mild. The study calculated the volume variance inflation factor (VIF), finding that the highest VIF value among the variables was 4.22. The average VIF value was 1.61, which is well below the generally required critical value of 10. Thus, the covariance interference is not a significant problem in this study.

Hypotheses Testing

Table 3 reports the results of the negative binomial model regressions in this study. Model 1 includes only all control variables. Model 2 includes the independent variables. Model 3 includes the moderating

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Firm_Green_Innovation</td>
<td>Firm_Green_Innovation</td>
<td>Firm_Green_Innovation</td>
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<tr>
<td>Firm_Digital_Frequency</td>
<td>0.051 (0.054)</td>
<td>0.045 (0.054)</td>
<td>0.021 (0.054)</td>
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<tr>
<td>CEO_ownshare</td>
<td>0.017** (0.008)</td>
<td>0.019** (0.008)</td>
<td>0.02** (0.008)</td>
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<tr>
<td>Duality</td>
<td>0.046 (0.126)</td>
<td>0.035 (0.125)</td>
<td>0.046 (0.126)</td>
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<tr>
<td>Firm_age</td>
<td>-0.008 (0.016)</td>
<td>-0.009 (0.016)</td>
<td>-0.007 (0.016)</td>
</tr>
<tr>
<td>Stateownershipshare</td>
<td>-0.753* (0.449)</td>
<td>-0.785* (0.475)</td>
<td>-0.783* (0.473)</td>
</tr>
<tr>
<td>Net_Cash_Flow</td>
<td>-0.045 (0.046)</td>
<td>-0.043 (0.046)</td>
<td>-0.043 (0.045)</td>
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<tr>
<td>Government_grants</td>
<td>0 (0.01)</td>
<td>-0.002 (0.01)</td>
<td>-0.003 (0.01)</td>
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<tr>
<td>Firm_size</td>
<td>0.285*** (0.084)</td>
<td>0.324*** (0.083)</td>
<td>0.347*** (0.085)</td>
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<tr>
<td>TobinQ_a</td>
<td>-0.02 (0.04)</td>
<td>-0.032 (0.04)</td>
<td>-0.02 (0.041)</td>
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<tr>
<td>Financial slack</td>
<td>0.007 (0.022)</td>
<td>0.003 (0.022)</td>
<td>0.007 (0.023)</td>
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<tr>
<td>Province_GDP</td>
<td>-0.624*** (0.215)</td>
<td>-0.026 (1.249)</td>
<td>-0.16 (1.257)</td>
</tr>
<tr>
<td>Province_green_ugrantapplyratio</td>
<td>13.546* (7.224)</td>
<td>15.649** (7.054)</td>
<td>13.925** (6.979)</td>
</tr>
<tr>
<td>Firm_EPI_Entropy</td>
<td>-0.256*** (0.078)</td>
<td>-0.248*** (0.079)</td>
<td>0.143** (0.06)</td>
</tr>
<tr>
<td>Firm_EPI_Entropy×Firm_Digital_Frequency</td>
<td>0.143*** (0.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-6.558 (11.658)</td>
<td>-5.604 (11.746)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>548</td>
<td>548</td>
<td>548</td>
</tr>
</tbody>
</table>

Note: *p < 0.05; **p < 0.01; ***p < 0.001. Year dummies, industry dummies, and province dummies are included in the regressions. All variables are standardized.
variables and their interaction terms (Firm_EPI_Entropy × Firm_Digital_Frequency), in addition to
the independent variables and all control variables to test the two hypotheses of the study.

Hypothesis 1 proposes that the diversity of environmental practice gaps among different countries
to which the sub-parent firm belongs will inhibit firms from environmental innovation. Therefore,
the direction of the main relationship is negative. This verifies the negative influence of the diversity
of environmental practice gaps between different countries on corporate green innovation. Thus,
hypothesis 1 is supported.

Hypothesis 2 proposes a positive moderating effect of firm digitalization on firm green innovation.
In Model 3, the interaction term (Firm_EPI_Entropy × Firm_Digital_Frequency) coefficient of firm
digitalization and diversity of environmental practice gaps in firms is 0.143. The p-value is less than
0.05, which is positively significant. This implies that the higher the degree of digitalization of the
firm, the less negative the effect of the diversity of the gap in environmental practices of the firm.
This is due to the difference in systems between countries on the environmental innovation performed
by the firm. Thus, hypothesis 2 is supported.

DISCUSSION

This study aims to explore the relationship between the diversity of environmental practice gaps
between different countries to which the sub-parent firms belong and corporate green innovation.
It also considers the moderating role of the degree of digitalization of firms. Through an empirical
examination of data from Chinese listed firms from 2007 to 2018, the researchers found that the
diversity of environmental practice gaps has a significant impact on corporate green innovation.
Specifically, the greater the diversity of gaps in the environmental practices faced by firms, the more
reluctant firms are to engage in green innovation. This result supports the study’s hypothesis about
what motivates firms to conduct green innovation. Per KBV, the knowledge of firms determines firm
efficiency. This suggests that it is difficult for firms to effectively absorb and transform knowledge
when they have too much information and face information overload.

The study also found that digital transformation of firms can alleviate this dilemma and positively
moderate the relationship between the dependent and independent variables. This supports the
hypotheses about the moderating effect of digitalization on corporate green innovation. Digitalization
can assist firms in dealing with large amounts of internal and external or nonstandard and unstructured
data to improve the speed and quality of information processing. Thus, it can improve knowledge
uptake and utilization, assisting firms in green innovation (Liu et al., 2011; Liu et al., 2021b).

Theoretical Contributions

This study contributes to the existing literature in the following ways. First, based on the previous
literature, this study integrates environmental studies and international business research. The
researchers explain why the diversity of corporate environmental practices influences corporate
green innovation. Although knowledge is the most important resource in the strategic sense of
the organization, too many subsidiaries in different countries bring cumbersome and disorganized
knowledge back to the parent firm rather than enhancing the efficiency of corporate green innovation.
The study focuses on the conditions that influence corporate green innovation and explain the
differences in green innovation among firms with overseas subsidiaries in different countries.

Second, this study also focuses on the mechanisms by which corporate digitalization affects
corporate green innovation. It grafts on the different environmental knowledge learned by digitalization
and parent firms through differences in the environmental practices of their subsidiaries. The findings
are like those of previous studies. Overall, digitalization helps firms make better use of knowledge.
In addition, this study enriches the research related to KBV.
Limitation and Future Research

There are limitations to this study that provide direction for future research. First, although the study illustrated the impact of diversity on corporate green innovation in terms of environmental practice gaps, this diversity only indicates feedback on the environmental knowledge brought to parent firms by the different subsidiaries opened by each parent firm in different years and in different countries. In other words, it is only the difference in the amount and size of the gap between firms that makes a difference. It is not the gap itself. Thus, the impact of a gap in environmental practices between countries due to institutional differences affects corporate green innovation. Future research could focus on the impact of this gap itself on corporate green innovation.

The study uses the impact of corporate digitalization on a firm’s green innovation; however, corporate digitalization is not perfectly measured. This study uses the frequency of words in annual reports for the digitalization of firms, which is the most used in the literature. There may be a better way to measure the degree of digitalization of firms in the future to reflect the impact of the trend of digitalization more accurately on firms.

CONCLUSION

This study analyzed financial, patent, and digital data, as well as country-level environmental practice data for Chinese listed firms and their overseas subsidiaries from 2007 to 2018. It demonstrated the impact of the diversity of environmental practice gaps between countries on corporate green innovation behavior. However, firms with more overseas subsidiaries in different regions are not better at green innovation. Rather, overseas expansion has a negative impact on firms. Too much environmental knowledge diversity means that firms have to absorb more knowledge, face higher learning costs, and confront the problem of knowledge overload. This makes them less efficient in green innovation.

However, digitalization is an important regulatory system that can play a positive role as an important supplement to knowledge learning by firms, enhancing learning efficiency and optimizing the way information is processed. The researchers hope this study will help firms focus on their digitalization level in the future and use the acquired overseas knowledge for better green innovation. Future research could bring new insights into corporate green innovation by examining the environmental knowledge gap between countries, such as the difference in ratings of environmental performance, or by exploring more institutional topics like the political connections of firms.

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REFERENCES


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