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Impacts of Industrial Heterogeneity and Technical Innovation on the Relationship between Environmental Performance and Financial Performance

Ruiqian Li [1] **and Ramakrishnan Ramanathan** [2,*]

[1] Accounting School, Harbin University of Commerce, Harbin 150028, China; liruiqian0451@163.com
[2] Business & Management Research Institute, University of Bedfordshire, Putteridge Bury Campus, Luton, Bedfordshire LU2 8LE, UK
* Correspondence: ram.ramanathan@beds.ac.uk; Tel.: +044-1582-743516

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Abstract: In this paper, we investigate the relationship between environmental performance (EP) and financial performance (FP) from the perspective of technical innovation in Chinese industrial sectors. We also consider industrial heterogeneity and take temporal variations of the link into account. We collect the required data from different Chinese statistical yearbooks from 2004 to 2015. We use an aggregated index of environmental pollutants as a proxy for EP and return on assets as a proxy for FP, and we employ research and development expenditure to capture technical innovation. The empirical results indicate that industrial heterogeneity exists and the EP–FP link varies in different industrial groups. There is no evidence that the EP–FP link becomes more positive and more significant over time. Furthermore, the mediation effect of technical innovation and environmental pressures can jointly affect the link. Finally, technical innovation partially mediates the EP–FP link but only in Chinese light-polluting sectors not in heavy-polluting sectors. The mediating role of technical innovation has a great impact on shaping the EP–FP link. When technical innovation partially mediates the focal link, apart from the indirect link, the direct EP–FP link is likely to be positive. If not, the direct EP–FP link is likely to be negative.

Keywords: environmental performance; financial performance; technical innovation; industrial heterogeneity; mediation

1. Introduction

Topics related to the environment have always been key issues all over the world on the trade-off with economic development. How to realize the coordinated development of economy and the environment has attracted a lot of attention from academics, practitioners and the government [1]. Scholars have also strongly called on firms to tackle environmental and social problems properly [2–4]. A lot of studies have been carried out focusing on related topics in the environmental management literature. As for China, the rapid growth of the economy has also resulted in environmental degradation in recent years [5]. Thus, it is also urgent to balance economic development and environmental protection [6].

One topic of wide concern is the relationship between the environmental performance (EP) and financial performance (FP) of firms. This research topic has been studied theoretically as well as empirically for several decades, but the results remain inconclusive [7–10].

In the early literature, a majority of scholars mainly employ linear models to study the direct EP–FP link. However, the results are mixed, being positive, negative and neutral [11–13]. These conflicting results have led researchers to consider that the real EP–FP link may be more complex [14]. The empirical results show that the link could also be U-shaped [15], inverted U-shaped [16], asymmetrical [17], concave [18] or bidirectional [19,20].

Since the early studies, scholars have preferred to reveal the overall picture of the link and have ignored the fact that the relationship is likely to keep changing over time. Given that environmental pressures (i.e., environmental regulations and stakeholder pressures) increase over time, firms may respond to these pressures dynamically [21] so that the focal link is likely to keep changing. Thus, the dynamic behavior of the EP–FP nexus over a period of time has been neglected by scholars. To fill this gap, we investigate whether the focal link and its significance have kept changing over the years or not. Besides, different industrial sectors are generally different. Thus, we take industrial heterogeneity into consideration and divide our sample into two groups according to their pollutant level, namely heavy-polluting sectors (HPS) and light-polluting sectors (LPS). We also investigate whether the EP–FP link varies in different industrial groups or not.

Since no consensus has been reached on the direct EP–FP link, scholars also look beneath the surface and explore the role of some relevant organizational variables that may affect the focal relationship [22,23]. A wide range of moderators and mediators has been considered. See Albertini [7], Dixon-Fowler et al. [13], Grewatsch and Kleindienst [8], Guenther and Hoppe [9], Orlitzky [24] for comprehensive reviews. Scholars have posited that failing to take moderating or mediating factors into consideration may be one reason for the inconsistent of empirical results [22,25], and have called for increasing attention to investigating when and how it pays to be green [7,8,26].

In this sense, we also investigate the EP–FP link from the perspective of technical innovation. Technical innovation has always been treated as an important variable in affecting the focal link [27]. However, most of prior studies have incorporated it into the regression model as a control variable [15]. In this paper, we extend previous studies by investigating whether technical innovation mediates the EP–FP link rather than treating it as a control variable. Moreover, we also examine whether the mediating role of technical innovation in the EP–FP link varies in the two industrial groups (HPS and LPS) or not. Combining all the results together, our analysis can provide deeper insights into understanding the impact of the mediating role of technical innovation on shaping the focal relationship and the nature of the EP–FP nexus.

Following these research questions, we collect the required data from different Chinese statistical yearbooks. Unlike the majority of previous studies which are based on micro enterprises [28], we use sector-level data instead of firm-level data. Moreover, a large percentage of prior studies focusing on the focal link have been developed in the US or European context [8], and studies focus on developing countries are scarce [29,30]. Hence, another contribution of our study is that we can provide more empirical evidence from an emerging country.

In sum, this study attempts to contribute to both research and practice. From a research perspective, our study aims to advance our understanding on the EP–FP link from the perspective of the mediating role of technical innovation. Besides, the study considers the dynamic behavior of the focal link instead of presenting an overall picture of the EP–FP nexus. Furthermore, our findings from Chinese industrial sectors can bring some new evidence to the academic debate on the EP–FP link in the environmental management literature. From a practical perspective, this study provides some implications for firms and the government to shift the EP–FP link from negative to positive in HPS and further achieve "win–win" between economic development and environmental protection in China.

The remainder of this paper is organized as follows. We review the literature and posit our hypotheses in Section 2. In Section 3, we describe our data and variable measurements. Regression results, discussions and sensitivity analysis are presented in Section 4. Our conclusions are available in the final section.

2. The Ongoing Debate on the Environmental Performance and Financial Performance (EP–FP) Link and Hypothesis Development

2.1. Literature on the Direct Link of EP–FP

The direct EP–FP link has been investigated for several decades. However, the results remain inclusive and all possible outcomes have arisen [8,13].

2.1.1. Positive Relationship

The following studies demonstrate the positive relationship: Hart and Ahuja [11], Russo and Fouts [31], Orlitzky [32], Nakao et al. [33], Qi et al. [28], Bergmann [34], Gómez-Bezares et al. [35], and Kim and Lee [36]. Huang and Yang [37] show a positive corporate social performance (CSP)–FP link of firms in Taiwan. Nevado-Peña et al. [38] find that cities with the best positions on sustainability have better economic performance. Hategan et al. [39] emphasize that firms which engage in corporate social activities can create more profits. Horváthová [40] suggests that the relationship between EP and FP is negative when lagged 1 year, while it becomes positive when lagged 2 years. Dobre et al. [41] and Zhang and Chen [42] also prove that the EP–FP link is likely to be negative in the short run, but becomes positive in the long run. Apart from the widely used linear models, some scholars also use meta-analysis to study the focal link and indicate the overall positive link (e.g., [7,13,22,24,43,44]). A detailed literature review on meta-analysis is provided by Hang et al. [10].

2.1.2. Negative Relationship

The following studies indicate a negative relationship between EP and FP: Cordeiro and Sarkis [45], Filbeck and Gorman [46], Fisher-Vanden and Thorburn [47], and Rodrigo et al. [48]. Cordeiro and Sarkis [45] use security analyst earnings forecasts as the proxy for FP and demonstrate a negative relationship between environmental pro-activism and FP. Filbeck and Gorman [46] find there is a negative link between FP and a more pro-active measure of EP. Fisher-Vanden and Thorburn [47] suggest that corporate commitments to reduce greenhouse gas emissions appear to conflict with firm value maximization. Ruggiero and Lehkonen [49] find a negative relationship between renewable energy increase and short-term as well as long-term FP.

2.1.3. No Relationship

Studies that give support to the neutral relationship between EP and FP include Graves and Waddock [50], Mcwilliams and Siegel [27], Zhang and Stern [51], Aras et al. [52], Chetty et al. [53], and Lucato et al. [54]. Graves and Waddock [50] find that CSP has insignificant or negligible impact on FP. Mcwilliams and Siegel [27] demonstrate the relationship between corporate social responsibility (CSR) and FP is neutral after controlling for research and development (R&D). Lucato et al. [54] show there is no statistically significant relationship between EP and FP.

2.1.4. Non-Linear Relationship

Since the conflicting results of the direct EP–FP link increase and there is no widely accepted theoretical framework, some scholars feel that the real EP–FP link might be more complex [15]. Scholars have explored the potential non-linear relationship. However, there are still no valid conclusions. The non-linear EP–FP link has been found to be U-shaped (e.g., [15,23,55]), or inverted U-shaped (e.g., [16,56–58]). Van Der Laan et al. [17] claim that the impact of negative versus positive CSP on FP is asymmetric. Flammer [18] find that the CSP–FP link is concave.

2.2. Literature on the Impact of Industrial Heterogeneity

According to legitimacy theory, firms are inseparable from society and they have no inherent right to exist—they exist only as far as society confers legitimacy upon them. Hence, firms must continuously legitimize their activities to retain congruence between society's and organizational objectives [59–63]. However, different industrial sectors are significantly different in their resources and capabilities [9], stakeholder pressures [64], and the market's reaction to their improvement in EP [65,66]. Due to these heterogeneities, firms in different industrial sectors are likely to adopt different environmental strategies to gain or maintain their legitimacy [10]. The adoption of different environmental strategies usually results in different economic results. Generally, firms pursuing reactive environmental strategies may have more costs than benefits so that the link is likely to be negative, whereas firms pursuing proactive environmental strategies may have higher benefits than costs so that the link tends to be positive [7,13,15,22]. Hang et al. [10] employ meta-regression analysis and demonstrate that reactive environmental actions are likely to result in negative relationships. Hence, the EP–FP nexus is likely to vary in different industrial groups due to industrial heterogeneity [7,9,10].

Some prior studies also support the idea that industrial heterogeneity exists and the EP–FP link varies in different industrial groups (e.g., [11,65,67–71]). Hart and Ahuja [11] indicate that EP has no significant impact on FP in a low-polluting subsample, but has a positive impact on FP in a high-polluting subsample. Iwata and Okada [70] demonstrate that greenhouse gas emissions have positive impacts on FP in clean industries, but EP does not have significant impacts on FP in dirty industries. Thus, taking industrial heterogeneity into account, we propose our first hypothesis.

Hypothesis 1 (H1). *The relationship between EP and FP varies in different industrial groups.*

2.3. Literature on Temporal Variations of the EP–FP Link

Extant literature mainly focuses on revealing the overall picture of the link and has overlooked the possibility that the link is likely to keep changing during the observed time span as environmental pressures increase over time.

From the holistic perspective, stakeholders are more and more concerned about environmental issues and environmental regulations have become increasingly stringent [21,72,73]. It is also the same in China [74]. As a response to the increasing environmental pressures and in order to achieve legitimacy, firms may start to seek more reasonable strategies to deal with environmental issues. Consequently, firms may abandon their original reactive environmental strategies and tend to adopt proactive environmental strategies gradually [16,75,76]. As elaborated above, proactive environmental strategies usually result in positive outcomes, whereas reactive environmental strategies usually lead to negative outcomes [77,78]. Hence, the changes in the adoption of environmental strategies from reactive to proactive can result in the shift of the link from negative to positive. Accordingly, the significance of the negative link may reduce during this process.

Some prior studies have also proved that increasing environmental pressures can enhance the focal link. Nakao et al. [33] find that information-based environmental policy can make the EP–FP link more strongly significant in the firms that publish relevant information in their environmental reports. Nishitani and Kokubu [79] demonstrate that with strong market discipline imposed by stockholders/investors, firms that reduce more greenhouse gas emissions are more likely to enhance firm value. Delmas et al. [75] conduct the research under the background of increasing climate change legislation and find that a decline in greenhouse gas emissions can result in an increase in Tobin's q.

It is also possible that firms adopt proactive environmental strategies to go beyond the requirements of environmental regulations and meet the expectations of stakeholders at an early stage. Hence, the EP–FP link is likely to be positive already. According to resource-based view, when firms adopt proactive environmental strategies and engage in developing their resources and capabilities, it will help them to accumulate competitive advantages [28,80]. The continuous accumulated competitive advantages will easily result in larger levels of accumulated knowledge and technical innovation [23]. Hence, the positive outcomes have strong economic incentives to encourage managers to continue engaging in proactive environmental strategies and technical innovation, let alone in the context of ever-increasing environmental pressures. In this regard, the positive link between EP and FP will become more significant over the years.

In sum, with the ever-increasing environmental pressures, the EP–FP link is likely to be dynamic. The significance of the negative relationship will reduce, whereas the significance of the positive relationship will increase. Hence, we posit our second hypothesis.

Hypothesis 2 (H2). *The relationship between EP and FP will become more positive and more significant over time.*

2.4. Literature on the Role of Technical Innovation in EP–FP Link

The mixed conclusions of the direct EP–FP link have forced researchers to look deeper. Scholars take a more sophisticated view and consider more complex possibilities in order to give a better explanation [22,23]. A variety of moderators and mediators have been incorporated into research frameworks to investigate the indirect link between EP and FP.

These moderators include firm growth (e.g., [31,70,81]), shareholder value-oriented strategies (e.g., [82]), environmental strategies (e.g., [83]), advertising intensity (e.g., [84]), slack resources (e.g., [28,85]), operations efficiency (e.g., [25]), environmental process (e.g., [58]), industry-level environmental risk (e.g., [86]), interdimensional consistency of environmental, social and governance (e.g., [87]), geographical location (e.g., [19,30]). The mediators include a firm's resources and competitive advantage (e.g., [88]), intangible resources (e.g., [89]), customer satisfaction and customer loyalty (e.g., [90]). A more detailed review of moderators or mediators is undertaken in the research conducted by Albertini [7], Grewatsch and Kleindienst [8], Guenther and Hoppe [9].

Among these variables, technical innovation has been widely recognized as an important variable in affecting the EP–FP nexus. However, most prior studies prefer to incorporate technical innovation as a control variable (e.g., [11,15,16,22,27,33,70]). A few studies also investigate the moderating role of innovation. Hull and Rothenberg [91] argue that innovation activities moderate the link between CSP and FP. Wagner [84] investigates the moderation effect of R&D activities on the EP–FP link. Lioui and Sharma [92] suggest that R&D efforts play a moderating role in the link between environmental corporate social responsibility and FP.

However, the mediating role of technical innovation in the EP–FP link has been largely overlooked. Moreover, the limited literature on investigating the mediating role of technical innovation mainly focuses on studying its impacts on the link between corporate responsibility and FP, not on the EP–FP link. Both Surroca et al. [89] and Blanco and Guillamo [93] demonstrate that innovation mediates the relationship between corporate responsibility and FP. Guenther and Hoppe [9] propose that innovation mediates the EP–FP link via a literature review.

Hence, we consider the mediation effect of technical innovation in the EP–FP link to address this gap. Theoretically, drawing on a resource-based view, the better EP that firms expect to have means that firms have engaged in developing their abilities and resources and accumulated some competitive advantages. The accumulated competitive advantages can lay solid foundations for firms and motivate them to innovate their products or production process. Besides, the improvement in EP can promote technical innovation as firms always need innovative approaches to deal with environmental issues [94]. Hence, the link between EP and innovation can be connected tightly [93,95]. On the other hand, when firms engage in improving EP through technical innovation, it can represent the innovation capability from knowledge enhancement and further lead to the changing of FP [15,27]. Hence, technical innovation is strongly associated with FP as well. Previous studies suggest that innovation may have a negative impact on FP in the short-term, but may have a positive impact in the long-term [15,16,70].

Based on the theory and literature discussed above, we propose our third hypothesis.

Hypothesis 3 (H3). *Technical innovation will mediate the relationship between EP and FP.*

The theoretical framework of this study is presented in Figure 1.

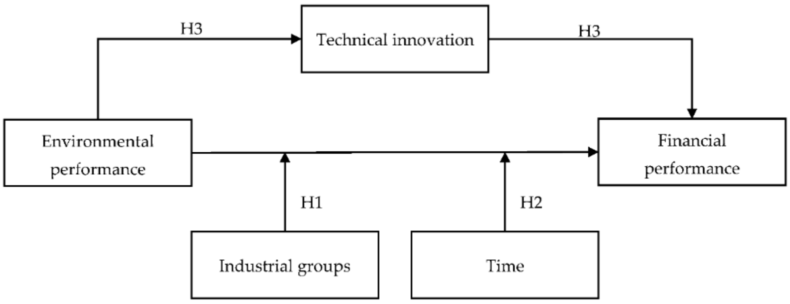

Figure 1. Theoretical framework of this study.

3. Data and Methodology

3.1. Data

Unlike prior studies, we use sector-level data instead of firm-level data in this study. We collect the required data from different Chinses statistical yearbooks as they can represent the reliability and authority of data [96]. Many scholars conducting similar research also collect the required data from different statistical yearbooks (e.g., [74,97]). Specifically, we collect the data related to the environment from the *China Statistical Yearbook on Environment*, the data related to economy is collected from the *China Industry Economy Statistical Yearbook* (name changed to *China Industry Statistical Yearbook* in 2013), and the data related to technical innovation is collected from the *Statistics on Science and Technology Activities of Industrial Enterprises*. There are 41 two-digit industrial sectors now. However, due to the availability of data, 36 industrial sectors are included from 2004 to 2015 finally.

As outlined earlier, we take industrial heterogeneity into consideration. To do this, we classify all industrial sectors into two groups (HPS and LPS). The standards of classification are based on the two official documents issued by the related departments of the Chinese government. One is the *Industrial classification management directory of environmental verification for listed companies* issued by the Ministry of Environmental Protection of the People's Republic of China in 2008 and the other is the *Guidelines for industry classification of listed companies* issued by China Securities Regulatory Commission in 2012. These two official documents can jointly tell us whether the industrial sector is heavy-polluting one or not. For those ambiguous sectors not indicated clearly by these two official documents, we further calculate the mean value of EP of those sectors separately. If the mean value of EP of the selected sector is larger than the mean value of EP of all sectors, the selected sector can be classified as HPS, and we use a negative indicator to capture EP (see more details for the measurement of EP in 3.2.1). After classification, HPS includes 16 sectors and LPS includes 20 sectors. The details are shown in Table 1.

Table 1. The classification details of industrial sectors.

Heavy-Polluting Sectors	Light-Polluting Sectors
Mining and Washing of Coal	Processing of Food from Agricultural Products
Extraction of Petroleum and Natural Gas	Manufacture of Foods
Mining and Processing of Ferrous Metal Ores	Manufacture of Tobacco
Mining and Processing of Non-ferrous Metal Ores	Manufacture of Textile Wearing and Apparel
Mining and Processing of Nonmetal Ores	Manufacture of Leather, Fur, Feather and Related Products and Footwear
Manufacture of Alcohol, Beverage and Refined Tea	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
Manufacture of Textile	Manufacture of Furniture
Manufacture of Paper and Paper Products	Printing, Reproduction of Recording Media

Table 1. *Cont.*

Heavy-Polluting Sectors	Light-Polluting Sectors
Processing of Petroleum, Coking, processing of Nuclear Fuel	Manufacture of Articles for Culture, Education and Sport Activity
Manufacture of Raw Chemical Materials and Chemical Products	Manufacture of Rubber and Plastic
Manufacture of Medicines	Manufacture of Metal Products
Manufacture of Chemical Fibers	Manufacture of General Purpose Machinery
Manufacture of Non-metallic Mineral Products	Manufacture of Special Purpose Machinery
Smelting and Pressing of Ferrous Metals	Manufacture of Transportation Equipment
Smelting and Pressing of Non-ferrous Metals	Manufacture of Electrical Machinery and Equipment
Production and Supply of Electric Power and Heat Power	Manufacture of Computers, Communication, and Other Electronic Equipment
	Manufacture of Measuring Instrument
	Other Manufactures
	Production and Supply of Gas
	Production and Supply of Water

3.2. Variables and Measurement

3.2.1. Dependent Variable: Environmental Performance

EP can be defined as "measures how successful a firm is in reducing and minimizing its impact on the environment, often relative to some industry average or peer group" [66] (p. 1199). It has been measured in many different methods. The most popular way is to use independent databases, such as Toxic Release Inventory (TRI) (e.g., [45,98]), Kinder, Lydenberg, Domini index (KLD) (e.g., [50,64,75]), Council on Economic Priorities rankings (e.g., [99–101]), Britain's Most Admired Companies in UK (e.g., [25]), European Pollutant Release and Transfer Register (EPRTR) (e.g., [40]), Australia PRTR (APRTR) (e.g., [1]), Japanese PRTR (JPRTR) (e.g., [16,102]). Besides, some scholars also use pollutant emissions as proxies for EP, such as waste intensity and greenhouse gas emissions (e.g., [15,16,70]), industry environmental emission intensity (e.g., [28]), or aggregated index of emissions (e.g., [14,83,103]). To some extent, pollutant emissions are similar among TRI, EPRTR, JPRTR and APRTR, as they all consist of several environmental pollutants and can reflect firms' environmental impact. Furthermore, some other methods have also been used including environmental ratings or environmental certifications (e.g., [31,104]), the results of a questionnaire survey (e.g., [23,33]), the adoption of environmental policy, environmental management systems or environmental strategy (e.g., [105,106]).

Due to the lack of an independent database such as TRI, PRTR, KLD in China, we select five main environmental pollutants that each industrial sector releases to air, water and land in order to reflect the overall environmental impact of each industrial sector. The details of environmental pollutants included can be seen in Table 2.

Table 2. Environmental pollutants included in this study.

Indicator	Description	Unit
Waste water	Total volume of industrial waste water discharged	10,000 tons
	Total volume of industrial waste gas emission	100 million cu.m
Waste gas	Total volume of industrial soot and dust emission	ton
	Total volume of industrial Sulphur dioxide emission	ton
Waste solid	Total volume of industrial solid wastes discharged	10,000 tons

All the data should be integrated properly so that it can reflect the effect of each industrial sector on the environment overall. Here we use the comprehensive index method and follow the three-step process suggested by Zhao and Sun [107]. The final calculation results are used to capture EP.

Step1: Standardize each indicator by the standardized method.

$$G_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \tag{1}$$

where X_{ij} is the indicator j of the industrial sector i, i = 1,2, ... 36, j = 1,2, ... 5. Indicator j is the ratio of the number of one exact environmental pollutant discharged by sector i to its sales output value and all environmental pollutants mentioned above are included. The minimum and the maximum of indicator j is denoted as min(X_j) and max(X_j) respectively. G_{ij} is the standardized indicator j of the industrial sector i.

Step2: Calculate the weight.

$$W_{ij} = \frac{T_{ij}}{\sum T_{ij}} \Big/ \frac{P_i}{\sum P_i} \tag{2}$$

where W_{ij} is the weight of indicator j of the industrial sector i. T_{ij} is the discharge or emission amount of indicator j of the industrial sector i. P_i is the industrial sales output value of the industrial sector i. $\sum T_{ij}$ is the sum of T_{ij} in all the relative industrial sectors, such as $\sum P_i$. This weight can represent the difference across different industrial sectors.

Step3: Calculate the total EP index.

$$EP_i = \sum_j G_{ij} \times W_{ij} \tag{3}$$

where EP_i is the EP of the industrial sector i, which is the sum of all the indicators' indexes. The calculation results can be a comprehensive indicator to capture EP (denoted as EP_score). Obviously, the lower the EP_Score, the better the EP.

3.2.2. Independent Variable: Financial Performance

Contrary to EP, the proxies used to measure FP do not vary so much. The most widely used measurements of FP include accounting-based performance, such as return on assets (ROA), return on sales and return on equity; and market-based performance, such as market value, stock returns, and Tobin's q [22]. Each of these different financial variables can reflect the evaluation of various stakeholders with different interests [70].

ROA is the proportion of earnings before interest and tax to total average assets. ROA indicates the efficient use of a firm's total assets. ROA is also an indicator of the amount of profit that a firm generates for each unit of investment in assets [108]. To go much further, it can not only reflect the equity capital contributed by stockholders, but can also reflect the borrowed capital provided by creditors and investors [70]. In this paper, we employ ROA to capture FP.

3.2.3. Mediator: Technical Innovation

For the measurement of technical innovation, there are two widely used methods. R&D expenditure is widely used [9,89]. Another widely used method is the number of patents [109]. Generally, R&D expenditures can be seen as the beginning of an innovation process, while patents can be seen as the output of an innovation process [110]. In the present study, we use R&D expenditure to measure innovation. To further eliminate the effect of different industrial scales, R&D expenditure is divided by industrial sales output value.

3.2.4. Control Variables

Following extant literature, we include several control variables. Size is likely to affect the EP–FP link [54,111]. As we study from the sector-level, we use the number of firms (denoted as Firms) in each sector and the natural logarithm of total assets (denoted as Assets) to control the effect of size. In addition, financial risk may also affect the focal relationship [22]. We use debt ratio (measured as the ratio of debt to assets, denoted as D2A) to control financial risk, as it can indicate the difference of capital structure which is the determinant of financial risk [11,83].

All estimations are implemented in STATA 14.0 software. All variables are winsorized at the 1% and 99% levels to control the effect of outliers. The descriptive statistics of all variables are presented in Table 3. The results of mean difference between two industrial groups demonstrate that all variables are significantly different, except ROA. Table 4 presents the correlation coefficients of all variables. For all sectors, the correlation between EP_Score and ROA is positive and significant at the 1% level. For HPS, the results are consistent with all sectors and significant at the 1% level as well. For LPS, EP_Score and ROA are negatively correlated. These results can preliminarily show that industrial heterogeneity exists and the EP–FP link varies in different industrial groups.

Table 3. Descriptive statistics of variables included.

Variable	All Sectors					Heavy-Polluting Sectors					Light-Polluting Sectors					Mean Difference
	N	Min	Max	Mean	S.D.	N	Min	Max	Mean	S.D.	N	Min	Max	Mean	S.D.	
ROA	432	0.0091	0.3088	0.0994	0.0497	192	0.009	0.309	0.102	0.062	240	0.009	0.201	0.098	0.037	0.004
EP_Score	432	0.0000	61.0279	3.6300	9.8628	192	0.002	61.028	7.326	13.742	240	0.000	12.038	0.673	2.179	6.654 ***
R&D	432	4.8851	212.5373	75.7547	52.2888	192	4.885	205.616	69.087	42.872	240	7.997	212.537	81.089	58.288	−12.001 **
Firms	432	4.2047	8.4453	6.7221	1.0741	192	4.205	8.445	6.449	1.116	240	4.407	8.445	6.941	0.988	−0.492 ***
Assets	432	6.1263	11.1273	8.6417	1.2378	192	6.126	10.950	8.797	1.180	240	6.126	11.127	8.518	1.271	0.279 **
D2A	432	0.2427	0.6804	0.5451	0.0790	192	0.346	0.680	0.554	0.072	240	0.243	0.655	0.538	0.084	0.015 **

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. ROA—return on assets; EP—environmental performance; R&D—research and development; D2A—debt ratio; S.D.—standard deviation.

Table 4. The correlation matrix of variables included.

Variable	All Sectors						Heavy-Polluting Sectors						Light-Polluting Sectors					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1.ROA	1						1						1					
2.EP_Score	0.134 ***	1					0.197 ***	1					−0.348 ***	1				
3.R&D	−0.058	−0.224 ***	1				−0.041	−0.277 ***	1				−0.076	−0.327 ***	1			
4.Firms	−0.153 ***	−0.129 ***	0.468 ***	1			−0.300 ***	−0.09	0.413 ***	1			0.075	0.04	0.502 ***	1		
5.Assets	−0.096 **	−0.122 **	0.393 ***	0.607 ***	1		−0.145 **	−0.347 ***	0.385 ***	0.623 ***	1		−0.058	0.351 ***	0.429 ***	0.686 ***	1	
6.D2A	−0.556 ***	−0.045	0.201 ***	0.473 ***	0.327 ***		−0.703 ***	−0.173 **	−0.02	0.401 ***	0.390 ***		−0.469 ***	0.151 **	0.334 ***	0.604 ***	0.275 ***	1

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

4. Results and Discussion

We first test the data used in our study. The highest values of variance inflation factors (VIF) among all regression models are 2.02. Generally, if the values of VIF are under 10, it can avoid multi-collinearity [112]. Hence, multi-collinearity is not a problem in our estimation. Besides, Durbin–Watson values of all regression models are quite close to 2. Thus, there is no auto correlation issue in our data. Furthermore, we employ the augmented Dickey–Fuller test to examine the stationarity of data. The results show the data has no unit roots but the details are not included in this paper due to lack of space. All these show that using the data we collected to do the regression analysis is valid. Finally, we conduct the regression analysis with cluster-robust standard errors to control for potential heteroscedasticity [113].

4.1. Examining the Direct EP–FP Link

Regression results for examining the direct EP–FP link across HPS and LPS are shown in Table 5. This table presents results in terms of multiple time periods (2004–2007, 2008–2011 and 2012–2015) and for all 12 years (2004–2015) for HPS, LPS and all sectors.

The reason for dividing the whole research periods into three groups equally is to ensure a big enough sample size (with a minimum of 64) so that it will not affect the regression results [114]. We also conduct an additional test to examine whether there are significant structure changes among the three periods [115]. The results demonstrate that all coefficients are significantly different among the three periods for all sectors, HPS or LPS (chi2 = 42.03, $p < 0.01$; chi2 = 25.60, $p < 0.01$; chi2 = 84.30, $p < 0.01$).

We first focus on the results for all 12 years (2004–2015). Looking at column 4 of the table, the coefficient of EP_Score is significantly positive ($\beta = 0.0006$, $p < 0.01$) in all sectors. Since EP_score in this paper measures negative environmental performance (i.e., emissions), this positive coefficient actually signifies the negative EP–FP link.

Results for HPS are presented in column 8 of the table while the results for LPS are presented in the last column. For HPS, the coefficient of EP_Score ($\beta = 0.0008$, $p < 0.01$) is positive and significant. This result shows that the EP–FP link in HPS is also negative. However, the case for LPS shows contrasting results. The coefficient of EP_Score ($\beta = -0.0024$, $p < 0.01$) is significantly negative. This shows that EP is positively associated with EP in LPS.

Therefore, we can conclude that industrial heterogeneity exists and the EP–FP nexus varies in different industrial groups, which fully supports H1.

The results of temporal variation of the EP–FP link are also presented in Table 5. For all sectors, the significance of the negative relationship between EP and FP keeps unchanged in the first two periods (see columns 1 and 2) but declines in the last period (see column 3). We can conclude that the significance of this negative relationship declines over the years. For HPS, the changing trend of the significance of the negative relationship is consistent with all sectors. For LPS, the significance of the positive relationship decreases gradually in the first two periods (see columns 9 and 10). Moreover, the EP–FP link changes from positive to negative in the last period (see column 11). Hence, there is no evidence that the EP–FP link becomes more positive and more significant over time. Based on these empirical results, H2 is not supported.

Table 5. Regression results.

Variable	All Sectors				High-polluting Sectors				Light-Polluting Sectors			
	2004–2007	**2008–2011**	**2012–2015**	**2004–2015**	**2004–2007**	**2008–2011**	**2012–2015**	**2004–2015**	**2004–2007**	**2008–2011**	**2012–2015**	**2004–2015**
EP_Score	0.0010 **	0.0009 **	0.0001	0.0006 ***	0.0013 **	0.0011 **	−0.0000	0.0008 ***	−0.0054 ***	−0.0025 *	0.0024 **	−0.0024 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Firms	−0.0089	0.0078	0.0091	0.0053	−0.0194 **	−0.0135 *	−0.0043	−0.0118 ***	0.0198 **	0.0445 ***	0.0294 ***	0.0290 ***
	(0.010)	(0.006)	(0.006)	(0.004)	(0.009)	(0.007)	(0.009)	(0.004)	(0.009)	(0.008)	(0.005)	(0.004)
Assets	0.0097	0.0011	−0.0042	0.0010	0.0302 **	0.0184 ***	0.0050	0.0183 ***	−0.0042	−0.0119 ***	−0.0130 ***	−0.0105 ***
	(0.007)	(0.005)	(0.004)	(0.003)	(0.011)	(0.007)	(0.009)	(0.005)	(0.005)	(0.004)	(0.003)	(0.002)
D2A	−0.2939 ***	−0.3811 ***	−0.3639 ***	−0.3849 ***	−0.6058 ***	−0.6522 ***	−0.4973 ***	−0.6129 ***	−0.2787 ***	−0.4681 ***	−0.4137 ***	−0.3547 ***
	(0.069)	(0.058)	(0.032)	(0.035)	(0.126)	(0.084)	(0.074)	(0.051)	(0.074)	(0.064)	(0.049)	(0.035)
_cons	0.2254 ***	0.2514 ***	0.2718 ***	0.2500 ***	0.2929 ***	0.3913 ***	0.3539 ***	0.3449 ***	0.1412 ***	0.1509 ***	0.2248 ***	0.1673 ***
	(0.043)	(0.031)	(0.022)	(0.022)	(0.109)	(0.042)	(0.038)	(0.040)	(0.030)	(0.026)	(0.022)	(0.017)
N	144	144	144	432	64	64	64	192	80	80	80	240
R2	0.2832	0.3296	0.5132	0.3978	0.5163	0.6840	0.6316	0.6144	0.2983	0.5728	0.6215	0.5910
Adj-R2	0.2625	0.3103	0.4992	0.3761	0.4835	0.6625	0.6067	0.5815	0.2609	0.5501	0.6013	0.5636
F	7.2828	13.8949	61.3382	20.7424	16.1877	18.7274	32.1709	16.4383	7.9858	35.2196	55.6840	24.0131

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, robust standard errors in parentheses.

4.2. Examining the Mediation role of Technical Innovation on EP–FP Link

Following Baron and Kenny [116], we use hierarchical regression analysis to test mediation and three models are constructed. The results are presented in Table 6. For all sectors, EP_Score has a significantly positive impact on ROA ($\beta = 0.0006$, $p < 0.01$) and a significantly negative impact on R&D ($\beta = -0.8513$, $p < 0.01$). However, when both the independent variable (EP_Score) and the mediator (R&D) are added, the influence of R&D on ROA is positive but not significant ($\beta = 0.00003$, p = n.s.), whereas the significant positive impact of EP_Score on ROA remains unchanged ($\beta = 0.0007$, $p < 0.01$). According to the procedure of testing mediation proposed by Baron and Kenny [116], we further conduct the Sobel test to examine whether technical innovation mediates the EP–FP link or not. The result shows that technical innovation does not mediate the link in all sectors (t = 0.9437, p = n.s.). For HPS, the EP_Score has a positive impact on ROA ($\beta = 0.0008$, $p < 0.01$) and a negative impact on R&D ($\beta = -0.\ 7872$, $p < 0.01$). but the positive impact of R&D on ROA disappears ($\beta = -0.0001$, p = n.s.), when both the EP_Score and EP are included in the third model. The result of the Sobel test indicates that technical innovation also does not have a mediation effect on the EP–FP link in HPS (t = 0.9482, p = n.s.). For LPS, the EP_Score has a significantly negative impact on ROA ($\beta = -0.0024$, $p < 0.01$) and a significantly positive impact on R&D ($\beta = -15.4169$, $p < 0.01$). When the EP_Score and R&D are added into the third model, the significance of these two variables is significant as well. These results indicate that technical innovation partially mediates the EP–FP link in LPS. In conclusion, H3 is partially supported as technical innovation partially mediates the EP–FP link but only in LPS.

Taken together, this approach can provide deeper insights for understanding the impacts of the mediating role of technical innovation on shaping the EP–FP link. As mentioned above, there is a negative link in all sectors and HPS. Technical innovation also does not mediate the focal link both in all sectors and in HPS. In contrast, technical innovation partially mediates the EP–FP link in LPS and the direct EP–FP link is positive in LPS. Thus, we can find evidence that technical innovation plays an important role in shaping the EP–FP nexus. If technical innovation can partially mediate the focal link, apart from the indirect link, the direct EP–FP link is likely to be positive. If technical innovation does not have a mediating impact, the direct EP–FP link is likely to be negative.

This conclusion can be further proved by our results in LPS. We present a surprise result that the EP–FP link in LPS shifts from positive to negative in the last period (see Table 5, column 11). In order to find out the potential reason, we examine whether the mediation role of technical innovation disappears or not in the last period. As illustrated in Table 7, the coefficient of the EP_Score and R&D are all significant in all three models during 2004–2007. The results are almost the same as the results during 2008–2011. These results suggest that technical innovation both partially mediates the focal link during these two periods. In the last period, although the coefficients of the EP_Score are both significant in the first and second model ($\beta = -0.\ 0024$, $p < 0.05$; $\beta = -15.7004$, $p < 0.01$), the significance of R&D disappears ($\beta = -0.0001$, p = n.s.) when both the EP_Score and R&D are included in the third model. We thus conduct Sobel test and the result proves that the mediation impact disappears in the last period (t = 1.455, p = n.s.). These results provide an explanation of why the relationship shifts from positive to negative in the last period. Because technical innovation does not mediate the relationship, the direct link changes from positive to negative.

Table 6. Results of regression analysis for mediation of technical innovation.

Variable	All Sectors			High-Polluting Sectors			Light-Polluting Sectors		
	ROA	**R&D**	**ROA**	**ROA**	**R&D**	**ROA**	**ROA**	**R&D**	**ROA**
EP_Score	0.0006 ***	−0.8513 ***	0.0007 ***	0.0008 ***	−0.7872 ***	0.0007 ***	−0.0024 ***	−15.4169 ***	−0.0046 ***
	(0.000)	(0.165)	(0.000)	(0.000)	(0.171)	(0.000)	(0.001)	(1.069)	(0.001)
R&D			0.00003			−0.0001			−0.0001 ***
			(0.000)			(0.000)			(0.000)
Firms	0.0053	17.4487 ***	0.0048	−0.0118 ***	16.2153 ***	−0.0106 ***	0.0290 ***	−6.6407	0.0281 ***
	(0.004)	(2.630)	(0.004)	(0.004)	(3.297)	(0.004)	(0.004)	(6.281)	(0.005)
Assets	0.0010	5.8034 ***	0.0008	0.0183 ***	3.8742	0.0186 ***	−0.0105 ***	25.8108 ***	−0.0069 **
	(0.003)	(2.186)	(0.003)	(0.005)	(2.833)	(0.005)	(0.002)	(2.891)	(0.003)
D2A	−0.3849 ***	−10.6333	−0.3846 ***	−0.6129 ***	−171.9633 ***	−0.6263 ***	−0.3547 ***	250.8711 ***	−0.3192 ***
	(0.035)	(33.648)	(0.035)	(0.051)	(56.722)	(0.055)	(0.035)	(55.484)	(0.041)
_cons	0.2500 ***	−86.6433 ***	0.2526 ***	0.3449 ***	26.2164	0.3469 ***	0.1673 ***	−228.1956 ***	0.1351 ***
	(0.022)	(17.747)	(0.022)	(0.040)	(26.744)	(0.042)	(0.017)	(19.436)	(0.019)
N	432	432	432	192	192	192	240	240	240
R2	0.3978	0.2698	0.3985	0.6144	0.3151	0.6164	0.5910	0.5220	0.6145
Adj−R2	0.3761	0.2435	0.3753	0.5815	0.2567	0.5813	0.5636	0.4900	0.5868
F	20.7424	14.4880	19.3353	16.4383	7.3722	16.2758	24.0131	28.6369	24.5791

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, robust standard errors in parentheses.

Table 7. Results of regression analysis for mediation of technical innovation in light-polluting sectors (LPS).

Variable	2004–2007			2008–2011			2012–2015		
	ROA	R&D	ROA	ROA	R&D	ROA	ROA	R&D	ROA
EP_Score	−0.0054 ***	−14.6089 ***	−0.0072 ***	−0.0025 *	−17.0604 ***	−0.0058 **	0.0024 **	−15.7004 ***	0.0005
	(0.001)	(1.008)	(0.002)	(0.001)	(2.288)	(0.002)	(0.001)	(1.949)	(0.002)
R&D			−0.0001 **			−0.0002 ***			−0.0001
			(0.000)			(0.000)			(0.000)
Firms	0.0198 **	−23.7336 **	0.0169	0.0445 ***	−13.7431	0.0419 ***	0.0294 ***	−3.9133	0.0290 ***
	(0.009)	(9.790)	(0.011)	(0.008)	(11.981)	(0.009)	(0.005)	(8.679)	(0.005)
Assets	−0.0042	36.4658 ***	0.0003	−0.0119 ***	29.6551 ***	−0.0062	−0.0130 ***	19.3481 ***	−0.0107 ***
	(0.005)	(5.060)	(0.007)	(0.004)	(5.660)	(0.005)	(0.003)	(4.773)	(0.003)
D2A	−0.2787 ***	382.8198 ***	−0.2320 **	−0.4681 ***	282.1787 ***	−0.4137 ***	−0.4137 ***	272.8859 ***	−0.3812 ***
	(0.074)	(80.566)	(0.093)	(0.064)	(102.770)	(0.075)	(0.049)	(91.806)	(0.060)
_cons	0.1412 ***	−272.7391 ***	0.1079 ***	0.1509 ***	−215.1365 ***	0.1094 ***	0.2248 ***	−181.7043 ***	0.2032 ***
	(0.030)	(27.048)	(0.041)	(0.026)	(31.487)	(0.029)	(0.022)	(42.341)	(0.022)
N	80	80	80	80	80	80	80	80	80
R2	0.2983	0.6635	0.3151	0.5728	0.5480	0.6113	0.6215	0.3798	0.6462
Adj−R2	0.2609	0.6456	0.2689	0.5501	0.5238	0.5851	0.6013	0.3467	0.6223
F	7.9858	63.9530	8.0117	35.2196	32.0307	37.0438	55.6840	28.4968	43.8362

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, robust standard errors in parentheses.

4.3. Discussion

Drawing on theoretical analysis, we can provide some explanations as to why the mediation effect of technical innovation plays an important role in shaping the focal relationship. When technical innovation does not mediate the link, the additional compliance cost is hard to offset. Thus, the link is likely to be negative. When technical innovation mediates the link, the additional compliance cost can be offset, the efficiency in the use of resources can be improved and the competitive advantages can be cultivated. Hence, firms engaging in innovation can gain a win–win solution, which can bring positive outcomes both for the environment and economy, especially in the long run [117,118].

However, it is surprising that technical innovation only mediates the EP–FP link in LPS not in HPS. The mean values of R&D expenditure presented in Table 3 show that firms in LPS invest more in innovation than firms in HPS. Hence, firms in LPS pay considerably more attention to technical innovation than firms in HPS. With limited investment in innovation, technical innovation may not mediate the EP–FP link in HPS.

Further to our hypothesis 2, we claim that the EP–FP link will become more positive and more significant as the significance of the negative relationship will reduce, whereas the significance of the positive relationship will increase under the background of environmental pressures increasing. But it is not supported. In addition to the increasing environmental pressures, technical innovation may be another reason. As discussed above, the mediating role of technical innovation plays an important role in shaping the EP–FP link and affects the significance of the link as well. Combining these two influence factors, the significance of the link may be more complex than simply increasing or reducing so that the link does not become more positive and more significant over time.

Finally, we show that the EP–FP nexus is negative and technical innovation does not have a mediating role in HPS. On the basis of our empirical findings, we can provide some valuable implications for firms and the government to shift this situation. For firms, especially in HPS, it is essential to pay close attention to technical innovation and make sure that technical innovation can play a mediating role. In this sense, the direct EP–FP link is likely to be positive. The positive outcomes can convince more firms to engage in proactive environmental strategies to address their environmental issues. Moreover, the key to improving the overall environment in the Chinese context is to realize the positive relationship between EP and FP in HPS. Hence, for government, the intensity of environmental regulations still needs to be improved, and stricter but properly designed environmental regulations for firms in HPS are especially in need. Scholars reveal that the intensity of environmental pressures is a big driver for firms to adopt proactive environmental strategies [119,120]. Although the pressures of environmental regulations in China have been increasing in recent years, it is still not enough [121]. Once the intensity of environmental regulations arrives at a certain level, firms will be forced to adopt more proactive environmental strategies and pay more attention to innovation and use pollution prevention approaches [122]. As mentioned above, adopting proactive environmental strategies instead of reactive environmental strategies can have a positive impact on the linkage of EP–FP [16,77,78,123–125]. Therefore, the EP–FP link is likely to shift from negative to positive in HPS.

4.4. Sensitivity Analysis

Some scholars have pointed out that it takes certain time to see the effect of EP on FP [15,43,71]. Therefore, some prior studies have used the lagged EP when conducting research (e.g., [11,16,40,81,85]). In addition, using lagged EP can avoid the endogeneity problem [15,16]. Hence, we conduct a similar analysis but EP is lagged by one year to further check whether our results are robust or not. The results are presented in Table 8.

Besides, the number of patents is also widely used to capture technical innovation [109]. We also use the natural logarithm of patents (denoted as *Patent*) to capture technical innovation and conduct the regression analysis again. Relevant results are available in Table 9.

All the results of sensitivity analysis prove that our results are robust.

Table 8. Results of regression analysis for mediation of technical innovation when EP lagged one-year.

Variable	All Sectors			High-Polluting Sectors			Light-Polluting Sectors		
	ROA	R&D	ROA	ROA	R&D	ROA	ROA	R&D	ROA
$(EP\_score)_{t-1}$	0.0007 ***	−0.8537 ***	0.0008 ***	0.0009 ***	−0.7891 ***	0.0008 ***	−0.0020 **	−16.3108 ***	−0.0044 ***
	(0.000)	(0.180)	(0.000)	(0.000)	(0.192)	(0.000)	(0.001)	(1.125)	(0.001)
R&D			0.0000			−0.0001			−0.0001 ***
			(0.000)			(0.000)			(0.000)
Firms	0.0059	17.9488 ***	0.0055	−0.0124 ***	16.2717 ***	−0.0110 ***	0.0305 ***	−8.8035	0.0292 ***
	(0.004)	(2.705)	(0.004)	(0.004)	(3.422)	(0.004)	(0.004)	(6.347)	(0.005)
Assets	0.0007	6.1396 ***	0.0005	0.0177 ***	4.1439	0.0181 ***	−0.0106 ***	27.5197 ***	−0.0066 **
	(0.003)	(2.303)	(0.003)	(0.005)	(3.080)	(0.005)	(0.002)	(2.881)	(0.003)
D2A	−0.3904 ***	−20.1099	−0.3899 ***	−0.6130 ***	−186.1599 ***	−0.6292 ***	−0.3747 ***	269.9119 ***	−0.3354 ***
	(0.035)	(35.232)	(0.035)	(0.049)	(60.407)	(0.052)	(0.034)	(55.658)	(0.041)
_cons	0.2536 ***	−86.4477 ***	0.2557 ***	0.3547 ***	33.6237	0.3576 ***	0.1700 ***	−237.2355 ***	0.1354 ***
	(0.022)	(19.142)	(0.022)	(0.040)	(30.252)	(0.041)	(0.016)	(20.041)	(0.018)
N	396	396	396	176	176	176	220	220	220
R2	0.4157	0.2602	0.4162	0.6440	0.3043	0.6466	0.5978	0.5407	0.6223
Adj−R2	0.3942	0.2330	0.3932	0.6130	0.2439	0.6135	0.5703	0.5094	0.5946
F	21.0859	13.7625	19.6100	19.2968	6.3647	19.3215	22.5842	31.3630	23.1098

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, robust standard errors in parentheses.

Table 9. Results of regression analysis for mediation of technical innovation measured by patent.

Variable	All Sectors			High-Polluting Sectors			Light-Polluting Sectors		
	ROA	**Patent**	**ROA**	**ROA**	**Patent**	**ROA**	**ROA**	**Patent**	**ROA**
EP_Score	0.0006 **	−0.0374 ***	0.0009 *	0.0007 **	−0.0156 ***	0.0007 **	−0.0022 **	−0.2519 ***	−0.0012
	(0.000)	(0.005)	(0.000)	(0.000)	(0.004)	(0.000)	(0.001)	(0.048)	(0.001)
Patent			0.0065			−0.0002			0.0039 *
			(0.006)			(0.005)			(0.002)
Firms	0.0062	0.9872 ***	−0.0002	−0.0106 **	0.6477 ***	−0.0104 *	0.0318 ***	0.7279 ***	0.0290 ***
	(0.004)	(0.071)	(0.013)	(0.005)	(0.059)	(0.006)	(0.004)	(0.144)	(0.003)
Assets	0.0017	0.5579 ***	−0.0019	0.0163 ***	1.0061 ***	0.0165 ***	−0.0104 ***	0.7107 ***	−0.0131 ***
	(0.003)	(0.057)	(0.007)	(0.005)	(0.062)	(0.005)	(0.002)	(0.083)	(0.003)
D2A	−0.3947 ***	−3.4495 ***	−0.3721 ***	−0.6183 ***	−5.2813 ***	−0.6194 ***	−0.3828 ***	0.0311	−0.3829 ***
	(0.029)	(0.638)	(0.068)	(0.052)	(0.911)	(0.060)	(0.027)	(0.939)	(0.027)
_cons	0.2555 ***	−2.1163 ***	0.2693 ***	0.3631 ***	−3.2220 ***	0.3624 ***	0.1730 ***	−3.1817 ***	0.1852 ***
	(0.021)	(0.415)	(0.052)	(0.040)	(0.565)	(0.035)	(0.016)	(0.453)	(0.016)
N	432	432	432	192	192	192	240	240	240
R2	0.3413	0.7093	0.3587	0.5501	0.8133	0.5501	0.5324	0.7035	0.5421
Adj−R2	0.3351	0.7066	0.3512	0.5405	0.8093	0.5380	0.5244	0.6985	0.5323
F	57.0385	250.3612	45.1179	41.3157	227.8993	33.8403	63.5061	190.0949	58.7432

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, robust standard errors in parentheses.

5. Conclusions

In this paper, we consider industrial heterogeneity and examine whether the EP–FP nexus varies in different industrial groups or not. We also take the dynamic behavior of the link into consideration and investigate the changing trend of the significance of the focal link. Furthermore, we investigate whether technical innovation plays a mediating role in the EP–FP link and whether the mediation effect varies in different industrial groups or not. In doing so, we collect the required data from different Chinese statistical yearbooks; 36 industrial sectors from 2004–2015 are included. The key findings of our research show that the EP–FP link is complex and technical innovation plays a crucial role in shaping the link. When technical innovation partially mediates the EP–FP link, apart from the indirect link, the direct link is likely to be positive. If not, the direct link is likely to be negative. The empirical results in LPS are the best proof. Besides, the direct EP–FP link in HPS and LPS is negative and positive, respectively. The results provide evidence that industrial heterogeneity does exist and the EP–FP link varies in different industrial groups. Furthermore, since the significance of the EP–FP link is more complex than simply reducing or increasing over years, the EP–FP link does not become more positive and more significant. Both the mediation effect of technical innovation and increasing environmental pressures can jointly affect the link.

This study extends the literature by investigating the mediating role of technical innovation in the EP–FP link. Most prior studies only incorporate technical innovation into the regression model as a control variable. Instead of presenting an overall picture of the EP–FP nexus, this study also contributes to the literature by taking the dynamic behavior of the focal link into consideration and investigating the changing trend of the significance of the focal link. Furthermore, given the large percentage of prior studies focusing on developed countries [29,30], our empirical results can provide more evidence from an emerging country. We also take industrial heterogeneity into account and examine whether the focal link varies in different industrial groups or not. Combining all these factors, this study can provide deeper insights for exploring the nature of the EP–FP link.

Despite the significant contributions, this study has certain limitations as well. Firstly, we reveal that the mediating role of technical innovation plays an important role in shaping the focal link. However, the way it plays its mediating role persistently is not included in our study. Future study should focus on revealing this inherent logic to make sure the EP–FP link can be positive persistently. Secondly, in this paper we use R&D intensity to capture technical innovation. However, innovation can be divided into technical innovation and environmental innovation [126]. We do not differentiate these two kinds of innovation in this study. Future study should distinguish the different types of innovation and examine whether our results are robust or not. Third, our research periods cover the period from 2004 to 2015 and we only focus on Chinese industrial sectors. Future research should expand research periods with the latest data and collect data from several different countries. Using the latest and wider range of data can further confirm the results we obtained in this study.

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