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How Does Environmental Protection Law Affect Industrial Upgrading of Chinese Firms: The Mediating Role of Technological Innovation?

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Abstract: In the context of addressing environmental pollution and promoting sustainable development, it is necessary to evaluate the impact of environmental regulations on Chinese firm's industrial upgrading. Treating the environmental protection law (EPL) as a quasi-natural experiment, the current study investigated the effects of EPL on industrial upgrading, measured in the form of total factor productivity (TFP) of Chinese firms. Based on the data from 2008-2020 of 247 firms from polluting industries and 1929 firms from other industries listed on the Shanghai and Shenzhen stock exchanges, the firm-level TFP was calculated using the Levinsohn-Petrin (LP) method. To evaluate the effect of EPL on the TFP, a difference-in-differences (DID) method was then adopted. The results show that the new environmental protection law of China has a positive and significant effect on firm-level industrial upgrading in China. Empirical evidence also shows that technological innovation measured in the form of total patents could mediate the nexus between EPL and firms' TFP. Furthermore, the regional heterogeneity and

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replacing the dependent and mediating variables in the main model also supported the empirical findings. Based on the derived results, conclusions including policy suggestions are implicated in the enforcement of environmental regulations in the future, and the current study also provides China's micro-firm level evidence for the Porter hypothesis.

Keywords: total factor productivity, environmental regulations, patents, sustainable development, green development

1. INTRODUCTION

In the global economic development, the historical progress of China's economy since the reforms and opening-up agenda implementation is considered a miracle (Shahid *et al.*, 2023). The information released by the 20th National Congress of CPC (the Communist Party of China) evidently mentioned the need for the country to adhere to the theme of promotion of high-quality and sustainable development, acceleration of innovative developmental paths, promotion of quality improvement, alignment of supply-side deepening of structural reforms and domestic demand expansion, along with the rational economic growth. For the supply-side deepening of structural reforms, a significant force for the promotion of growth of the economy is the industrial upgrading and transformation via accentuated market force and industrial structure adjustment (Li &Liu, 2023). Moreover, for the optimisation of the allocation of resources, the promotion of conversion of kinetic energy, as well as suppression of pollution emissions and industrial upgradation are significant drivers. On the other hand, over the past four decades, serious environmental degradation issues have been raised due to the miraculous economic development and growth of China. This led to the depletion of resources and the deterioration of the ecological environment (Li & Liu, 2023; Shahid *et al.*, 2022a). The trends of environmental pollution and industrial growth in China are presented in Figure 1.

In the light of the traditional Chinese developmental model, the phrase "pollute first and control later" evokes the public demand to find novel ways for the improvement of economy and nature protection simultaneously. As discussed by Chang *et al.* (2015), a series of environmental regulations were issued by the Chinese government as a response to escalating environmental issues. As of 2013 and after, a total of 358 regulations and laws under

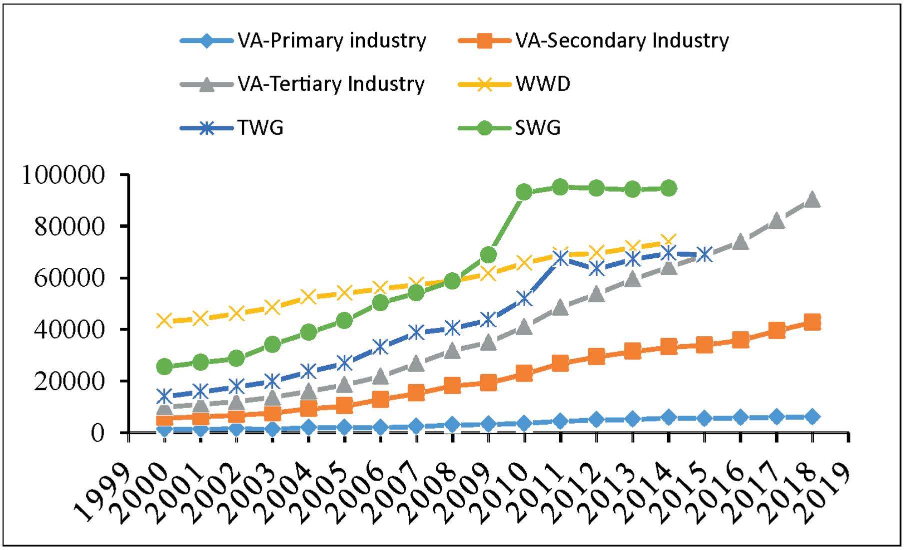

Figure 1: Trend of Environmental Pollution and Industrial Growth in China (2000-2018).

Abbreviations: VA=Value-added; WWD=Waste Water Discharge in Million Tons; TWG=Total Volume of Industrial Waste Gas Emission in Billion Cubic M; SWG=Industrial Solid Waste Generated in Million Tons

environmental protection goals had been issued by the Chinese government, and before 2016, around 67 more regulations related to environmental protection were unveiled. Stricter environmental regulations are increasingly being faced by companies. Moreover, the solutions for internal problems also remained a dilemma for the companies. For example, for the survival of an enterprise in the globalisation of economies, the improvement of product competition is needed. Further, to avoid the extra cost of production, attention must be paid to the pollution discharge of enterprises (Sun *et al.*, 2020). The stringency of environmental regulations is considered to be a significant determinant of industrial upgrading (Wang *et al.*, 2022). Although environmental protection law (EPL) is an effective and more direct measure of environmental regulations, their use is rare due to qualifying difficulties. Moreover, extant literature is mostly focused on investigating the impact of environmental regulations on upgrading panel datasets at the national level (Acemoglu *et al.*, 2012), the regional level (Li & Liu, 2023; Qiu *et al.*, 2022; Wang *et al.*, 2022), or the industry level (Shahid *et al.*, 2022b). However, total factor productivity, which is the measure of industrial upgrading, is an enterprise-level phenomenon, so testing of environmental regulations for their economic outcomes should be focused on the enterprise level as well.

According to Porter's hypothesis (PH), well-designed regulation could actually enhance competitiveness (Porter & Van der Linde, 1995; Porter, 1996). The "innovation compensation" effect describes that the adjustments in the product cycle, implementation of advanced technological equipment and innovation at enterprises are a result of simultaneous pressure from environmental regulations and accelerating linked marginal costs. To remain at higher tiers in industries, firms try to upgrade industrially by incorporating increasing pollution costs through the earlier-mentioned pathway (Qiu *et al.*, 2022). The implementation of environmental regulations enhances a firm's internal costs, leading to stimulating the transformation of production technologies, and finally driving the industrial upgrading of firms (Wang *et al.*, 2022). The accentuated pattern of changes in the industrial structure of China has been noticed with the increasing environmental regulations. As mentioned by Yu and Wang (2021), for the very first time, the contribution of the tertiary industry of China to GDP was more than 50% in 2015. In the case of China, a more systematic analysis of Porter's hypothesis for studying the impact of environmental regulations on firms' TFP should be focused, so that policy interventions can be based on this linkage.

The extant literature on environmental protection law is mainly focused on measuring its impact on green innovation (Liu *et al.*, 2021a), environmental performance (Chang *et al.*, 2015), and pollution emissions (Sun *et al.*, 2020). However, its impact on the industrial upgrading of firms and its mechanism is still unclear, and according to PH, the environmental protection law can have a significant impact on industrial upgrading. The industrial upgrading of firms has varying determinants, such as innovation (Sterlacchini, 1989), natural resources (Liu *et al.*, 2021b), economic development (Wang *et al.*, 2021), and market share (Sheng & Song, 2013). Among these factors, innovation is a key factor for mediating the nexus between EPL and industrial upgrading. It is because of the fact that environmental performance will get improved by environmental regulations, which will in turn alter the technological innovation in the manufacturing cycle of a firm, thus ultimately leading to changes in total factor productivity and causing industrial upgrading of firms (Wang *et al.*, 2021).

In the light of background given above, this paper aims to investigate the impact of the EPL (Environmental Protection Law) of China on the industrial upgrading of Chinese firms. Further, the mediating role of technological innovation on the nexus between EPL and industrial upgrading was analysed. The contribution of our research to extant literature is as follows: Firstly, the re-evaluation of the Porter hypothesis was conducted for Chinese micro-level data, which would provide significant indications of this theory for micro-firms of other developing nations. Secondly, as far as the underlying economic mechanism for the impact evaluation of China's environmental regulations on its industrial upgrading at the firm level is concerned, the mediating role of technological innovation for the nexus between EPL and firms' industrial upgrading is missing in hitherto studies. Thirdly, based on most environmental economics and enterprise management literature (Liu *et al.*, 2021a; He *et al.*, 2022), the EPL of China is taken as a proxy measure for the country's environmental regulations. Government policy can affect firm-level upgrading through several different channels, for instance by influencing the cost of accessing different output markets, by increasing the supply or directly subsidising different inputs, or by directly providing extension services or other consulting, as discussed in various policy-oriented reviews (Verhoogen, 2021). In the case of programs and policies implemented by the Chinese government, whether the EPL is contributing to the upgrading of the Chinese firms in real conditions, for the achievement of a win-win condition between sustainable environmental performance and economic development, this is a theoretical objective needing empirical investigation.

To achieve our objectives, a difference-in-differences (DID) analysis was carried out to study the impact of EPL on the industrial upgrading of Chinese firms. In the area of policy impact evaluation, the DID method has become one of the most popular methods, as it accounts for unobservable heterogeneity and omitted variable bias (Shahid *et al.*, 2022a). Further, a robustness analysis was carried out to test the efficacy of the results. Also, from a policy point of view, we discussed some policy implications. Our paper is divided into the following sub-sections. Section 2 describes the literature review and derives research hypotheses for the study. Section 3 gives an overview of data and sample, variables selection, and model specification. Section 4 discusses the empirical results in light of theory and literature. Finally, section 5 concludes the paper and suggests some policy implications based on derived results.

2. LITERATURE REVIEW AND THEORETICAL HYPOTHESIS

2.1. Background of Environmental Protection Law of China

Recently, global priorities have focused more on simultaneous economic growth and environmental sustainability, as ignoring the environment makes sustainable economic development difficult to achieve (Nilashi *et al.*, 2019). Being the world's second-largest economy and largest emerging market economy, the relevance of this issue is quite pertinent for China. As the rapid economic growth of China has been remarkable since the opening and reforms of the country in 1978 (Shahid *et al.*, 2023), increasing externalities in the form of environmental deterioration have also been faced by the country (Zhu *et al.*, 2019), as, unlike developed economies, the development model of the country did not focus parallel sustainability of environment along with fast pacing economic growth (Li & Lin, 2016). The very first specific law of the country concerning environmental protection is the Environmental Protection Law (EPL). This law aims to enforce increasing investments in green innovation by enterprises, with reductions in pollution emissions and acquiring country-wide sustainable economic growth (He *et al.*, 2022). The initial draft of EPL was released in early 1989. In 2006, the environmental performance review of China was released by the OECD (Organisation for Economic Co-operation and Development) in Beijing. According to a review report, it was revealed that China's environmental protection had achieved remarkable results. Nevertheless, there was an inadequacy regarding the efficacy of the country's prevailing environmental policies, such as deficiencies at the institutional level and policy implementation, thus recommending revisions and modifications of existing environmental protection policies and laws. Given this, amendments were made to the existing EPL by the Chinese government. The newly amended Environmental Protection Law (EPL) was officially implemented on January 1, 2015, and is deliberated as the country's top-listed EPL to date in terms of stringency. This law highlights three aspects. First, the environmental punishment for enterprises has been strengthened. The EPL stipulates that penalties for environmental violations of enterprises can be punished daily and continuously, and the amount of fines is not capped, which has increased both the authority of environmental law enforcement agencies and the environmental violations cost of enterprises. Second, the enterprises' environmental violations can be penalised individuals (such as the CEO of the firm) by administrative detention, which has enhanced the deterrent effect. Third, the environmental protection responsibilities of local governments have been highlighted to prevent local governments from undercutting their efforts. Thus, firms belonging to heavily polluting industries, than other industries, are pretentious more by the amended law (Liu *et al.*, 2021a).

2.2. Environmental Protection Law and Industrial Upgrading of Chinese Firms

Numerous academics have investigated the effects of the EPL on both the environment and the economy after realising how important it is, including the impact on environmental productivity growth (Wang *et al.*, 2019), pollution emissions (Li & Masui, 2019), firm performance (He *et al.*, 2020), intergenerational behaviours and welfare (Xiao *et al.*, 2022), and total factor productivity (He *et al.*, 2022). Previous studies (Wang *et al.*, 2019; Li & Masui, 2019) mostly employed simulation models, including computable general equilibrium models and dynamic stochastic general equilibrium models, to estimate EPL's influence at the macro level due to the absence of relevant data at the time of its adoption. The findings show that it may significantly decrease pollution emissions, although there is still debate over its effects on the country's economy. He *et al.* (2020) event study method-based empirical investigation of the micro-level effects of the EPL revealed that it raises environmental expenses for businesses and worsens business performance. Nevertheless Liu *et al.* (2022) found that the EPL may encourage businesses to make environmental expenditures, boosting corporate performance. In general, it is notable that businesses are immediately impacted by the EPL since they are the policy's biggest taxpayers. It is crucial to comprehend how this regulation impacts a firm's TFP. It could provide recommendations on how to make policy better while fostering the sustainable growth of businesses. According to the well-known Porter hypothesis (PH), reducing pollution is often coincident with improving the productivity with which resources are used (Lanoie *et al.*, 2015). Environmentalists, economists, and specifically, policymakers favour "win-win" solutions. The basic idea behind the PH is that environmental regulations can create incentives for companies to invest in new technologies and processes that reduce their environmental impact and that these investments can in turn lead to increased productivity, competitiveness, and profitability. Thus, in light of this literature review and Porter's hypothesis, our first hypothesis is as follows:

Hypothesis-1 (H_1): Environmental Protection Law has a positive effect on firm-level industrial upgrading in China.

2.3. The Mediating Role of Technological Innovation

Technological innovation has become an important means to promote the transformation and upgrading of industry (Lo *et al.*, 2022). The regulatory impact on technological innovation due to environmental concerns is crucial. Enhancing the support for scientific and technical innovation is also required to facilitate the modernisation and transformation of the industrial structure. As a result of this, we can see that there is a relationship between the three; hence, the question arises as to whether or not the application of technical innovation is an efficient approach to reach a condition in which environmental protection and industrial upgrading both result in a win-win situation. According to the existing body of literature on environmental regulation, technological innovation, and industrial structure upgrading, the synergistic effect of environmental regulation and technological innovation can only positively promote industrial structure upgrading once technological innovation has passed a certain threshold (Zhong *et al.*, 2015). Nevertheless, the literature that provides insights into upgrading industrial structures was few, and the elements covered within the articles that were most relevant were mostly industrial sustainability and industrial performance (Yuan *et al.*, 2017; Korhonen *et al.*, 2015). Companies that are accountable for high pollution emissions might, from the standpoint of policy and governance, be pushed to abide by the regulatory standards in order to avoid obtaining unfavourable media attention and hefty fines for emissions breaches (Johnson, 2020). Therefore, these fines and the publication of bad information might inspire responsible enterprises to modify their conduct, and they could induce other firms that have not violated the law to upgrade their operating systems to avoid expensive penalties and unfavourable attention. Therefore, to comply with stringent requirements regarding the environment, businesses may be able to reallocate a greater portion of their important financial resources into the production of more environmentally friendly goods. Because of this, environmental pollution regulations that include stringent monitoring might encourage businesses to innovate more (Mbanyele & Wang, 2022). Following the study of Mbanyele and Wang (2022), this study used patent data as a measure of technological innovation for the main indicator of technological innovation, and research and development (R&D) expenditures as an indicator of technological innovation in the robustness analysis. Further, out of the three patent classes including utility models, inventions, and designs, compared to utility and design patents, innovation patents are of better quality (Tan *et al.*, 2015). This study used a total number of patents and several invention patents as the main indicators of technological innovation (Mbanyele & Wang, 2022). Following this research background, the following hypotheses were formed to test the mediating role of technological innovation for the nexus between EPL and the industrial upgrading of Chinese firms:

Hypothesis-2 (H_2): EPL has a positive effect on total number of patents.

Hypothesis-3 (H_3): EPL has a positive effect on several invention patents.

Hypothesis-4 (H_4): A total number of patents has a mediating effect on the nexus between environmental protection law and firm-level industrial upgrading of China.

Hypothesis-5 (H_5): The number of invention patents has a mediating effect on the nexus between environmental protection law and firm-level industrial upgrading in China.

The complete conceptual framework of our research is portrayed in Figure 2.

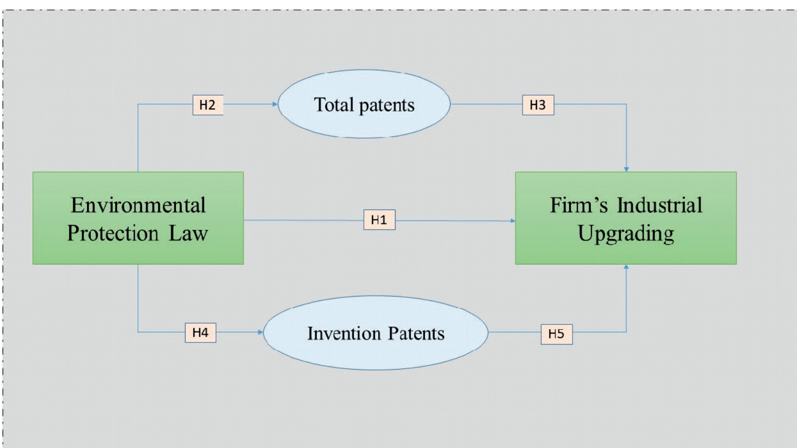

Figure 2: Theoretical Framework of Study

3. METHODOLOGY

3.1. Variables Description

3.2.1. Dependent Variable

For capturing the essence of firms' industrial upgrading, the key dependent variable used was the total factor productivity (TFP) (Verhoogen, 2021). As mentioned by Syverson (2011), the measurement method of TFP has always faced a lack of consensus. For instance, Del Gatto *et al.* (2011), elaborated that the selection bias and simultaneity problems are difficult to avoid in non-parametric approaches, including data envelopment analysis. Further, as described by Xiao *et al.* (2021), the assumption of TFP distribution is mandatory for parametric methods, like stochastic frontier analysis. Keeping this deficit in mind, two semi-parametric approaches were employed in the current study for the measurement of a firm's total factor productivity as the explained variable to measure the industrial upgrading of manufacturing firms. These methods, called LP and OP methods, were proposed by Levinsohn and Petrin (2003) and Olley and Pakes (1996), respectively. Cai and Ye (2020) described that due to the advantage of overcoming the sample loss and endogenous problems, as well as with the unbiased and consistent estimation results, the OP method was improved by the introduction of the LP method. Thus, we estimated firms' TFP by following the LP method (TFP_{LP}) for the main regression, whereas for the robustness check, firms' TFP was calculated by using the OP method (TFP_{OP}).

3.2.2. Explanatory Variables

A powerful quantitative tool for modelling impact assessment is the difference-in-differences method (Khandker *et al.* 2009), which is extensively applied in different subfields of economics and finance (Greenstone & Gayer, 2009). To investigate the effect of the EPL on enterprise TFP for the study time frame of 2008-2020, we used the DID approach. As per the basic principle of DID, three dummy variables were constructed: group treatment variable (TT), time dummy variable (T), and the interaction term of TT and T (TT*T). The grouping variable with the values 1 for the treatment group and 0 otherwise is referred to as "treatment". Additionally, the EPL is founded on the polluter-pays premise; the principal polluters and taxpayers are heavily polluting enterprises. Therefore, the sample of businesses from the eight industry categories with the highest pollution levels is referred to as the treatment group (TT), while a comparable collection of listed businesses from industries with lower pollution levels is used as the control group. Furthermore, for years' observations for and after 2014, time is equal to 1, and otherwise it is equal to 0.

3.2.3. Mediating Variable

Extant literature uses various types of patents for measuring technological innovation (Lee *et al.*, 2022; Lo *et al.*, 2022; Mbanyele & Wang, 2022). This study used the accumulated number of patent applications (TI_P) and number of invention patents (TI_{IP}) as a measure of technology innovation. Further, expenditures on research and development activities were taken as an indicator of technological innovation for the robustness analysis.

3.2.4. Control Variables

Based on an evaluation of the prior research, we additionally incorporated several control variables into our analysis to account for other significant factors influencing enterprises' TFP. In this research, the control variables were selected primarily at the enterprise level. The following variables were included in our research as the control variables to get a more reliable estimate of results. Based on extant literature (Ai *et al.*, 2020; Aghion *et al.*, 2005; Feng *et al.*, 2020; Mbanyele & Wang, 2022), this paper incorporated firm age (Age), return on assets (ROA), firm size (Size), asset tangibility (AT), Tobin-Q (T_Q), asset-liability ratio (Lev), board independence (BI), institutional ownership (IO) and product market competition represented by Herfindahl Hirshman Index (HHI). Table 1 presents the nature, name and definitions of all selected variables.

3.2. Econometric Model

The quantitative assessment of economic policy has often employed the difference-in-differences (DID) approach (Shahid *et al.*, 2022). The key idea of the DID model is to divide the samples into the treated group and the control group and evaluate the effect of policy implementation by comparing the differences between the treated group and the control group before and

Table 1: Description of Variables

Variable		*Definition*
Nature	*Name*	
Dependent Variable	TFP_{LP}	Natural logarithm of total factor productivity of firms calculated through LP method
	TFP_{OP}	Natural logarithm of total factor productivity of firms calculated through OP method
Independent Variables	TT	Dummy variable for treatment group; 1 for firms belonging to highly-polluting firms, 0 otherwise
	T	Dummy variable for the time period; 1 for 2014 and after 2014, 0 otherwise
	TT*T	An interaction term for treatment and time dummy variables
Mediating Variables	TI_{P}	The natural log of technological innovation is measured as the accumulated number of patent applications in the accounting year for a given firm.
	TI_{IP}	The natural log of technological innovation is measured as the number of invention patent applications in the accounting year for a given firm.
	$TI_{R\&D}$	The natural log of technological innovation is measured as expenditures on research and development activities in the accounting year for a given firm.
Control Variables	Age	Natural logarithm of age of firms by taking a difference between reporting year and date of establishment for a given firm
	Size	Natural logarithm of total assets for a given firm
	Lev	Natural logarithm of leverage calculated by dividing total assets by total liabilities for a given firm
	ROA	Natural logarithm of returns on assets calculated by dividing net income with total assets for a given firm
	AT	Natural logarithm of asset tangibility calculated by dividing capital expenditures with total assets for a given firm
	T_{Q}	Natural logarithm of value of Tobin-Q representing the firm growth opportunities for a given firm
	BI	Natural logarithm of board independence represented by the total number of independent directors for a given firm
	IO	The natural logarithm of institutional ownership is calculated by dividing the number of shares with other companies by the total shares for a given firm.
	HHI	Natural logarithm of Herfindahl Hirshman Index (HHI) value representing the product market competition for a given firm

after the policy intervention. That is, the net impact of policy implementation can be obtained by observing the change of an indicator in the treated group and the control group. Among them, the treated group is the set of individuals affected by the policy or event, and the control group is the set of individuals not affected by the policy or event (Chen *et al.*, 2023). For the verification of our hypotheses, following the methods of Feng and Shen (2022), we set the econometric models as follows:

$$TFP_{it} = \alpha_0 + \alpha_1 \times TT_i * T_t + \alpha_2 \times Z_{it} + \delta_i + \vartheta_t + \mu_{it} \tag{1}$$

$$TI_{P_{it}} = \beta_0 + \beta_1 \times TT_i * T_t + \beta_2 \times Z_{it} + \delta_i + \vartheta_t + \mu_{it} \tag{2}$$

$$TI_{IP_{it}} = \gamma_0 + \gamma_1 \times TT_i * T_t + \gamma_2 \times Z_{it} + \delta_i + \vartheta_t + \mu_{it} \tag{3}$$

$$TFP_{it} = \partial_0 + \partial_1 \times TT_i * T_t + \partial_2 \times TI_{P_{it}} + \partial_3 \times Z_{it} + \delta_i + \vartheta_t + \mu_{it} \tag{4}$$

$$TFP_{it} = \sigma_0 + \sigma_1 \times TT_i * T_t + \sigma_2 \times TI_{IP_{it}} + \sigma_3 \times Z_{it} + \delta_i + \vartheta_t + \mu_{it} \tag{5}$$

In equations 1-5, TFP_{it} is the firm's total factor productivity for the firm *i* in year *t*. *TT* is the group dummy variable, which will be 1 in case a firm belongs to the treatment group (heavy polluting industries), and 0 otherwise (firms belonging to other industries). Cap^{T} is the dummy variable for the time of policy implementation, and it will be 1 for and after the year of policy implementation (2014 and after 2014), and 0 otherwise (before 201$). Cap *IP* is the measure of technological subscription. TI_{Pthe} and TI_{IP} denote the number of patents and several invention patents, respectively. Z_{it} represents the set of control variables. The coefficients α_0, β_0, γ_0, ∂_0 and σ_0 are the constant terms for all models. The coefficients $\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2, \partial_1, \partial_2, \partial_3, \sigma_1, \sigma_2,$ and σ_3 are the estimators of corresponding terms. Further, the firm-level fixed effects, time-fixed effects, and residual terms are denoted by δ_i, ϑ_t and μ_{it}, respectively.

According to the theoretical framework of our study (Figure 2), $\alpha_1$was used to test hypothesis-1 (H_1); i.e. it would give the direct impact of EPL on the industrial upgrading of firms. β_1 and γ_1 were used to test the H_2 and H_3, respectively, i.e. would provide the direct impact of EPL on patents and invention patents. For the testing of H_4 and H_5, $\beta_1 \times \partial_2$ and $\gamma_1 \times \sigma_2$, respectively, were used to check the indirect impact of EPL on the industrial upgrading of Chinese firms. In other words, $\beta_1 \times \partial_2$ and $\gamma_1 \times \sigma_2$ would calculate the mediating influence of technological innovation on the relationship between EPL and industrial upgrading of Chinese firms.

3.3. Sample Selection

For investigating the impact of EPL on Firms' TFP, the sample of Chinese A-listed enterprises was used from 2008 to 2020. The firm-level dataset was collected from China Stock Market and Accounting Research (CSMAR). Following the sample selection criterion of Liu *et al.* (2021), according to the Ministry of Ecology and Environment of China's notice on "The enactment of the comprehensive emission standard for industrial pollution sources", published in November 2016, the eight most polluting sectors (waste incineration and sewage treatment plants, dyeing, paper & printing, coal, cement, thermal power and steel industries) were chosen. The two-digit industrial codes assigned by the CSRC (China Securities Regulatory Commission) to these sectors were determined, and the list of Chinese companies operating in these sectors was collected from CSMAR. Using a sample of businesses from the eight sectors with the highest pollution levels as well as a set of comparably sized, lower polluting listed businesses selected as the control group, we evaluated our hypothesis. Further, to guarantee the validity of the empirical results, the samples were screened to get a comprehensive sample for empirical analysis (Table 2). After data cleaning, 247 firms from polluting industries and 1929 firms from other industries were included in our analysis. Finally, following previous research, we winsorized all the variables that are continuous at 1% and 99% cut-off to remove skewness bias (Mbanyele & Wang, 2022).

3.4. Descriptive Statistics and Correlation Analysis

Descriptive statistics of all variables for the selected sample are given in Table 3. For a full-size sample, the average value of TFP, as measured by the LP method, is 6.3050, whereas its maximum and minimum values are 11.2931 and 4.5112, respectively. The average value of TT is 0.1931, which indicates that 19.31% of sample observations were classified as heavily polluting firms. Furthermore, the t-test for the difference was conducted to estimate the statistical difference between heavily polluting firms and other firms, which indicates that for firms' TFP, there existed no significant difference between the TFP of the two groups.

Table 2: Process of Data Screening

Excluded Samples	Justification
All enterprises that didn't exist from 2010-2020, as well as any businesses that were industry codes, shifted during this time.	For obtaining data on existing firms in the sample period
Companies that did not fall within the CSRC's quarterly revised industry categorisation for listed enterprises, which identified the eight most polluting sectors	To g*et al*l the necessary data for our model
Firms having abnormal trading statuses*	As current study was focused on general discussion, and not the special cases.
Firms that had suffered continuous losses and had been delisted during the experiment period were removed.	The value-added must be positive in the TFP estimation frame (Xiao *et al.*, 2021)
Firms belonging to the financial industry	Financial companies are not subjected to the same regulations.
Enterprises not fulfilling basic accounting standards.	(Zhang *et al.*, 2018)

Note: *Abnormal trading statuses mean that such companies have a high probability of delisting in the upcoming 2 or 3 years.

Firms belonging to heavily polluting industries show weaker institutional ownership as compared to enterprises belonging to other industries. Similarly, innovation is lower in the case of heavily polluting enterprises than in companies belonging to other industries. Additionally, the mean values of firm age, leverage, ROA, growth opportunities, and board independence are higher for other firms as compared to firms belonging to heavy-polluting industries. Finally, mean values for firm size, asset tangibility, and product market competition are higher for heavy-polluting firms than firms belonging to other industries.

In Table 4, the Pearson correlation estimates are reported between all regressors (including the key explanatory variables, the mediating variable, and the control variables). These results depict that correlation amid variables are generally small. The highest estimate for correlation found in variables pairs was 0.350, indicating the absence of a serious multicollinearity issue. Further, VIF (variance inflation factor) was also calculated at the same time. The highest value for VIF was 2.07, which also indicates that the concern of multicollinearity can be ignored safely. Thus, it is concluded that our sample was clear from the issue of multicollinearity.

Table 3: Descriptive statistics

Variable	*Panel-1: Full-size Sample (N=28288)*				*Panel-2: Samples of Heavily Polluting Firms vs. Other Firms*			
					HP-Firms (N=3211)	*Other Firms (N=25077)*	*t-test*	
	Mean	*SD*	*Min*	*Max*	*Mean*	*Mean*	*Diff.*	*t-stat*
Dependent Variables								
TFP_{LP}	6.3050	1.0806	4.5112	11.2931	6.2901	6.3006	-0.0105	-0.9912
TFP_{OP}	5.0951	0.9405	2.1331	10.9211	4.9131	5.0031	-0.0900	-0.6824
Independent Variables								
TT	0.1931	0.7237	0	1	-	-	-	-
T	0.2326	0.6325	0	1	-	-	-	-
TT*T	0.1064	0.8648	0	1	-	-	-	-
Mediating Variables								
TI_{P}	3.5843	1.0063	0.4923	6.948	3.1682	3.6248	-0.4566**	-2.9106
TI_{IP}	1.5824	1.2941	0	7.9826	1.5488	1.5951	-0.0463	-0.8241
$TI_{R\&D}$	4.4432	1.5629	1.9263	11.3264	4.3062	4.5321	-0.2259**	-3.0061
Control Variables								
Age	1.0704	1.0203	0.7621	1.3101	1.0641	1.0692	-0.0051*	-3.5162
Size	22.0931	1.6134	16.161	26.5108	21.6225	21.3406	0.2819*	0.7954
Lev	0.5107	0.2106	0.0134	1.6215	0.4918	0.5124	-0.0206**	-4.006
ROA	0.0931	0.0628	-2.9134	0.6208	0.0810	0.0907	-0.0097**	-3.9584
AT	0.3231	0.1238	0.0028	0.8604	0.3214	0.3209	0.0005	1.2643
T_{Q}	1.0631	1.2106	0.6321	4.8231	1.0623	1.0634	-0.0011*	-4.3812
BI	1.1764	0.7912	0	2.07	1.1743	1.1791	-0.0048*	-3.9258
IO	1.3206	0.9214	0.0061	6.25	1.3192	1.3209	-0.0017**	-2.8988
HHI	0.1634	0.6842	0	1	0.1659	0.1631	0.0028***	0.5849

Note: N= Number of observations. SD= Standard Deviation of Variable. Diff= Difference in value of two samples. *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively. HP Firms= Heavily Polluting Firms belonging to 8 heavily polluting industries. TT= Treatment group, T=Time, and TT*T=Treatment × Time

Table 4: Correlation Analysis

Variable	*VIF*	*TT*	*T*	*TI_P*	*TI_{IP}*	*Age*	*Size*	*Lev*	*ROA*	*AT*	*T_Q*	*BI*	*IO*	*HHI*
TT	1.62	1												
T	1.31	0.061*	1											
TI_P	1.21	0.123**	0.236**	1										
TI_{IP}	2.06	-0.308*	-0.005	0.086**	1									
Age	1.41	0.091	-0.067	0.103*	0.135**	1								
Size	1.15	0.086**	0.308**	-0.284**	-0.076	0.216***	1							
Lev	1.52	-0.163*	0.296*	0.316*	0.238**	-0.127**	0.223**	1						
ROA	1.43	0.094**	-0.204*	0.196***	0.306**	-0.164*	-0.031	0.224***	1					
AT	1.28	-0.062	0.168**	0.026	-0.163**	0.006	-0.105**	-0.161**	0.208*	1				
T_Q	2.07	-0.321*	0.283*	0.008	0.106***	-0.226**	0.350***	-0.004	0.003	0.117**	1			
BI	1.36	0.261***	-0.008	0.132**	0.092**	0.131**	0.268**	0.200***	0.001	0.169*	0.306*	1		
IO	2.02	0.208**	-0.206**	-0.246**	0.208**	0.303**	0.091***	0.196*	-0.151*	0.209**	0.219***	0.323**	1	
HHI	1.24	0.192*	0.329***	-0.018**	-0.001	-0.299*	0.111**	0.004	0.166**	-0.126*	0.005	0.003	0.165*	1

Note: *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively

4. RESULTS AND DISCUSSION

4.1. Common Trend Analysis

The DID model is best fit if the trends of the dependent variable for the control and experimental group are parallel in the pre-policy period. A parallel trend analysis was carried out in the current study to obtain distinct results amid experimental and control groups and remove the potential for the pre-existing elements behind carbon emission reduction. We visually checked the parallel trend for the logarithm of the total factor productivity of Chinese firms (Figure 3). Before the implementation of the environmental protection law, the treatment and control groups followed a similar course and did not exhibit a dramatic difference. A parallel trend is visually clear between heavily polluting firms and other firms before 2014, and the parallel-trends assumption is supported through this graphical analysis.

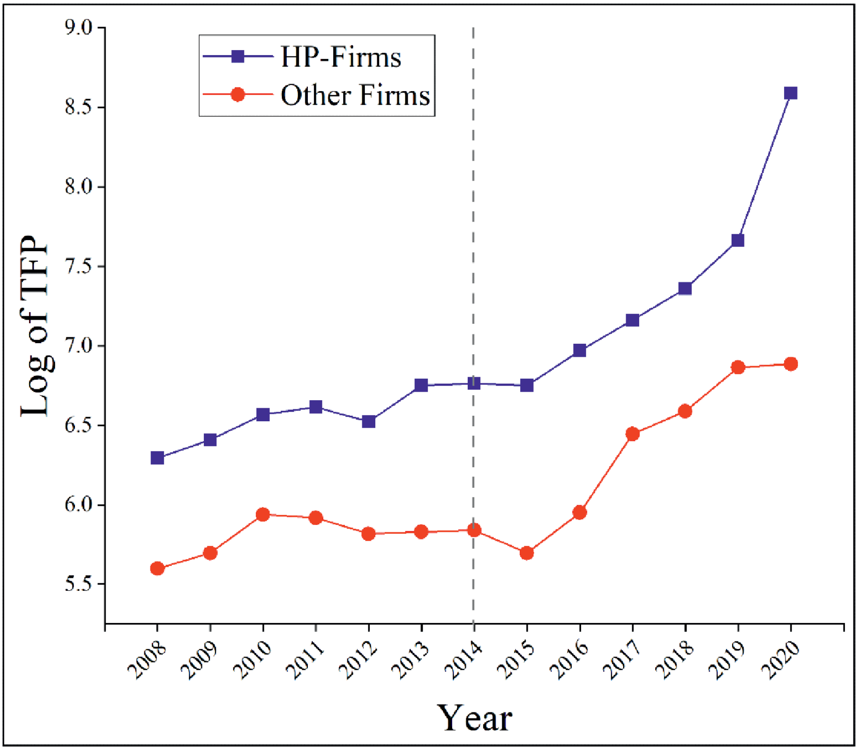

Figure 3: Parallel Trend Analysis of log of TFP for Firms belonging to Heavily Polluting Industries and Other Industries

4.2. Baseline Regression

This study performed an estimation based on equations 1–5, and Table 5 presents the empirical findings for the whole sample. Table 5 reports the direct impact of EPL on firm industrial upgrading, along with the mediating effect of technological innovation (measured by using several total patents and invention patents) for the nexus between EPL and industrial upgrading. The environmental protection law shows a significant positive impact on the firm' TFP (Column-1), suggesting that environmental protection law directly and effectively encourages industrial upgrading of the firms from highly polluting industries. Thus, for full sample analysis, hypothesis 1 is confirmed and supported. These results are in line with the Porter hypothesis, which suggests that more severe environmental regulation may have a positive effect on firms' performance by stimulating innovation (Lanoie *et al.*, 2008). The environmental protection law leads to the upgrading of Chinese firms, as driven by environmental regulations, Materials from social production stream to low-pollution, high-efficiency industries, inspiring high-pollution, and low-efficiency businesses to innovate technologically. This procedure has successfully pushed for increased energy efficiency and savings in businesses, in addition to industrial modernisation and emissions reduction (Li & Liu, 2023). Thus, environmental regulations can lead to industrial upgrading (Franco & Marin, 2017). The environmental protection law also shows a significant positive impact on total patents, suggesting that environmental protection law helps to enhance technological innovation as measured by using several total patents of the polluting enterprises (Column-2). Further, the coefficient of TI_p in column (3), is also positive and significant, indicating the positive mediating effect of technological innovation as measured by using several total patents on the nexus between environmental protection law and firms' industrial upgrading is proved; thus, both hypothesis-2 and hypothesis-3 are also held for full-size sample. This implies that the existence of a positive effect of environmental regulation on total factor productivity indicates that the environmental regulations have sparked enough innovations that the negative effects of end-of-pipe equipment expenditures that are merely ineffective are outweighed (Lanoie *et al.*, 2008). Third, column (4) shows that the coefficient of TT*T is negative and insignificant, and the estimate of technological innovation is positive but significant (column 5). Thus, it is indicated that the mediating effect of technological innovation as calculated by invention patents on the nexus between environmental protection law and firms' industrial upgrading is not true; meaning that both hypothesis-4 and hypothesis-5 are not true for the full-size sample.

Table 5: Baseline Regression Results using the DID Model

Variable	*TFP* (1)	TI_P (2)	*TFP* (3)	TI_{IP} (4)	*TFP* (5)
TT*T	0.8282* (3.9621)	0.0262* (3.6252)	0.8119* (4.0031)	-0.0062 (-0.9919)	0.7971** (2.3213)
TI_P	-	-	0.1628** (2.6959)	-	-
TI_{IP}	-	-	-	-	0.2006*** (3.0031)
Z	Yes	Yes	Yes	Yes	Yes
R^2	0.6945	0.2654	0.7073	0.1288	0.5653

Note: N= 28288 for all regressions. The dependent variable is the logarithm of the total factor productivity of firms. For all the regressions, t-statistics are reported in the parentheses. Z is the vector of the control variable. R^2 is the R-square value of each regression. Moreover, *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively.

4.3. Heterogeneity Analysis at Regional-Level

The findings took into account the mediating function of technical innovation factors provided in Table 5 and separated the whole sample into three groups based on the geographic location's heterogeneity: the eastern, central, and western samples.

4.3.1. DID Analysis with Eastern Regions

The results for the eastern sample considering the mediating role of technological innovation parameters are presented in Table 6. The environmental protection law shows a significant positive impact on the firm' TFP (column-1), thus, the environmental protection law directly and effectively encourages industrial upgrading of the firms from highly polluting industries. Thus, for the eastern sample analysis, hypothesis 1 is confirmed and supported. This effect is clear as businesses in China's eastern coastal regions have both internal incentives for reducing pollution and cutting-edge technology to do it, economic expansion and environmental conservation could initially be achieved concurrently and without conflict (Tan, 2006). Further, environmental protection law shows a significant positive effect on total patents (column 2), suggesting that environmental protection law helps to enhance technological innovation as measured by using several total patents of the polluting enterprises in eastern regions. Further, the coefficient of TI_P in column (3), is also significant and positive, therefore the positive mediating effect of technological innovation as measured by using several total patents on the nexus between environmental protection law and industrial upgrading of firms is confirmed for the eastern sample as well; that is, both hypothesis-2 and hypothesis-3 are also proved for the sample of the eastern region. Third, the coefficient of TT*T is negative and insignificant (column 4), and the estimate of technological innovation is positive (column 5) but insignificant. Thus, it is indicated that the mediating effect of technological innovation as calculated through the total invention patents on the nexus between environmental protection law and industrial upgrading of firms is still not established for the eastern sample; that is, both hypothesis-4 and hypothesis-5 are not proved for the sample of the eastern region.

Table 6: DID Analysis with Eastern Regions

Variable	*TFP* (1)	*TI_P* (2)	*TFP* (3)	*TI_{IP}* (4)	*TFP* (5)
TT*T	0.9106** (3.0064)	0.0621* (3.0062)	0.8251** (2.9656)	-0.0028 (-0.0632)	0.8056* (4.0512)
TI_P	-	-	0.1226* (3.0062)	-	-
TI_{IP}	-	-	-	-	0.3268 (2.9639)
Z	Yes	Yes	Yes	Yes	Yes
R^2	0.7006	0.3165	0.6993	0.2320	0.5429

Note: N= 18062 for all regressions. The dependent variable is the logarithm of the total factor productivity of firms. For all the regressions, t-statistics are reported in the parentheses. Z is the vector of the control variable. R^2 is the R-square value of each regression. Moreover, *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively.

4.3.2. DID Analysis with Central Regions

The results for the central sample considering the mediating role of technological innovation parameters are reported in Table 7. First, the coefficient of TT*T in column (1) is positive and significant, implying that environmental protection law has directly and effectively enhanced the total factor productivity of Chinese firms; that is, hypothesis 1 is supported for the central sample. Second, the coefficient of TT*T in column (2) is positive and significant, and the coefficient of TI_P in column (3) is positive and significant, indicating that technological innovation as measured by a total number of patents exhibits a positive mediating role for the nexus between EPL and industrial upgrading of Chinese firms; thus, both hypothesis-2 and hypothesis-3 are true and held for the sample of the central region. Thirdly, the parameter of TT*T is significantly positive (column-4), and the estimates for TI_{IP} and TT*T are also significantly positive, indicating that the technological innovation as measured by total number of invention patents shows a positive mediating role of technological innovation for the nexus between EPL and industrial upgrading of Chinese firms; therefore, hypothesis-4 and hypothesis-5 are supported for the central sample.

Table 7: DID Analysis with Central Regions

Variable	*TFP* (1)	TI_P (2)	*TFP* (3)	TI_{IP} (4)	*TFP* (5)
TT*T	0.7992* (4.0082)	0.0219*** (2.1008)	0.8208** (3.0638)	0.0904** (3.0010)	0.8054* (3.1452)
TI_P	-	-	0.1463* (3.9928)	-	-
TI_{IP}	-	-	-	-	0.3348* (4.0915)
Z	Yes	Yes	Yes	Yes	Yes
R^2	0.7625	0.1169	0.6558	0.2699	0.70331

Note: N= 6998 for all regressions. The dependent variable is the logarithm of the total factor productivity of firms. For all the regressions, t-statistics are reported in the parentheses. Z is the vector of the control variable. R^2 is the R-square value of each regression. Moreover, *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively.

4.3.3. DID Analysis with Western Regions

Table 8 reports the findings for the western sample taking into account the mediated effect of technological innovation parameters. The environmental protection law shows a significant positive impact on the firm' TFP (column-1), implying that environmental protection law directly and effectively encourages industrial upgrading of the firms from highly polluting industries. Thus, for Western sample analysis, hypothesis 1 is confirmed and supported. The environmental protection law also shows a significant positive effect on total patents (column 2), suggesting that environmental protection law helps to enhance technological innovation as measured by using several total patents of the polluting enterprises in western regions. Further, the coefficient of TI_P in column (3), which represents technological innovation, is positive and significant, thereby, the positive mediating effect of technological innovation as measured by using number of total patents on the nexus between environmental protection law and industrial upgrading of firms is confirmed for the western sample as well; that is, both hypothesis-2 and hypothesis-3 are also proved for the sample of western regions. Third, the coefficient of TT*T is negative and insignificant (column 4), and the estimate of technological innovation is positive, but insignificant (column 5). Thus, it is indicated that the mediating effect of technological innovation as measured by the number of invention patents on the nexus between environmental protection law and firms' industrial upgrading is still not valid for the sample of western regions; that is, both hypothesis-4 and hypothesis-5 are false for the sample of western regions.

Table 8: DID Analysis with Western Regions

Variable	*TFP* (1)	TI_P (2)	*TFP* (3)	TI_{IP} (4)	*TFP* (5)
TT*T	0.8906* (3.2158)	0.0549** (2.0921)	0.8034* (4.001)	-0.0030 (-0.9523)	0.7954** (2.6581)
TI_P	-	-	0.2958* (3.5189)	-	-
TI_{IP}	-	-	-	-	0.2624 (0.8679)
Z	Yes	Yes	Yes	Yes	Yes
R^2	0.7108	0.2957	0.7246	0.1682	0.6003

Note: N= 3228 for all regressions. The dependent variable is the logarithm of the total factor productivity of firms. For all the regressions, t-statistics are reported in the parentheses. Z is the vector of the control variable. R^2 is the R-square value of each regression. Moreover, *, **, and *** represent statistical significance at 1%, 5%, and 10% level respectively.

4.4. Substituting the key-dependent and mediating variable

For the robustness checking, current research has measured the total factor productivity of firms (dependent variable) following the OP method (Olley &

Pakes, 1996), and technological innovation (mediating variable) in the form of expenditures on research and development (Mbanyele & Wang, 2022). Overall, the updated findings after the dependent and mediating factors were changed are essentially similar to the earlier findings, thus reiterating the study's hypotheses.

5. CONCLUSION AND POLICY SUGGESTIONS

By employing the mediating model, this research examined the effects of China's environmental protection laws on the industrial upgrading of Chinese businesses by using the polluting companies as the treatment group, and the other firms as the control group. The analysis was carried out mainly from the mediating role of technological innovation, by taking total patents and invention patents as a proxy for technological innovation. Based on the results of the difference-in-differences model applied to a sample of 247 firms from polluting industries (treatment group) and 1929 firms from other industries (control group) from 2008 to 2020, The conclusions of this study are as follows:

Firstly, the influence of China's new environmental protection legislation, which is partially conveyed through technical innovation, has successfully and immediately increased total factor productivity at the company level in China. Second, the regional level is where the variety of environmental protection legislation impacting total factor productivity is developed. The same as for the entire sample, environmental protection legislation has successfully and directly boosted the industrial upgrading measured in terms of total factor productivity at the business level in the eastern and western regions. Further, the mediated effect of technological innovation as measured by using invention patents is not supported for eastern and western regions, whereas this role was supported for central regions. Finally, the mediated effect of technological innovation as measured by using total patents was fully supported for all regions. Concluding this, our data confirm the Porter hypothesis that environmental regulation greatly raises enterprises' total factor productivity (TFP), a finding that holds up even after a battery of robustness tests.

In light of public environmental regulations, our study helps to clarify the prerequisites for business industrial upgrading. This research carefully analyses the effect of environmental regulation on enterprises' TFP and presents China's micro evidence for the Porter hypothesis in light of the ongoing discussion in academic circles regarding whether the Porter hypothesis is accurate. In addition to its academic contribution, our study offers China and other developing nations useful practical advice. First, the central government should develop stringent, reasonable, and flexible environmental regulating laws, keeping in mind that there is still much potential for improvement in industrial upgrading. To successfully minimise pollution emissions and promote industrial upgrades, the government may expand the environmental protection regulations to other areas. The results of the mediating effect of technological innovation suggest that the government should provide businesses with technical innovation incentives and actively advise them at the technological level if it hopes to increase corporate productivity and industrial upgrading. This would be considerably more successful than using government incentives to encourage businesses to create and pollute simultaneously.

While our findings have the potential to capture the interest of scholars in fields as diverse as management, economics, and environmental research, we must admit that they are not without constraints. To begin, the paper's examination of heterogeneity is not thorough; future studies may begin with a higher degree of heterogeneity. Second, the article can only get data on listed firms due to data availability, although the data might not be the most comprehensive. While listed firms are often bigger organisations and small companies are overlooked in this process, environmental protection legislation applies to all businesses in sectors with high levels of pollution. In the future, we may include additional data from Chinese industrial businesses to reach more general and accepted findings.

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