Fuel Cells Bulletin
ISSN: 1464-2859

The Impact of Environmental Pollution Liability Insurance on Firms' Green Total Factor Productivity: Evidence from China

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Abstract: Improving green total factor productivity (GTFP) is crucial for firms to enhance competitiveness and sustainable development capacity. Environmental pollution liability insurance (EPLI) facilitates firms better manage environmental risks and encourages firms to enhance GTFP. This study examines the impact of EPLI coverage on GTFP using data from Chinese heavy-polluting firms. Results show that EPLI enhances GTFP, with the effect persisting over time. Further mechanisms study suggests that EPLI enhances GTFP through external stakeholders' pressure and internal incentive mechanisms. Finally, the magnitude of EPLI's impact depends on the quality of firms' human capital.

Keywords: environmental pollution liability insurance; green total factor productivity; stakeholders' pressure; incentive mechanism; human capital

1. Introduction

Green total factor productivity (GTFP hereafter) is an indicator used to assess firms' economic development efficiency by incorporating resource consumption and pollution emission constraints into the measurement of total factor productivity (TFP hereafter) [1, 2]. Compared to TFP, GTFP integrates both economic and environmental benefits, which aligns more closely with the principles of sustainable and green development. Firms with higher GTFP operate with a more efficient and environmentally friendly production and operational practices, thereby enhancing its competitiveness.

Existing studies centred around GTFP take the perspective of green innovation (GI hereafter), human capital, market environment, and environmental regulations[1, 3]. GI focuses on developing environmentally friendly technologies and products that contribute to both firm and environmental sustainability, which not only generates economic value but also reduces firms' resource consumption and environmental costs, thereby further improving GTFP[4].High-quality human capital facilitates the learning or development of clean technologies and improve environmental management practices, thereby enhancing firms' operational efficiency, strengthening their competitiveness, and ultimately increasing GTFP[5, 6]. Moreover, the market environment also has a significant impact on GTFP[7]. A favourable market environment helps firms secure financial support and optimize resource allocation, thus enhancing GTFP. Additionally, environmental regulation can guide firms to adopt cleaner production practices, thereby enhancing economic sustainability [8].

However, limited research discusses GTFP from an environmental risk management perspective. As a risk management tool, environmental pollution liability insurance (EPLI hereafter) directly impacts firms by providing risk protection for their production. EPLI not only equips firms with environmental risk management experience and reduces operational risks but also indirectly encourages them to focus on cleaner production. EPLI and GTFP have a complex association. Intuitively, EPLI could incur two opposite effects on GTFP. On the one hand, EPLI brings moral hazards, and firms with EPLI coverage may be less likely to increasing GTFP [9]. The compliance cost brought by EPLI may also reduce GTFP, which would crowd out the investment in enhancing GTFP. On the other hand, EPLI enhances the stability of firms' production and R&D activities by covering potential compensation for environmental liabilities[8]. Moreover, EPLI coverage is regarded as a positive signal to the market, attracting additional financing and generating resource

effects, enhancing GTFP[10].Theoretically, examining whether the positive impact of EPLI on GTFP outweighs its negative impact or *vice versa* is complicated. Hence, this question should be studied empirically.

This study examines the impact of EPLI on GTFP using firm-level data from the China Stock Market &Accounting Research (CSMAR) database from 2013 to 2019. In 2013, the Chinese Ministry of Ecology and Environment issued the 'Guidance on the Pilot Work for Mandatory Environmental Pollution Liability Insurance', explicitly encouraging firms with high-pollution risks to be covered by EPLI. The study shows that EPLI coverage enhances GTFP significantly. EPLI coverage has a long-term positive impact on GTFP. Further, this study finds that external stakeholder pressure, internal incentive mechanisms and firms' human quality are the important mechanisms governing the impact of EPLI on firms' GTFP.

The study contributes to the literature in the following manner. First, existing studies on GTFP have primarily focused on commonly environmental regulations. This study focuses on the impact of EPLI on GTFP. Second, the literature mainly focuses on the influence mechanisms of environmental regulations on GTFP from the perspective of green innovation (GI hereafter) and financing constraints. This study offers new mechanisms of EPLI's influence on GTFP. Third, this study uses evidence from China, which extends the study for future EPLI optimization in developing countries.

2. Literature Review

The underlying potential indirect associations between EPLI and GTFP demonstrate mixed patterns.

Theoretically, EPLI may potentially enhance GTFP. EPLI coverage can improve firms' cash flow conditions, primarily through two channels. First, EPLI provides coverage or partial coverage for environmental pollution liabilities when firms experience contractually stipulated pollution incidents, thereby mitigating the operational impact and enhancing firms' sustainability [11, 12]. Second, EPLI serves as a positive signal to the market, alleviating the problem of information asymmetry in the investment market [13]. Firms covered by EPLI may obtain more favourable financing conditions and attract long-term investors.

The improvement of a firm's financial situation contributes to enhancing GTFP[14]. On the one hand, the capital inflow indirectly brought by EPLI provides firms with additional funds to acquire clean technologies and equipment, thereby improving resource utilization efficiency and reducing environmental pollution [15]. On the other hand, the capital inflow increases firms' R&D investment. Long-term investor participation also mitigates managerial short-termism and encourage firms to engage in R&D activities. When firms enhance production technology and optimize production methods through GI [8], production efficiency and resource utilization efficiency improve, leading to lower input requirements for the same output level, which means higher GTFP. Moreover, when firms improve product design and develop greener products via GI, product differentiation and the positive external image established by firms reduce risks in the sales process and strengthen their market competitiveness, enabling them to gain a larger market share and achieve higher expected output, thereby increasing GTFP [2, 8, 16].

However, EPLI may also exert a negative impact on GTFP [14]. First, EPLI directly increases costs. On the one hand, firms must pay high insurance premiums to obtain EPLI coverage. On the other hand, when applying for EPLI, insurers set certain conditions, such as requiring firms to rectify environmental safety hazards, which incurs compliance costs. These extra costs may crowd out investments in advanced technologies and clean equipment, thereby reducing GTFP. Second, the potential moral hazard associated with EPLI may weaken firms' motivation to proactively optimize their production methods, which may reduce GTFP [9].

In summary, the literature has focused on how internal factors and external environmental conditions affect firms' GTFP, specifically environmental regulation. As an effective risk management tool, EPLI may have a complex impact on GTFP. However, existing studies has rarely quantified this association and lacks an in-depth exploration of the mechanisms. This study quantitatively examines this association using empirical evidence from China. Further, this study explores the mechanisms of potential associations between EPLI and GTFP, aside from GI and financing constraints.

3. Data and Empirical Strategy

3.1 Data

This study uses three data sources. First, the firm-level data and macro-level data is drawn from the CSMAR and WIND from 2013 to 2019. Specifically, the data of 2013 is used as the base period for calculating GTFP. Second, this study collects the industrial-level EPLI-eligibility data using the information from the policy document 'Guiding Opinions on Pilot Work for Environmental Pollution Liability Insurance'. Third, EPLI coverage data is drawn from the list of insured firms published by MEE for 2014 and 2015. This study excludes firms classified as ST and *ST, suspended from trading, delisted, newly listed in the current year or with missing values in core variables. This study winsorises all continuous variables at the 1st and 99th percentiles to eliminate the impact of outliers. Finally, a sample of 1,120 firm-year observations is obtained, with 300 observations covered by EPLI.

3.2 Variables

Dependent variable: The core dependent variable is GTFP. The directional distance function is a method for measuring GTFP. The traditional directional distance function is a radical and oriented approach, which may lead to significant bias in the calculated results. On the one hand, if slack variables exist, the radial nature of the production function may result in an overestimation of GTFP [17]. On the other hand, the oriented nature of the production function fails to account for non-proportional changes in both inputs and outputs simultaneously. Therefore, we use the global Malmquist–Luenberger index of the slacks-based measure directional distance function to calculate GTFP [18, 19]. The technical details can be found in the online appendix.

Explanatory variable: EPLI is a dummy variable indicating whether a firm is covered by EPLI (Ins) or not. If a listed firm or its subsidiary is covered by EPLI in the current year, Ins is assigned a value of 1 and 0 if otherwise.

Control variables: Following the literature, we introduce a number of control variables to capture firm-level heterogeneities: asset–liability ratio ($Aslbrt$), represented as the ratio of liabilities to assets; years since establishment (Age), calculated as the current year minus the year of firm establishment; current ratio ($Curtrt$), represented as the ratio of current assets to liabilities; largest shareholder ownership percentage ($Lrghldrt$); return on assets (Roa), represented as the ratio of the current-year net profit to total assets; cash holdings ($Cash$), represented as the proportion of cash and cash equivalents to total assets; capital expenditure (Cap), represented as the proportion of cash spent on acquiring fixed, intangible and other long-term assets to total assets; a dummy variable losses in profit ($Loss$), assigned a value of 1 if a company's net profit is negative in the current year and 0 if otherwise; independent director proportion (Id), represented as the proportion of independent directors to the total number of directors; and regional financial development index ($Fina$), represented as the ratio of the RMB loan and deposit balances of financial institutions to the province's GDP.

3.3 Descriptive Statistics

Table 1 presents the descriptive statistics of the abovementioned variables conditional on EPLI coverage status. Table 1 shows that the mean GTFP of firms covered by EPLI is 1.0092, whereas it is 1.0003 for uncovered firms. In the T + 1 period, the mean GTFP of firms covered by EPLI is 1.0194, whereas that for firms not covered by EPLI is 1.0005. In the T + 2 period, the mean GTFP for firms with EPLI coverage is 1.0198, significantly higher than that of 1.0006 for firms without EPLI coverage. Overall, firms with EPLI have higher GTFP compared with those without.

Table 1. Descriptive Statistics

Variable	Not insured EPLI		Insured EPLI		Mean T-test
	Mean	Standard deviation	Mean	Standard deviation	
$GTFP_t$	1.0003	0.0033	1.0092	0.0343	-0.0088***
$GTFP_{t+1}$	1.0005	0.0052	1.0194	0.0558	-0.0189***
$GTFP_{t+2}$	1.0006	0.0065	1.0198	0.0576	-0.0192***
$GTFP_{t+3}$	1.0007	0.0075	1.0162	0.0255	-0.0154***

$GTFP_{t+4}$	1.0007	0.0094	1.0032	0.0200	-0.0026***
$Aslbrt$	0.4267	0.2110	0.4810	0.1851	-0.0543***
Age	17.3152	4.5230	17.0167	3.9836	0.2985
$Curtrt$	2.2649	2.5339	1.4007	1.2467	0.8642***
$Lrghldrt$	36.1772	14.7734	40.5995	17.6199	-4.4223***
Roa	0.0347	0.0570	0.0263	0.0449	0.0084**
$Cash$	0.1471	0.0995	0.1175	0.0894	0.0296***
Cap	0.0502	0.0426	0.0588	0.0364	-0.0085***
$Loss$	0.1321	0.3388	0.1400	0.3476	-0.0079
Id	0.4343	0.0820	0.4246	0.0712	0.0097*
$Fina$	3.3947	1.2840	3.0391	0.7657	0.3556***
N	1120		300		-

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively. $GTFP_t$, $GTFP_{t+1}$, $GTFP_{t+2}$, $GTFP_{t+3}$, and $GTFP_{t+4}$ represent GTFP for the T, T + 1 ,T + 2, T + 3, and T + 4 periods, respectively. $Aslbrt$ represents asset–liability ratio. Age represents the number of years in operation. $Curtrt$ represents current ratio. $Lrghldrt$ represents largest shareholder ownership percentage. Roa represents return on assets. $Cash$ represents cash holdings. Cap represents capital expenditure. $Loss$ represents losses in profit. Id represents proportion of independent directors. $Fina$ represents regional financial development index.

3.4 Empirical Strategy

We estimate the following model in Eq. (1).

$$GTFP_{kd(t+h)} = \beta_0 + \beta_1 \times Ins_{kdt} + \boldsymbol{X}_{\boldsymbol{kdt}}^{'}\boldsymbol{\gamma} + \boldsymbol{\theta_d} + \boldsymbol{\lambda_t} + \varepsilon_{kd(t+h)}, \quad (1)$$

where $GTFP_{kd(t+h)}$ represents GTFP of the i-th firm in the d-th industry in the year $t+h$, where $h \in \{0, 1, 2, 3, 4\}$. This study considers not only the effects of EPLI on GTFP in period T but also its effects in the long term. There are two reasons why we also consider the effects in the long term. First, firms can allocate the funds indirectly obtained through EPLI to purchase clean facilities and enhance clean production capacity, which may have a sustained impact on GTFP over several years. Second, the effect of GI on GTFP may exhibit a lag. Therefore, the dependent variable includes firms' GTFP in the T ($h = 0$), T + 1 ($h = 1$), T + 2 ($h = 2$), T + 3 ($h = 3$), and T + 4 ($h = 4$) periods. Ins_{idt} represents whether the firm has purchased EPLI or not. $\boldsymbol{X_{idt}}$ denotes the vector of covariates mentioned in Section 3.2. We also controlled for industrial fixed effects $\boldsymbol{\theta_d}$ and year fixed effects $\boldsymbol{\lambda_t}$ to capture cross-industry and cross-year heterogeneities, respectively. The error term $\varepsilon_{id(t+h)}$ absorbs other idiosyncratic shocks; we consider heteroscedasticity and clustered robust standard errors to capture the correlation structure within this term.

4. Empirical Results

4.1 Baseline Regression Results

Table 2 reports the estimated impact of EPLI on GTFP using model (1). Columns (1)-(5) show the results using GTFP as the dependent variable for the T, T + 1 , T + 2, T + 3, and T + 4 periods, respectively. This study considered the results for the lagged effects to examine whether EPLI has a persistent or temporary effect. Column (1) indicates that, EPLI has a significant positive effect on GTFP in the current period. Investing in EPLI is associated with a 0.0063

higher GTFP, which is significant at the 1% level. Meanwhile, the results in columns (2)-(5) indicate that EPLI coverage has a significant positive impact on GTFP in the T, T + 1, T + 2, T + 3, and T + 4 periods, suggesting that EPLI has a long-lasting positive effect on firms' GTFP. The overall results imply that, although EPLI coverage may incur high premiums, compliance costs and potential moral hazard, the positive effects of EPLI coverage outweigh the negative ones.

The persistence primarily stems from two aspects. First, EPLI has a strong inertia effect in directly enhancing firms' environmental awareness and environmental management capabilities. Moreover, firms can utilize the financial resources indirectly brought by EPLI coverage to purchase clean facilities and upgrade production methods, thereby achieving cleaner production, which may have a lasting impact. Second, innovative activities are highly uncertain, and there is a time lag between the initiation of research and development and the achievement of tangible outcomes. Additionally, the application of GI to production activities and the subsequent realization of returns also exhibit a time lag.

Table 2. Baseline Regression Results: Heteroscedasticity-Robust Standard Errors

Variable	(1) $GTFP_t$	(2) $GTFP_{t+1}$	(3) $GTFP_{t+2}$	(4) $GTFP_{t+3}$	(5) $GTFP_{t+4}$
Ins	0.0063***	0.0122***	0.0121***	0.0135***	0.0033***
	(5.05)	(6.64)	(6.64)	(15.07)	(3.15)
$Aslbrt$	-0.0048***	-0.0051*	-0.0034	0.0026*	0.0004
	(-2.70)	(-1.75)	(-1.14)	(1.69)	(0.22)
Age	0.0002***	0.0002**	0.0002**	0.0000	0.0001*
	(3.03)	(2.52)	(2.11)	(0.02)	(1.84)
$Curtrt$	-0.0001	0.0002	0.0003*	0.0002*	0.0001
	(-0.64)	(1.33)	(1.95)	(1.88)	(0.79)
$Lrghldrt$	0.0002***	0.0005***	0.0005***	0.0001***	0.0000
	(5.16)	(7.34)	(7.20)	(3.75)	(1.39)
Roa	-0.0165**	-0.0081	-0.0024	0.0124*	-0.0036
	(-2.49)	(-0.72)	(-0.21)	(1.80)	(-0.42)
$Cash$	-0.0074***	-0.0262***	-0.0302***	-0.0124***	-0.0061**
	(-2.65)	(-5.12)	(-5.27)	(-3.70)	(-2.01)
Cap	0.0233***	0.0479***	0.0546***	0.0222***	0.0176***
	(3.87)	(4.50)	(4.83)	(3.53)	(2.77)
$Loss$	-0.0046***	-0.0083***	-0.0084***	-0.0031***	-0.0032**
	(-3.99)	(-4.35)	(-4.34)	(-2.98)	(-2.32)
Id	0.0014	0.0035	0.0053	-0.0011	-0.0121**
	(0.48)	(0.62)	(0.88)	(-0.33)	(-2.45)
$Fina$	0.0004	0.0000	-0.0002	-0.0003	0.0004
	(1.13)	(0.02)	(-0.39)	(-0.81)	(1.22)
$Constant$	0.9986***	1.0063***	1.0061***	1.0012***	0.9959***

	(416.59)	(214.46)	(207.96)	(381.98)	(449.40)
N	1420	1420	1420	1420	1420
R^2	0.191	0.310	0.295	0.243	0.075

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively. T value is reported in parentheses. $Aslbrt$ represents asset–liability ratio. Age represents the number of years in operation. $Curtrt$ represents the current ratio. $Lrghldrt$ represents largest shareholder ownership percentage. Roa represents return on assets. $Cash$ represents cash holdings. Cap represents capital expenditure. $Bsize$ represents board size. $Loss$ represents losses in profit. Id represents independent director proportion. $Fina$ represents regional financial development index. Columns (1)–(5) respectively present the results controlling for year and industrial fixed effects with GTFP as the dependent variable for the T, T + 1, T + 2, T + 3, and T + 4 periods, reporting the heteroscedasticity-robust standard errors.

4.2 Endogeneity Check: IV Regression Analysis

A potential threat to the baseline model is the issue of endogeneity. Potential reverse causality may bias the estimation results, as a higher GTFP may indicate that firms place greater emphasis on clean production and environmental management, making them more likely to apply for EPLI coverage. Additionally, omitted variable bias may also affect the estimation results. Therefore, this study proposes and conducts an instrumental variable (IV) analysis to examine and address potential endogeneity issues.

This study constructs the IV by calculating the annual participation rate of EPLI in the province where the firm is located [14]. First, the IV reflects the extent of EPLI adoption in the province. A higher annual participation rate indicates greater promotion efforts and a higher level of adoption. Given that firms are more likely to purchase EPLI, the IV satisfies the relevance assumption. Second, EPLI is an exclusive product that cannot be shared among firms. Therefore, the IV affects a firm's level of GTFP only through its insurance participation decision and has no direct impact on GTFP, thus satisfying the exclusion restriction assumption. Overall, the relevance and exogeneity assumptions of the IV are highly likely to hold. In the following IV regression results, this study reports relevant test statistics, and the IV satisfies these assumptions.

This study employs the two-stage least squares (2SLS) estimation process by instrumenting the potential endogenous variable Ins_{idt} using the annual EPLI participation rates as the IV. The F-values in the first stage are much greater than 10, with p-values of 0.00, indicating that the IV satisfies the relevance assumption. The p-values of the Kleibergen–Paap LM statistic for the overidentification test are 0.00, strongly rejecting the null hypothesis of under-identification. The Cragg-Donald Wald F-statistics are all above the 10% critical value, indicating that the weak instrument issue does not exist.

The results in Table 3 shows that EPLI coverage still has a positive and significant impact on GTFP in all periods even after considering potential endogeneity issues. Notably, the significance levels decrease because the 2SLS process has employed part of the information in Ins_{idt} projected on the IV. However, the economic and statistical significance of the estimates are retained.

Table 3. Robustness Check: IV Regression Results

Variable	(1) $GTFP_t$	(2) $GTFP_{t+1}$	(3) $GTFP_{t+2}$	(4) $GTFP_{t+3}$	(5) $GTFP_{t+4}$
Ins	0.0102***	0.0131***	0.0120***	0.0090***	0.0049**
	(3.49)	(3.44)	(3.18)	(6.25)	(2.49)
$Control$	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes

N	1420	1420	1420	1420	1420
R^2	0.183	0.310	0.295	0.229	0.073

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively, when heteroscedasticity-robust standard errors are employed. T value is reported in parentheses. Columns (1)–(5) present the IV regression results controlling for year and industrial fixed effects, which use the regional level EPLI adoption rates as the IV, with GTFP for the T, T + 1, T + 2, T + 3, and T + 4 periods as the dependent variables and EPLI as the explanatory variable. The control variables are the same as those in Table 2.

In addition to the IV results, this study considers the potential role of other confounding factors. The model results remain robust to changes in the addition of control variables. For example, in the online appendix, this study has conducted additional analyses by adding firm fixed effects and lagging the control variables by one period. All results are comparable with the main results.

5. Mechanisms

The regression results show that EPLI has a significant, persistent impact on GTFP. This section delves into the potential mechanisms that could explain how EPLI coverage can be translated into increased GTFP. This study proposes the following mechanisms: stakeholders' pressure, incentive mechanism, and human capital.

5.1 Stakeholders' Pressure

Existing studies have shown that pressure from stakeholders compels firms to weigh the consequences of their environmental pollution behaviours [14]. In the investment market, investors exhibit lower confidence in highly polluting firms, particularly those penalized for environmental violations, leading to lower valuations for such firms. In contrast, firms with strong environmental performance and those committed to clean production tend to inspire greater investor confidence and receive higher valuations. The stakeholders' pressure incentivizes firms to proactively enhance GTFP, thereby achieving better market performance.

EPLI enhances stakeholder supervision. On the one hand, insurers commission experts or relevant institutions to conduct environmental risk assessments and perform regular inspections of firms' environmental safety hazards. This serves as a market-based supervisory mechanism, reducing information asymmetry between stakeholders and firms. On the other hand, after applying for EPLI, firms' misconduct, such as illegal emissions or environmental pollution incidents, becomes more likely to be exposed due to the supervisory role of EPLI.

This study constructs a dummy variable to measure stakeholders' pressure: $Media$. If the number of media reports on a firm in a given year exceeds the sample median, the firm is considered to face higher stakeholders' pressure and $Media$ is assigned a value of 1; otherwise, the firm is considered to face lower stakeholders' pressure and $Media$ is assigned a value of 0. To test this mechanism, this study interacts $Media$ with EPLI and estimate the modified model (1) with the interaction term.

Table 4 presents the results. The interaction term coefficients in Column (1)-(5) are all positive and statistically significant at the 1% level, indicating that firms facing higher stakeholders' pressure benefits more from the EPLI coverage. In addition, the effects persist for the five-year period. The results confirm the expectation that firms' stakeholders' pressure strengthens the influence of EPLI on GTFP.

Table 4. Mechanisms: Stakeholders' Pressure

Variable	(1) $GTFP_t$	(2) $GTFP_{t+1}$	(3) $GTFP_{t+2}$	(4) $GTFP_{t+3}$	(5) $GTFP_{t+4}$
Ins	-0.0003	-0.0011	-0.0014	0.0091***	0.0001
	(-0.43)	(-0.93)	(-1.19)	(19.91)	(0.11)

$Ins * Media$	0.0111***	0.0223***	0.0228***	0.0074***	0.0054***
	(5.07)	(6.76)	(6.77)	(4.32)	(3.06)
$Control$	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes
N	1420	1420	1420	1420	1420
R^2	0.211	0.338	0.323	0.254	0.084

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively, when heteroscedasticity-robust standard errors are employed. T value is reported in parentheses. Columns (1)–(5) present the regression results controlling for year and industrial fixed effects, with GTFP for the T, T + 1, T + 2, T + 3, and T + 4 periods as the dependent variables and EPLI as the explanatory variable. The control variables are the same as those in Table 2.

5.2 Internal Incentive

Adjustments in firm strategy and culture influence firms' production. When environmental responsibility is given greater priority in strategic planning, firms are more likely to proactively enhance GTFP. It not only enables firms to meet environmental regulations but also allows their products to be labelled as "green" or "environmentally friendly", proving firms with a competitive edge in the product market and helping them secure a larger market share. Moreover, positive feedback from the market further incentivizes firms to invest in clean facilities or technologies and engage in GI activities, ultimately enhancing GTFP.

EPLI coverage enhances firms' environmental awareness, thereby increasing GTFP. On the one hand, EPLI strengthens firms' recognition of environmental risks. Through the environmental assessments and periodic inspections conducted by insurers, firms gain a clearer understanding of pollution risks and environmental management shortcomings. On the other hand, EPLI premiums are typically variable, with specific rates influenced by firms' environmental performance. Under the incentive of insurance premiums, firms are motivated to place greater emphasis on environmental protection.

This study constructs a dummy variable to measure stakeholders' pressure: $Salary$. If the compensation level of the top three executives in a firm exceeds the sample median in a given year, the firm is considered to have a higher level of internal incentives and $Salary$ is assigned a value of 1; otherwise, the firm is considered to have a lower level of internal incentives and $Salary$ is assigned a value of 0. To test this mechanism, this study interacts $Salary$ with EPLI and estimate the modified model (1) with the interaction term.

Table 5 presents the results. The interaction term coefficients in Column (1)-(5) are all positive and statistically significant at the 1% level, indicating that firms having a higher level of internal incentives benefits more from the EPLI coverage. In addition, the effects persist for the five-year period. The results confirm the expectation that the internal incentives strengthen the influence of EPLI on GTFP.

Table 5. Mechanisms: Internal Incentive

Variable	**(1)** $GTFP_t$	**(2)** $GTFP_{t+1}$	**(3)** $GTFP_{t+2}$	**(4)** $GTFP_{t+3}$	**(5)** $GTFP_{t+4}$
Ins	0.0017**	0.0004	-0.0002	0.0096***	0.0011*
	(2.49)	(0.35)	(-0.17)	(16.47)	(1.68)
$Ins * Salary$	0.0083***	0.0210***	0.0221***	0.0069***	0.0037**
	(3.75)	(6.03)	(6.05)	(3.66)	(2.12)

$Control$	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes
N	1420	1420	1420	1420	1420
R^2	0.202	0.335	0.321	0.254	0.080

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively, when heteroscedasticity-robust standard errors are employed. T value is reported in parentheses. Columns (1)–(5) present the regression results controlling for year and industrial fixed effects, with GTFP for the T, T + 1, T + 2, T + 3, and T + 4 periods as the dependent variables and EPLI as the explanatory variable. The control variables are the same as those in Table 2.

5.3 Human Capital

Existing studies have confirmed that human capital is one of the key factors influencing firms' GTFP. Human capital plays a moderating role in the impact of EPLI. On the one hand, high-quality human capital possesses strong technical and innovative capabilities, which enable firms to efficiently utilize the resource effects brought by EPLI. This includes effectively assimilating introduced clean technologies, utilizing newly purchased equipment, and conducting GI activities, all of which contribute to the increasement of GTFP.

On the other hand, high-quality human capital has superior strategic planning and execution capabilities, allowing firms to integrate the environmental risk management techniques and sustainability concepts associated with EPLI into their daily operations and long-term strategies. Through scientific management and efficient execution, firms can achieve optimal resource allocation, thereby enhancing GTFP. Additionally, highly skilled human capital is more likely to understand and support the use of tools such as EPLI for environmental risk management. They also advocate for and promote the establishment of a green culture focusing on environmental protection and sustainable development, raising employees' environmental awareness and sense of social responsibility. This, in turn, motivates employees to adopt proactive environmental protection measures in their work, further enhancing GTFP.

Moreover, high-quality human capital contributes to improving cross-departmental collaboration efficiency. Green projects often require the integration of knowledge and resources from multiple domains, making cross-departmental coordination crucial to their success. The implementation of EPLI initiatives also relies on effective collaboration across different departments. Skilled human capital can ensure smooth information flow and rational resource allocation, thereby enhancing internal coordination efficiency and facilitating the successful execution of green projects and EPLI initiatives, ultimately enhancing' GTFP.

This study uses the proportion of employees with a postgraduate degree or higher in the total number of employees (Hum) to measure the quality of the human capital. Then, this study centralises the measure using the respective firm-level averages. Larger value for the measure indicates that firms have a higher quality of the human capital. Finally, this study interacts Hum with EPLI and estimate the modified model (1) with these interaction terms.

Table 6 presents the results. The interaction term coefficients in Column (1)-(4) are all positive and statistically significant at the 1% level, indicating that firms having a higher quality of the human capital benefits more from the EPLI coverage. In addition, the effects persist for the four-year period. The results confirm the expectation that the human capital strengthens the influence of EPLI on GTFP.

Table 6 Mechanisms: Human Capital

Variable	**(1)** $GTFP_t$	**(2)** $GTFP_{t+1}$	**(3)** $GTFP_{t+2}$	**(4)** $GTFP_{t+3}$	**(5)** $GTFP_{t+4}$
Ins	0.0077***	0.0156***	0.0157***	0.0145***	0.0033***
	(4.74)	(6.13)	(6.14)	(12.24)	(2.97)

$Ins * Hum$	0.0042***	0.0102***	0.0106***	0.0028***	0.0001
	(3.29)	(4.53)	(4.58)	(2.75)	(0.25)
$Control$	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes
N	1420	1420	1420	1420	1420
R^2	0.226	0.389	0.376	0.270	0.077

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels, respectively, when heteroscedasticity-robust standard errors are employed. T value is reported in parentheses. Columns (1)–(5) present the regression results controlling for year and industrial fixed effects, with GTFP for the T, T + 1, T + 2, T + 3, and T + 4 periods as the dependent variables and EPLI as the explanatory variable. The control variables are the same as those in Table 2.

4. Conclusion

This study examines the impact of firms' EPLI adoption on GTFP processes using evidence from firm-level data from China. This study employs the slacks-based measure directional distance function to calculate GTFP for Chinese firms using CSMAR data and WIND data from 2013 to 2019. The empirical results show that firms' EPLI coverage significantly enhances GTFP, with the effect persisting over five years. The study further examines the mechanisms through which EPLI produces this effect. The results of mechanisms suggest that, first, EPLI influences GTFP through external pressure. The greater the pressure a firm faces from stakeholders, the more pronounced the positive effect of EPLI on GTFP. Second, EPLI affects GTFP through internal incentives. The internal incentives strengthen the influence of EPLI on GTFP. Third, the quality of a firm's human capital also affects the relationship between EPLI coverage and GTFP. Firms with higher human capital quality are more likely to be affected by EPLI coverage.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, author-ship, and/or publication of this article.

Data Sharing Agreement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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