# The Impact of Integration of Environmental Protection Policy on FIRM's Green Innovation

## A Quasi-natural Experiment Based on China's Shenzhen-Dongguan-Huizhou Economic Circle

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**Abstract.** Based on the characteristic data, green patent data, and industrial chain connection data of China's A-share listed companies from 2006 to 2019, for the first time, we use the multi-dimensional fixed-effect difference-in-differences (DID) model to empirically examine the impact and mechanism of the integration of environmental protection policy (IEPP)-Shenzhen-Dongguan-Huizhou economic circle (SDHEC) on corporate green innovation from the perspective of industrial chain linkages. Our research found that, IEPP-SDHEC implementation has a positive impact on green innovation of listed companies in the jurisdiction. In addition, we use the industry chain forward link production length and position index to investigate its mechanism. It proves that the climbing effect of the industrial chain is an important mechanism for IEPP-SDHEC to enhance the green innovation of enterprises.

**Keywords:** Integration of environmental protection policy (IEPP) · Shenzhen-Dongguan-Huizhou economic circle (SDHEC) · Industrial chain · difference-in-differences (DID) · green innovation · listed companies

## 1 Introduction

Resource and environmental issues have become an important constraint restricting China's economic growth, and the issue of green and sustainable development is imminent [1]. The 19th National Congress of the Communist Party of China proposed: "China's economy has shifted from a stage of high-speed growth to a stage of high-quality development and is in a critical period of transforming its development mode, optimizing its economic structure, and transforming its growth drivers." To this end, the Chinese government has made many policy attempts. Among them, Integration of environmental protection policy (IEPP) is an important policy tool for China's cross-regional environmental protection collaborative governance which is an important measure for urban agglomerations to deal with cross-regional environmental pollution. However, the


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existing literature lacks research on the policy effects of IEPP, especially the application of causal identification techniques to examine IEPP on corporate green innovation.

In addition, the cross-regional environmental protection technology and industry synergy in the metropolitan circle's environmental protection cooperation will have a positive impact on the level of enterprises in the jurisdiction participating in the global value chain. Existing research shows that the rise of GVC embedding position significantly promotes the green innovation performance of enterprises [2, 3]. Therefore, in theory, IEPP may achieve corporate green innovation by improving the embedded position of corporate GVC. However, the existing research lacks discussions on how IEPP can stimulate green innovation of enterprises through mechanisms such as industrial chain climbing.

Based on the above discussion, we introduce the Shenzhen-Dongguan-Huizhou Economic Circle (SDHEC), which has already carried out IEPP, as the space research object. By using multi-dimensional fixed effects DID and other quantitative estimation methods, this paper investigates the impact of China's IEPP on enterprise green innovation.

## 2 Literature

### 2.1 Integration of Environmental Protection Policy and Firms' Green Innovation

In theory, IEPP, like other environmental protection policies, is a government-led corporate environmental behavior intervention policy. According to previous studies on environmental regulation and corporate green innovation, environmental regulation policies will have a positive impact on corporate green production [4, 5]. That is, under the pressure of environmental protection policies, enterprises will be forced or actively engaged in green innovation activities to cope with the pressure or increase monopoly profits. IEPP is a multi-city environmental protection collaborative governance policy in the economic circle. Compared with traditional environmental policies, it has the characteristics of multi-government entities and cross-administrative regions. Therefore, compared with traditional environmental policies, it will bring more complex supervision to polluting enterprises, and will inevitably face cross-regional management from multiple government management departments. Therefore, logically, we propose key hypotheses for this study:

***H1****: IEPP will have a positive impact on corporate green innovation.*

### 2.2 Mechanistic Role of Industrial Chain Linkage

IEPP-SDMEC clearly proposes cross-regional environmental protection technology sharing and industry collaborative governance. It means that SDHM links cross-regional environmental collaborative governance with cross-regional industrial collaboration, which makes Shenzhen, Dongguan, and Huizhou increase regional industrial synergy in the process of environmental governance, and accelerates the renewal and elimination of the industrial chain, while the renewal and elimination of the industrial chain, or the adjustment direction, is to adjust in the direction of green and sustainable. This adjustment logic is in line with the green requirements of international competition for local

enterprises, and therefore helps local enterprises to embed themselves further upstream in the global industrial chain and value chain. Previous studies have confirmed that the embedding of developing countries in global value chains significantly improves the green technology level of local enterprises [2, 3].

On the one hand, the rising position of enterprises in the global value chain can more easily learn and absorb the advanced green production processes, green management systems and cutting-edge green technologies of developed countries when participating in international economic and trade, and through the international and domestic linkages of the industrial chain, it can effectively promote the diffusion and absorption of cutting-edge green technologies between regions and enterprises within the metropolitan circle, thereby effectively promoting the green innovation of the region as a whole and the microeconomic entities within the region [6]. On the other hand, when enterprises move up the global industrial chain and value chain, they will face higher green and sustainable requirements from global consumers and more intense green and sustainable technology competition among their peers [7]. At this time, enterprises will choose to continue to make green and sustainable behavior decisions to improve their own green innovation level, and then defeat international competitors to achieve market share improvement and higher monopoly profits. Therefore, we believe that the climbing effect of the industrial chain is a mechanism factor for IEPP-SDMEC to enhance the green innovation of enterprises. In conclusion, we propose key mechanistic hypotheses for this study:

***H2****: IEPP-SDMEC can significantly improve the green innovation level of enterprises by improving the upstream position of enterprises within the metropolitan circle to embed in the global industrial chain.*

## 3 Research Design

### 3.1 Benchmark Model

To identify the policy effects of IEPP scientifically and credibly, we mainly use the DID model of multi-dimensional fixed effects to examine the impact of IEPP on the green innovation of micro-enterprises.

$$GP_{ijt} = \alpha DID_{it} + \sum_{k} \beta_k Z_{jk(t-1)} + Province_j + Year_t + Province_j * Year_t + \varepsilon_{ijt} \quad (1)$$

Where $i$ represents the listed company, $j$ represents the province, and $t$ represents the year. $GP_{ijt}$ is the dependent variable, and represents the green innovation level of listed companies. $Z_{jk(t-1)}$ is the control variable with a lag of one period. $Province_j$, $Year_t$, $Province_j * Year_t$ represent the province, time fixed effect items, and province*year interactive fixed effect term, respectively. $\varepsilon_{ijt}$ is the error term.

### 3.2 Variables and Data Sources

#### 3.2.1 Variables

Here are the variables in this research:

Dependent Variable. Based on the research of Wang & Wang (2021) [8], etc., we use the number of green patent applications of listed companies to measure the level of corporate green innovation.

Key Explanatory Variable. The key explanatory variable in the benchmark model (1) is the multiplication term of the dummy variable of the time when the IEPP is established and the dummy variable of the treatment group whether the enterprise is within the spatial scope of the SDHEC.

Industry chain mechanism variables. According to the research of WWYZ (2017a [9], 2017b [10]), we use the production chain forward link production length (Plv) index to measure the upstream degree of the industry chain. The larger the Plv value, the farther the sector is from the final consumer, and the more upstream the sector is in the global value chain and industrial chain. We also use the ratio of forward linkage production length to backward linkage production length (POS) to measure the industrial chain position index [9]. When the Position value is high, it means that this sector is relatively further from the final consumption end.

Control Variables. Based on the research from Zhang & Liu (2022) [11], Si & Cao (2022) [12], we control the following variables at the enterprise level: ① Enterprise size (Size); ② Asset-liability ratio (Lev); ③ Return on Equity (ROE); ④ Enterprise TobinQ (TobinQ); ⑤ The age of the enterprise (Age); ⑥ Corporate cash flow ratio (CashFlow). In addition, we also control the fixed effect of the province where the enterprise is located, the fixed effect of year and the interactive fixed effect of province*year to remove the unobservable confounding factors at the interactive level of province, year and province-year, and improve the credibility of the policy effect estimation process.

#### 3.2.2 Data Sources

The data of this study mainly includes three parts, namely the financial characteristic data of listed companies, green patent data and industrial chain connection data. Among them, the financial characteristics data of listed companies come from the CSMAR database. Green patent data comes from the matching of CNRDS and WIPO's "International Patent Classification Green List". The industry chain contact data comes from UIBE GVC Indicators database of University of International Business and Economics [13]. To eliminate the influence of extreme values, this paper conducts Winsorize processing of 1% up and down the main variables.

## 4 Results and Discussion

### 4.1 Parallel Trend Test

The premise of DID method to estimate the policy effect is that before the policy is implemented, there was no significant difference between the treatment group and the control group. Therefore, we first perform a parallel trend test. The results are shown in

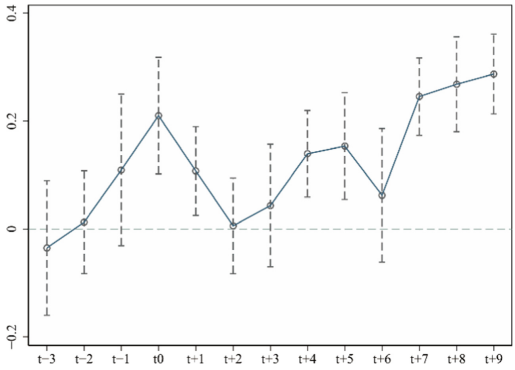


**Fig. 1.** Parallel trend test figure.

Fig. 1. Obviously, before the implementation of the policy, that is, before t0, there is no significant difference between the treatment group and the control group, which satisfies the parallel trend hypothesis.

### 4.2 Benchmark Results

The estimation results of the benchmark model are shown in column (4) of Table 1. Columns (1)-(3) are control regressions with or without control variables and with or without fixed effects, which are convenient for comparing results. The results in the table show that after controlling the financial characteristics of listed companies, the year effect, the regional effect and the year*province effect, SDHEC's IEPP implementation has a positive impact on green innovation of listed companies in the jurisdiction, a result that validates Hypothesis H1. In addition, column (5) in Table 1 is the result of benchmark regression only on the sample of listed companies in Guangdong Province, and the same result verifies the hypothesis H1 again.

### 4.3 Robustness Tests

#### 4.3.1 Change the Dependent Variable

To test the robustness of the benchmark regression results, we added three variables (GPratio, Gip, Gup) and re-identifies and estimates the benchmark model (1). The estimation results are shown in Table 2. It found that after changing the dependent variable, the estimation results are robust, which verifies the hypothesis H1 again.

#### 4.3.2 Heckman Two-Step Correction

We further apply the Heckman two-step method (Heckman, 1976 [14]; Yang & Ma, 2022 [15]) for another robust test. The estimation results are shown in Table 3. It found that after Heckman two-step correction, the estimation results are robust, which verifies the hypothesis H1 again.

**Table 1.** Baseline regression results.

| Model | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| DID | 0.187*** | 0.286*** | 0.235*** | 0.233*** | 0.251*** |
| | (0.032) | (0.030) | (0.000) | (0.008) | (0.045) |
| Obs. | 13,421 | 12,103 | 13,400 | 12,083 | 2,017 |
| R-squared | 0.003 | 0.189 | 0.077 | 0.245 | 0.210 |
| Controls | N | Y | N | Y | Y |
| Province*Year FE | N | N | Y | Y | N |
| Province FE | N | N | Y | Y | N |
| Year FE | N | N | Y | Y | Y |

Ps: Robust standard errors in parentheses, *** $p < 0.01$.

**Table 2.** Baseline regression with other dependent variables.

| Variable | *GPratio* | | *Gip* | | *Gup* | |
|---|---|---|---|---|---|---|
| Model | (1) | (2) | (3) | (4) | (5) | (6) |
| DID | 0.032*** | 0.034*** | 0.263*** | 0.278*** | 0.133*** | 0.148*** |
| | (0.001) | (0.009) | (0.007) | (0.045) | (0.007) | (0.044) |
| Obs. | 12,083 | 2,017 | 12,083 | 2,017 | 12,083 | 2,017 |
| R-squared | 0.057 | 0.022 | 0.223 | 0.209 | 0.201 | 0.154 |
| Controls | Y | Y | Y | Y | Y | Y |
| Province*Year FE | Y | N | Y | N | Y | N |
| Province FE | Y | N | Y | N | Y | N |
| Year FE | Y | Y | Y | Y | Y | Y |

Ps: Robust standard errors in parentheses, *** $p < 0.01$.

**Table 3.** Heckman two-step correction results.

| Model | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variable | *ifGP* | *GP* | *ifGip* | *Gip* | *ifGup* | *Gup* |
| DID | 0.177** | 0.239*** | 0.246*** | 0.173*** | 0.154* | 0.091*** |
| | (0.081) | (0.041) | (0.081) | (0.059) | (0.082) | (0.025) |
| Obs. | 34,619 | 13,637 | 34,425 | 10,804 | 34,413 | 10,432 |

(*continued*)

**Table 3.** (*continued*)

| Model | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Variable | *ifGP* | *GP* | *ifGip* | *Gip* | *ifGup* | *Gup* |
| R-squared | | 0.243 | | 0.241 | | 0.238 |
| Controls | Y | Y | Y | Y | Y | Y |
| Province*Year FE | Y | Y | Y | Y | Y | Y |
| Province FE | Y | Y | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y | Y | Y |

Ps: Robust standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1.

## 5 Mechanism Analysis

We use the industry chain forward link production length Plv and industry chain position POS to measure the level of listed companies embedded in the global industry chain and value chain. We construct the following model to test hypothesis H2:

$$\underset{POS_{ijt}}{Plv_{ijt}} = \alpha DID_{it} + \sum_{k} \beta_k Z_{jk(t-1)} + Firm_i + Province_j + Year_t + Province_j * Year_t + \varepsilon_{ijt} \tag{2}$$

The estimated results are shown in columns (1)–(4) of Table 4. The study found that the results in column (1) and (2) show that IEPP-SDHEC helps to improve the production length of the forward linkage of the industrial chain of listed companies, and the estimated coefficient is significant at the 1% level. The results in column (3) and (4) show that IEPP-SDHEC helps to improve the upstream position of listed companies embedded in the global industrial chain value chain, and the estimated coefficient is significant at the

**Table 4.** Industry chain linkage mechanism estimation results.

| Variable | *Plv* | | *POS* | |
|---|---|---|---|---|
| Model | (1) | (2) | (3) | (4) |
| DID | 0.078*** | 0.143*** | 0.023*** | 0.055*** |
| | (0.005) | (0.034) | (0.002) | (0.020) |
| Obs. | 11,516 | 3,988 | 11,516 | 3,988 |
| R-squared | 0.915 | 0.845 | 0.921 | 0.840 |
| Controls | Y | Y | Y | Y |
| Province*Year FE | Y | Y | Y | Y |
| Province FE | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y |

Ps: Robust standard errors in parentheses, *** p < 0.01.

1% level. On the one hand, it proves that the climbing effect of the industrial chain is an important mechanism for IEPP-SDHEC to enhance the green innovation of enterprises, that is, assuming that H2 is proved.

On the other hand, the results show that after the implementation of the IEPP-SDHEC policy, the cross-regional environmental protection technology and industry synergy adopted by the Shenzhen, Dongguan, and Huizhou governments will have a positive impact on the level of enterprises in the jurisdiction to participate in global competition. When an enterprise is in a higher upstream position in the value chain of the global industrial chain, it will face higher environmental green requirements in the international market, which in turn will stimulate the enterprise to make decisions on green environmental behavior and improve the level of green innovation.

## 6 Conclusions

IEPP under the background of regional environmental collaborative governance is a new form of environmental space policy for the government to deal with the governance of environmental problems across administrative regions under the requirements of green and sustainable development. We take the establishment of IEPP in the three cities of SDHM Shenzhen, Dongguan and Huizhou in 2010 as the policy entry point. By constructing IEPP-SDHEC dummy variables, manually collecting the characteristic data, green patent data, and industrial chain connection data of China's A-share listed companies from 2006 to 2019, for the first time, we use the multi-dimensional fixed-effect DID model to empirically examine the impact and mechanism of IEPP-SDHEC on corporate green innovation from the perspective of industrial chain linkages.

Our research found that, after controlling the financial characteristics of listed companies, the year effect, the regional effect and the year*province effect, IEPP-SDHEC implementation has a positive impact on green innovation of listed companies in the jurisdiction. In addition, we use the industry chain forward link production length Plv and industry chain position POS to measure the level of listed companies embedded in the global industry chain. It proves that the climbing effect of the industrial chain is an important mechanism for IEPP-SDHEC to enhance the green innovation of enterprises. It means that, on the one hand, the higher the position of the enterprise embedded in the global value chain, the easier it is to learn and absorb the advanced green production processes, green management systems and cutting-edge green technologies of developed countries in international economic and trade, and the faster the industrial upgrading and breakthrough innovation of the industrial manufacturing industry will be realized. On the other hand, The higher the position of the enterprise embedded in the global value chain, the greater the competitive pressure of green technology innovation faced by international competitors. Enterprises need continuous technological iteration and innovation to maintain their position in the global industrial chain, which will further accelerate the transformation & upgrading of the industrial manufacturing industry and corner overtaking in SDHEC, which will greatly stimulate the green innovation and development of the industrial manufacturing industry.

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