

# Can Fee-to-Tax Reform Deliver Multiple Dividends? Evidence on the Environmental, Technological, and Economic Effects in Water-Intensive Firms

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## Research Article

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# Abstract

China's water resource fee-to-tax reform, piloted in Hebei in 2016 and extended to nine further provinces in 2017, is the country's central attempt to price water through the tax system. Whether it delivers multiple dividends remains open: cost pressure may spur water saving and innovation, yet it may also erode profitability. Using panel data on 486 A-share listed water-intensive firms over 2012–2022 (3,855 firm-year observations) and a multi-period difference-in-differences design, this paper tests for environmental, technological, and economic dividends. Two of the three are identified. Firms in pilot provinces cut water consumption per hundred yuan of operating revenue by 2.896 units and raise water-saving patenting by 0.345, while return on equity shows no average response. Heterogeneity runs in opposite directions: the environmental dividend is larger in non-water-scarce provinces, the technological dividend is larger in water-stressed provinces, and both concentrate among growth- and mature-stage firms. The economic dividend appears only in non-water-scarce provinces and among decline-stage firms, making it a conditional rather than a general feature of the reform. Mechanism tests point to two channels: a heavier water tax burden and higher R&D investment. Results are robust to placebo tests, propensity score matching, and alternative fixed-effect specifications. The reform thus performs well as a water-conservation and innovation instrument while its economic payoff is uneven. This argues for expanding the pilot nationwide, unifying the base tax rate, earmarking revenue for water administration, mandating disclosure of water use, and anchoring the tax in the Water Law or the Resource Tax Law.

## 1 Introduction

China's water endowment is both scarce and unevenly distributed. Industry expanded on a resource-intensive model, and because water fees stayed low for decades water-intensive firms could abstract large volumes at negligible cost, aggravating an already strained supply. Water pricing has accordingly become a central instrument of Chinese environmental policy. Since the 18th National Congress of the Communist Party of China made ecological civilization a governing objective, the policy programme has sought to cap both the total volume and the intensity of water consumption, raise efficiency in the most water-dependent industries and expand wastewater reuse. Firms exist to maximize profit and cannot, in the short run, cut water use through in-house research alone; an external price signal is required, and the water resource tax supplies it. Because the tax bears directly on taxpayers' interests, it changes behaviour, internalizes externalities and serves environmental objectives, with consequences for sustainable growth and for the emergence of new quality productive forces. The reform began in 2016, when the State Council designated Hebei as the first province to convert the water resource fee into a tax. It was extended the following year to nine further provinces—Beijing, Tianjin, Inner Mongolia, Shanxi, Shandong, Henan, Sichuan, Shaanxi and Ningxia—producing the “1 + 9” pilot configuration. After several years in operation, the environmental, technological and economic effects of the policy now warrant systematic evaluation, and the design of the tax itself stands in need of refinement.

Three strands of scholarship have formed around the water resource tax. The first is theoretical: it asks why such a tax is justified, how it should be designed and what it is meant to achieve. On this reading the tax is a claim on resource rent—because the state owns water resources, it may levy charges on those who extract or use them and thereby steer consumption towards a rational level [14]. The underlying logic is Pigouvian [17]: abstraction imposes negative externalities on the ecosystem, and since a market left to itself will not reach a Pareto-optimal allocation, a tax is needed to internalize external costs and restore allocative efficiency. Revenue from the tax is usually treated as part of environmental taxation and tied to water protection and governance, and the rationale rests on equity across and within generations, so that present needs are met without foreclosing the options of those who come later. Pearce's double dividend proposition generalizes the argument [16]: environmental taxes may improve environmental quality and stimulate growth simultaneously, and as environmental tax systems have evolved some authors have added a third dividend covering employment [3] and welfare [23]. Design questions follow from three principles—benefit, fairness and efficiency. Units and individuals that directly abstract surface or groundwater are the taxpayers, surface and groundwater are the taxable objects, and the purpose is conservation, protection and rational use.

A second and larger strand asks what the reform has actually done, and it divides along an environmental axis and a technological–economic axis. Work on the environmental side concentrates on consumption volumes and efficiency. Levying the tax is repeatedly found to raise water use efficiency [15] and to alter the composition of use. Hebei is the standard case: industrial and agricultural abstraction fell appreciably after the reform while household consumption rose, an outcome generally read as a shift in relative water prices rather than a fall in total demand. Work on the technological and economic side ranges more widely. For firms with heavy pollution loads, higher water costs are said to push green innovation through R&D spending, which then feeds back into firm development and economy-wide technical progress. Other contributions stress the fiscal channel, arguing that the tax raises revenue, improves water allocation and cuts wastewater discharge. A third group identifies free cash flow and technological innovation as the mechanisms through which the tax restrains over-investment by water-intensive firms, shifting the growth model towards more sustainable patterns [29]. The literature is also alert to a limit: without gains in total factor productivity, stable growth cannot be sustained.

A third strand is prescriptive and addresses how the tax should be built: its design, the measures that surround it, its legal basis and the machinery of collection. On design, several weaknesses recur. The point of levy is poorly chosen and the treatment of taxpayers needs rethinking. Rate-setting is described as arbitrary, so a more defensible standard is called for. Certain items are hard to classify, which leads to proposals that geothermal and mineral water be brought explicitly within the tax base. The destination of the revenue is left vague, and the split between central and local government does not track spending responsibilities; hence the recommendation that a dedicated fund be created and the revenue shared between the two levels. Domestic and agricultural use lack clear reduction or exemption clauses, prompting suggestions that low rates be set for both. On supporting measures, residential users receive no preferential treatment; a low rate for residential water and an exemption for basic urban and rural

household consumption are the usual proposals, and thin metering infrastructure needs investment. On legal basis, the tax rests on the Water Law and its subordinate regulations, neither of which addresses it directly, a sign of weak statutory footing. Suggested remedies include inserting water resource tax provisions into the Water Law and defining water resources clearly in the Mineral Resources Law, though the more coherent route is to fold water resources into the Resource Tax Law while leaving water resource tax legislation standing on its own. On administration, the collection process is judged unnecessarily complicated and the coordination mechanism across departments weak, so closer information-sharing between tax authorities and other agencies is advised.

Existing work has produced a substantial body of results, but two gaps remain. The literature concentrates on the single or double dividend that the reform might deliver, and the possibility of several dividends arising at once has received comparatively little attention. And although many studies assess the reform at the level of cities or industries, far fewer trace how the tax reaches individual firms—least of all water-intensive firms whose water demand is large.

This paper takes the firm as its unit of analysis and concentrates on water-intensive firms. It asks how the water resource tax affects them and whether it delivers multiple dividends—environmental, technological and economic. Because water endowments differ sharply across provinces, the paper examines how those differences condition the overall policy effect, and it analyses how firms at different stages of their life cycle respond, revealing where sensitivity to the incentive is greatest and how firms adapt. The aim is a rounded account of the reform's effects and an evidential basis for policy that manages water more effectively.

The paper makes three contributions. First, it examines the environmental, technological and economic dividend effects of the water resource tax at the micro level, supplying firm-level evidence on how the tax reaches water-intensive firms—evidence that speaks both to the goal of ecological civilization and to corporate water conservation, innovation and performance. Second, drawing on water consumption disclosed by water-intensive firms, and working from two angles, water costs and R&D investment, it analyses empirically the internal mechanisms through which the tax shapes conservation and innovation, which gives greater explanatory purchase on the practical problems these firms face. The empirical results therefore illuminate both the effect of the tax on water-intensive firms and the direction further reform might take.

The paper proceeds as follows. Section 2 sets out the institutional background and the theoretical mechanisms. Section 3 describes the data, the construction of indicators and the econometric models. Section 4 reports the empirical tests: baseline regressions, the parallel trend test, robustness checks and heterogeneity analysis. Section 5 turns to mechanism testing, and Section 6 concludes with policy recommendations.

## **2 Institutional Background and Theoretical Mechanisms**

## 2.1 Institutional Background

Chinese water fee and tax policy has been assembled in three phases. A germination phase opened with the 1979 Shanghai Deep Well Management Measures, after which Hebei, Shanxi and other localities began collecting water resource fees; the Water Law of the People's Republic of China, enacted in 1988, set out collection standards and implementation rules and marks the point at which a legal framework began to take shape. An exploratory phase opened with the 2002 revision of the Water Law by the Standing Committee of the National People's Congress, undertaken to tighten water management and improve allocation and protection; the 2006 Regulations on the Administration of Water Abstraction Permits and Water Resource Fee Collection, issued by the State Council, then standardized both the permit system and fee collection. A consolidation phase arrived in 2016, when the Ministry of Finance, the State Taxation Administration and the Ministry of Water Resources jointly released the Interim Measures for the Pilot Reform of Water Resource Tax, launching the fee-to-tax conversion in Hebei. In 2017 the same three bodies issued the Implementation Measures for Expanding the Pilot Reform, widening the pilot to nine further provinces including Beijing (Fig. 1), with the aim of promoting conservation and circular use.

The reform converted a fee into a tax while preserving the principle that the burden shifts rather than multiplies. Three differences matter. First, the collecting authority changed: fees had been gathered by water administration departments, with finance and pricing departments overseeing management, whereas the tax is now collected and administered by local tax authorities while water administration departments verify actual abstraction volumes, and non-payment carries penalties, which gives local enforcement more bite. Second, the rate structure became finer: surface water and groundwater are treated separately, groundwater is further split into non-over-exploited, over-exploited and severely over-exploited zones, and additional categories—thermal power generation water, dewatering drainage water and ground-source heat pump water—each carry their own rate. Third, the level of the levy rose: fee rates had been low across the board, and the tax raises them (Table 1) while applying a double charge in over-exploited zones and to water-intensive and special industries. The intended effect is to cut groundwater abstraction and press firms to rework production processes, invest in innovation and use water more efficiently. Early evidence points that way. A thermal power plant in Beijing that had relied on groundwater shifted to surface water after the reform and cut groundwater use by 30,000 cubic metres in half a year, a year-on-year decrease of 64%. Six large paper-making enterprises in Sichuan reduced total water consumption by 63%. A paper mill in Shandong cut groundwater by 2.28 million cubic metres in half a year, with total consumption falling by 1.14 million cubic metres. And a coal chemical enterprise in Shaanxi reused 770,000 tons of circulating water, 7.45% of the company's total water consumption [15].

Table 1

Comparison of Water Resource Fees and Tax Rates for Other Industries in Pilot Regions (Unit: RMB/cubic meter)

| Province                                                                                                                                                                  | Surface Water Fee Rate | Surface Water Tax Rate | Groundwater Fee Rate | Groundwater Tax Rate |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------------|----------------------|----------------------|
| Hebei                                                                                                                                                                     | 0.500                  | 0.500                  | 0.650                | 3.000                |
| Beijing                                                                                                                                                                   | 1.770                  | 2.000                  | 2.000                | 4.300                |
| Tianjin                                                                                                                                                                   | 2.170                  | 1.600                  | 4.600                | 5.800                |
| Shanxi                                                                                                                                                                    | 0.500                  | 1.000                  | 1.000                | 6.000                |
| Inner Mongolia                                                                                                                                                            | 0.500                  | 0.700                  | 5.000                | 5.000                |
| Henan                                                                                                                                                                     | 0.250                  | 0.400                  | 1.490                | 2.300                |
| Shandong                                                                                                                                                                  | 0.400                  | 0.400                  | 1.160                | 2.000                |
| Sichuan                                                                                                                                                                   | 0.100                  | 0.110                  | 0.200                | 0.200                |
| Shaanxi                                                                                                                                                                   | 0.400                  | 0.400                  | 3.380                | 4.000                |
| Ningxia                                                                                                                                                                   | 0.200                  | 0.400                  | 0.300                | 3.300                |
| Note: Compiled by the author based on the notices on the implementation measures for water resource fee and water resource tax reforms issued by various pilot provinces. |                        |                        |                      |                      |

## 2.2 Theoretical Mechanisms

### 2.2.1 Water Resource Tax and Environmental Dividend Effect

Taxing water resources allows governments to internalize external costs [11], remedy the market failure that externalities create, and move resource allocation toward the social optimum. Based on the substitution and income effects of taxation, the water resource tax can curb excessive groundwater extraction, promote its sustainable utilization [21], improve the ecological environment, and generate significant environmental dividends [22]. The water resource tax policy primarily affects enterprises' water consumption and efficiency through two aspects. On one hand, from a negative constraint mechanism perspective, the setting of water resource tax rates is more reasonable compared to water resource fees. Unlike water resource fees, the water resource tax grants governments at all levels the right to formulate specific tax rates within the range specified in the "Minimum Average Tax Rate Table for Water Resources," meaning the state sets a lower limit for water resource tax, and local governments adjust the appropriate tax rate standards for their region based on the current water consumption, socio-economic development goals, etc. After the pilot began, provinces including Beijing, Tianjin and Hebei raised their collection standards by differing amounts and applied a double charge to water-intensive firms at the higher rates. Because a firm's tax liability moves with the volume it abstracts, the reform

raises the cost of water for these firms. The expected response is a production-side adjustment in how water is used, undertaken to lower the tax bill, which in turn strengthens their competitive position [20]. On the other hand, from a positive incentive mechanism perspective, the water resource tax offers preferential treatment to enterprises that install water metering facilities. This encourages enterprises to be more proactive in water conservation. For profit-maximizing enterprises, to enjoy these benefits, water-intensive firms have sufficient motivation to reduce water consumption. This not only effectively stimulates water-intensive firms to improve production processes but also encourages efficient utilization of water resources, promoting green development of enterprises. Furthermore, by incentivizing enterprises to install wastewater treatment equipment, wastewater discharge is reduced to a certain extent, achieving a "end-of-pipe treatment" effect, which raises treatment rates and the share of water recycled rates, and enhancing water resource recovery and utilization [13]. Based on this, this paper proposes research hypothesis 1.

H1: The water resource tax reform significantly promotes water use efficiency in water-intensive firms, exhibiting an environmental dividend effect.

## **2.2.2 Water Resource Tax and Technological Dividend Effect**

The Porter Hypothesis holds that well-designed environmental regulation can spur innovation, sharpen a firm's competitive edge [18], and ultimately lower the cost of compliance itself [9]. The water resource tax is one such regulation. It raises water costs in the near term, but over a longer horizon it improves internal allocative efficiency, lifts total factor productivity and pushes industrial structure toward upgrading [28]. It also gives firms a reason to change how they use water, to develop water-saving technology and to pursue green innovation [2], which shows up as more invention patents, higher R&D spending and greater innovation output. In the process of enterprises' green transformation, technological progress helps enhance the green momentum of new productive forces and is an important guarantee for enterprises to develop water-saving technologies. Firms have two options: spend more on water-saving R&D in order to build greener products and cut consumption, or keep existing processes and pay the tax on what they use. Faced with the same choice, the tax penalty makes the first option the more attractive one for most firms. Collection by tax authorities raises the cost of non-compliance, which improves the regularity of payment and gives firms a further reason to strengthen their innovation capacity in pursuit of water-saving goals. In addition, the water resource tax policy conveys a signal of green consumption to the public, which helps enhance water conservation awareness among enterprises and residents [10], guiding consumer preferences. Rational enterprises will transfer part of the water resource tax burden to consumers based on supply and demand elasticity, leading to an increase in the price of water-intensive products, while the price of green products becomes more attractive, and rational consumers will choose green products. Therefore, under consumer supervision, enterprises will strengthen "conceptual governance," develop environmental habits [27], form a good social atmosphere [26], and to increase investment in green technology R&D, which advances green innovation within firms. Based on this, this paper proposes research hypothesis 2.

H2: The water resource tax reform significantly promotes water-saving innovation in water-intensive firms, exhibiting a technological dividend effect.

## 2.2.3 Water Resource Tax and Economic Dividend Effect

Two competing accounts dominate the discussion of the economic dividend: the compliance-cost effect and the technological-compensation effect. Neoclassical economics favours the first. Environmental regulation of the kind embodied in the water resource tax raises compliance costs and compresses margins, damaging economic performance. Three channels are usually given. Compliance costs rise directly, and firms may try to recover them through higher prices; in competitive markets, however, that depresses sales, weakens the product's market position and squeezes margins further, working against long-run development. Where regulation is strict, firms may also relocate production to jurisdictions with lighter rules in order to escape the burden [1], which reallocates resources away from the strict region and hurts its economic performance. Finally, the tax can affect a water-intensive firm's standing with stakeholders and thereby shape its water-use behaviour [6]. An enterprise's water resource tax payments and water consumption are disclosed through annual reports, social responsibility reports, etc., increasing public supervision and attention, and sending positive signals to the outside world, allowing investors to obtain more information. Positive corporate social responsibility activities can reduce negative media coverage and help gain the trust of stakeholders. A negative reputation may convey unfavorable information to investors, affecting their financing activities and thus having a significant impact on corporate performance [25]. Therefore, the water resource tax may not exert its expected promotional effect and may fail to effectively improve corporate performance.

The compensation account, associated with a different group of scholars, reaches the opposite conclusion: properly calibrated regulation stimulates innovation, and the resulting gains may offset or even outweigh compliance costs, so economic development benefits. For water-dependent firms the picture is more complicated. The tax raises production costs at once, while green innovation depends on resources the firm must supply; in the near term, rapid adaptation through innovation is difficult, and efficiency and performance may suffer. Over a longer horizon, and in pursuit of profit, firms relieve cost pressure by cutting water use in production—adjusting the production model, refining processes, adopting water-saving technology, retiring outdated capacity [5], and improving industrial structure. This, in turn, improves corporate performance, drives economic growth, and achieves "source governance." Based on this, this paper proposes the following competing hypotheses 3.

H3A: The water resource tax reform does not have a promotional effect on the corporate performance of water-intensive firms and does not exhibit an economic dividend effect.

H3B: The water resource tax reform has a significant promotional effect on the corporate performance of water-intensive firms, exhibiting an economic dividend effect.

## 3 Research Design

## 3.1 Sample Selection and Data Sources

To accurately assess the multiple dividend effects of the water resource tax reform on water-intensive firms, this paper selects water-intensive firms among all A-share listed companies from 2012 to 2022 as the research sample. The water consumption of these enterprises is extracted by thoroughly analyzing the annual reports, social responsibility reports, and official websites of each listed company.

Additionally, patent data related to technological innovation are directly cited from the enterprise patent authorization information released by the China National Intellectual Property Administration. To ensure the validity and reasonableness of the sample data, the data are processed as follows: (i) excluding ST and \*ST listed companies; (ii) excluding companies delisted during the sample period; and (iii) excluding samples with missing variables and common outliers, such as enterprises with a liability ratio greater than 1. After the above data cleaning, a total of 3,855 observations from 486 listed enterprises were obtained. Other data for the listed companies are sourced from the Wind and CSMAR databases. To mitigate the influence of extreme values, all continuous variables are winsorized at the top and bottom 2%.

## 3.2 Model and Variable Specification

### 3.2.1 Model Design

This paper utilizes the water resource tax reform as a quasi-natural experiment and employs a Difference-in-Differences (DID) model to study whether the reform can achieve multiple dividend effects in water-intensive industries. Given that the policy was implemented in a total of 10 provinces ("1 + 9"), with Hebei starting as the first pilot region in 2016, and the remaining 9 provinces beginning the reform as the second batch of pilots in 2017, this paper divides the provinces into a treatment group and a control group and uses a multi-period DID model to construct the following three models with environmental dividend, technological dividend, and economic dividend as the respective dependent variables.

$$HCE_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (1)$$

$$REP_{i,t} = \delta_0 + \delta_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (2)$$

$$ROE_{i,t} = \beta_0 + \beta_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (3)$$

where the subscripts  $i$  and  $t$  represent the firm and year, respectively. The dependent variable represents the environmental dividend ( $HCE_{i,t}$ ), technological dividend ( $REP_{i,t}$ ), and economic dividend ( $ROE_{i,t}$ ), respectively. The core explanatory variable is the water resource tax reform ( $DID_{i,t} = treat_i \times post_{i,t}$ ).  $X_{i,t}$  is a series of firm-level control variables. Considering the differences in water use conditions among firms and the impact of external macroeconomic shocks faced by all firms, this

paper also controls for firm fixed effects ( $\mu_i$ ) and time fixed effects ( $\varphi_t$ ), ( $\epsilon_{i,t}$ ) represents the random error term.

## 3.2.2 Dependent Variables

This paper focuses on the multiple dividend effects of the water resource tax policy on water-intensive industries, covering indicators from three key dimensions: environmental dividend, technological dividend, and economic dividend. This framework aims to comprehensively evaluate the integrated effects of the water resource tax policy in promoting efficient water resource utilization (environmental dividend), stimulating water-saving technological innovation (technological dividend), and improving corporate financial performance (economic dividend).

### (1) Environmental Dividend

In the field of measuring corporate environmental dividends, common indicators include water consumption, water pollution levels, and water consumption per ten thousand yuan of GDP. This paper measures the water use efficiency of water-intensive firms ( $HCE_{i,t}$ ) by calculating their water consumption per hundred yuan of operating revenue; a lower value therefore indicates higher water use efficiency.  $HCE_{i,t}$  is the water consumption per hundred yuan of operating revenue of firm  $i$  in year  $t$ . This method has two advantages: First, by linking water consumption with operating revenue, it allows for a standardized comparison across enterprises of different scales and revenues, which helps to accurately assess their water use efficiency. Second, this indicator not only considers the enterprise's water consumption but also combines it with economic output, reflecting how efficiently the enterprise utilizes water resources while pursuing economic benefits, which is crucial for revealing the environmental dividend. Therefore, this paper selects  $HCE$  as the measure for the environmental dividend.

### (2) Technological Dividend

When discussing the measurement of corporate technological dividends, commonly used indicators include R&D investment, the number of patents, and intangible assets. This paper chooses to use the enterprise patent authorization information released by the China National Intellectual Property Administration to measure the technological dividend. Specifically, we manually screen for 'water-saving' patents ( $REP$ ) related to water resources, such as circulating water systems, water-saving sanitary equipment, water resource management systems, and seawater desalination technology, to compile the water-saving patent data for water-intensive firms. This choice is primarily based on the following two considerations: First, the implementation of the water resource tax increases the operating costs of enterprises, especially those in water-intensive industries. Faced with cost pressure, enterprises are motivated to seek more efficient and water-saving production technologies. This pressure prompts enterprises not only to improve existing technologies but also to develop new technological solutions for water conservation, which may lead to an increase in the number of water-saving patents. Second, as the water resource tax is rolled out, enterprises need to meet stricter environmental standards, which may

encourage them to increase their R&D investment in environmental protection technologies. This increased investment is not only reflected in the improvement of environmental technologies but also in the growth of the number of water-saving patents. Therefore, *REP* (the number of water-saving patents) is selected as the measure for the technological dividend in this paper.

### (3)Economic Dividend

In the field of assessing corporate economic dividends, financial and market performance indicators are widely adopted to measure a company's performance. These include, but are not limited to, financial indicators such as Return on Assets ( *ROA* ) and Return on Equity ( *ROE* ), as well as market indicators like Tobin's Q and annual stock returns. This paper specifically selects the Return on Equity ( *ROE* ) of water-intensive firms as the measurement tool for the economic dividend. This choice is based on the following two considerations: First, as a highly sensitive financial indicator, *ROE* can promptly reflect the impact of changes in the water resource tax policy on an enterprise's financial status. In the initial phase of policy implementation, the profitability and financial efficiency of enterprises are most susceptible to fluctuations. Therefore, *ROE* provides a highly timely measurement benchmark, facilitating the effective monitoring and evaluation of the direct impact on corporate profitability after the implementation of the water resource tax policy. Second, when facing environmental costs such as the water resource tax, water-intensive firms may implement various strategies to optimize their cost structure, for instance, by improving water use efficiency or investing in the development of water-saving technologies. *ROE* not only demonstrates the comprehensive capabilities of an enterprise in cost control and value creation but also provides a clear analytical framework for analyzing how an enterprise adjusts its business strategy under the new tax policy environment. Therefore, *ROE* is selected as the measure for the economic dividend in this paper.

## 3.2.3 Explanatory Variables

To accurately assess the impact of the water resource tax reform on enterprises, this paper constructs a dummy variable for the water resource tax reform (  $DID_{i,t} = treat_i \times post_{i,t}$  ).  $treat_i$  is the policy group dummy variable, which is 1 if firm  $i$  is located in a province that has implemented the water resource tax reform, and 0 otherwise;  $post_{i,t}$  is the policy implementation time dummy variable, which is 1 for the year the reform was implemented in firm  $i$  province and all subsequent years, and 0 otherwise.

## 3.2.4 Control Variables

When studying the multiple effects of the water resource tax, to mitigate the influence of other potential factors on corporate dividend performance, and drawing on the research of Yao and Li [28], this paper introduces a series of control variables (*Controls*) to ensure the accuracy and reliability of the research findings. These control variables include: Firm size (*Size*), the natural logarithm of total assets at the end of the year, which is a key factor in determining a firm's innovation investment; Leverage (*Lev*), expressed as the ratio of total liabilities to total assets at the end of the year, used to measure the firm's financial leverage; Board size (*Board*), represented as the natural logarithm of the number of board members,

reflecting an aspect of corporate governance structure; Ownership concentration (*Top1*), the ratio of shares held by the largest shareholder to the total number of shares, reflecting the degree of equity concentration; Fixed asset ratio (*Fixed*), the ratio of net fixed assets to total assets, used to assess the stability of the firm's asset structure; Listing age (*ListAge*), the natural logarithm of the actual number of years listed, to measure the firm's maturity and experience in the capital market; and Government subsidy (*Subsidy*), the natural logarithm of the firm's annual government subsidies, to examine the impact of policy support on business operations. The definitions of the main variables are shown in Table 2.

Table 2  
Variable Descriptions and Selections

| Variable Type             | Variable Name                  | Variable Code | Variable Definition                                                       |
|---------------------------|--------------------------------|---------------|---------------------------------------------------------------------------|
| Dependent Variables       | Water Use Efficiency           | HCE           | Water Consumption / (Operating Revenue / 100)                             |
|                           | Number of Water-saving Patents | REP           | Number of corporate water-saving patents                                  |
|                           | Return on Equity               | ROE           | Net Profit / Average Balance of Shareholders' Equity                      |
| Core Explanatory Variable | Water Resource Tax Reform      | DID           | Interaction term (treat × post)                                           |
| Control Variables         | Firm Size                      | Size          | ln(Total Assets)                                                          |
|                           | Leverage                       | Lev           | Total Liabilities at year-end / Total Assets at year-end                  |
|                           | Board Size                     | Board         | ln(Number of board members)                                               |
|                           | Ownership Concentration        | Top1          | Number of shares held by the largest shareholder / Total number of shares |
|                           | Fixed Asset Ratio              | Fixed         | Net Fixed Assets / Total Assets                                           |
|                           | Listing Age                    | ListAge       | ln(Current Year - Listing Year + 1)                                       |
|                           | Government Subsidy             | Subsidy       | ln(Government Subsidy + 1)                                                |
| Mechanism Variables       | Water Resource Taxes and Fees  | SZYS          | ln(Water Resource Taxes and Fees)                                         |
|                           | R&D Investment                 | R&D           | ln(R&D Investment)                                                        |

### 3.3 Descriptive Statistics

From the descriptive statistics of the main variables in Table 3, it can be observed that the data for *HCE* show significant distributional heterogeneity. Specifically, the median of *HCE* is 8.550, so roughly half of the firm-year observations fall below this level. The mean of *HCE* is 10.885, above the median, so the

distribution is right-skewed: most firms use relatively little water per hundred yuan of operating revenue while a few use much more. The minimum and maximum values of *HCE* are 0.002 and 84.137, respectively, and combined with a standard deviation of 10.976, further illustrate the extreme dispersion of water use across firms, revealing significant differences among enterprises in terms of water consumption and operating revenue. This situation suggests that the overall improvement in corporate environmental dividends needs to be revealed and understood through more in-depth empirical analysis.

Regarding *REP*, its median is 0, which indicates that during the study period most enterprises filed no new water-saving patents. However, the mean of 0.527 shows that some enterprises have still made progress in water-saving innovation. The minimum and maximum values of *REP* are 0 and 5.670, respectively, with a standard deviation of 0.855, further revealing considerable heterogeneity among enterprises in terms of water-saving patents. Therefore, it is particularly important to empirically test the incentive effect of the water resource tax on corporate technological dividends.

For *ROE*, the median is 0.077, indicating that the economic performance of most enterprises is below the average level, while the mean of 0.083 shows that corporate profitability is relatively balanced overall. The minimum and maximum values of *ROE*, -0.427 and 0.349 respectively, indicate that the enterprises in the sample differ significantly in their financial performance, with some facing financial losses while others exhibit high profitability. This situation underscores the necessity of conducting an in-depth analysis of the impact of the water resource tax on corporate economic dividends. Furthermore, the descriptive statistics for the other variables are consistent with the findings of existing literature, providing a robust foundation for this paper.

Table 3  
Descriptive Statistics

| Variable | Observations | Mean   | Std. Dev. | Min.   | Median | Max.   |
|----------|--------------|--------|-----------|--------|--------|--------|
| HCE      | 3855         | 10.885 | 10.976    | 0.002  | 8.550  | 84.137 |
| REP      | 3855         | 0.527  | 0.855     | 0.000  | 0.000  | 5.670  |
| ROE      | 3855         | 0.083  | 0.098     | -0.427 | 0.077  | 0.349  |
| Size     | 3855         | 22.614 | 1.398     | 20.100 | 22.357 | 26.710 |
| Lev      | 3855         | 0.414  | 0.193     | 0.020  | 0.413  | 0.856  |
| Board    | 3855         | 2.157  | 0.203     | 1.609  | 2.197  | 2.708  |
| Top1     | 3855         | 36.002 | 15.351    | 9.606  | 33.765 | 82.505 |
| Fixed    | 3855         | 0.314  | 0.167     | 0.027  | 0.289  | 0.832  |
| ListAge  | 3855         | 2.234  | 0.741     | 0.693  | 2.398  | 3.401  |
| Subsidy  | 3855         | 16.394 | 1.993     | 0.000  | 16.484 | 20.509 |
| SZYS     | 3749         | 14.036 | 2.844     | 8.577  | 13.993 | 20.870 |
| R&D      | 3596         | 17.930 | 1.511     | 13.551 | 17.928 | 20.868 |

## 4 Results Analysis and Robustness Checks

### 4.1 Baseline Regression Results

#### 4.1.1 Environmental Dividend

The baseline regression results in Table 4 provide empirical support for H1, revealing the significant impact of the water resource tax reform on the water use efficiency of water-intensive firms. A specific analysis is as follows: Column (1) presents the regression of *HCE* on *DID* alone, without fixed effects or control variables, and the result indicates that the policy variable can improve corporate water use efficiency. In column (2), after introducing firm and time fixed effects, although the policy coefficient becomes smaller in absolute value, the estimate is more credible. Firm and year fixed effects absorb time-invariant firm characteristics and common macroeconomic shocks, so the remaining variation is more plausibly attributable to the policy. In column (3), after further adding firm-level control variables, the policy coefficient is both larger in magnitude and negative at the 1% level. With other firm characteristics held constant, the reform is associated with a fall of 2.896 units in water consumption per hundred yuan of operating revenue. The above results verify the first hypothesis proposed in this paper: the water resource tax reform can significantly improve the water use efficiency of water-intensive firms, exhibiting an environmental dividend effect. The pattern is consistent with a cost channel: by

raising the price of water, the tax encourages firms to cut consumption, which improves water use efficiency at the micro level.

Table 4  
Regression Results for the Environmental Dividend

| Variable                                                                                                                              | HCE                     |                        |                       |
|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|-----------------------|
|                                                                                                                                       | (1)                     | (2)                    | (3)                   |
| DID                                                                                                                                   | -11.695***<br>(-29.268) | -2.823***<br>(-8.875)  | -2.896***<br>(-9.406) |
| Size                                                                                                                                  |                         |                        | 1.083**<br>(2.482)    |
| Lev                                                                                                                                   |                         |                        | -5.284***<br>(-4.138) |
| Board                                                                                                                                 |                         |                        | 0.209<br>(0.254)      |
| Top1                                                                                                                                  |                         |                        | -0.111***<br>(-5.385) |
| Fixed                                                                                                                                 |                         |                        | 2.744*<br>(1.931)     |
| ListAge                                                                                                                               |                         |                        | 0.110<br>(0.213)      |
| Subsidy                                                                                                                               |                         |                        | -0.414***<br>(-6.454) |
| Constant                                                                                                                              | 13.227***<br>(73.970)   | 11.450***<br>(119.706) | -1.621<br>(-0.166)    |
| Observations                                                                                                                          | 3,855                   | 3,855                  | 3,855                 |
| R                                                                                                                                     | 0.182                   | 0.830                  | 0.836                 |
| Firm Fixed Effects                                                                                                                    | No                      | Yes                    | Yes                   |
| Year Fixed Effects                                                                                                                    | No                      | Yes                    | Yes                   |
| R2                                                                                                                                    | 0.182                   | 0.805                  | 0.812                 |
| F                                                                                                                                     | 856.600                 | 78.770                 | 27.300                |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |                         |                        |                       |

# 4.1.2 Technological Dividend

Table 5 presents the baseline regression results for H2, aiming to investigate the impact of the water resource tax reform on the technological dividend of water-intensive firms. The results show that in the model specification of column (1), without controlling for fixed effects or including control variables, a direct regression of REP on DID yields a positive and significant policy coefficient. Subsequently, in the model in column (2), after introducing firm and time fixed effects, although the coefficient of the policy effect decreased, it remained significant, indicating that the positive association survives the inclusion of firm and year fixed effects. When the model is further augmented with firm-level control variables in column (3), the policy coefficient increases in magnitude and remains positive at the 1% level. This supports the second hypothesis: the reform is associated with more water-saving patents, with the count rising by roughly 0.345 on average. The water resource tax thus appears to encourage water-intensive firms to invest in water-saving technologies.

Table 5  
Regression Results for the Technological Dividend

| Variable                                                                                                                       | REP                  |                      |                      |
|--------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|----------------------|
|                                                                                                                                | (1)                  | (2)                  | (3)                  |
| DID                                                                                                                            | 0.407***<br>(12.031) | 0.343***<br>(8.583)  | 0.345***<br>(8.648)  |
| Size                                                                                                                           |                      |                      | 0.092***<br>(3.357)  |
| Lev                                                                                                                            |                      |                      | -0.042<br>(-0.402)   |
| Board                                                                                                                          |                      |                      | -0.142*<br>(-1.648)  |
| Top1                                                                                                                           |                      |                      | -0.003<br>(-1.575)   |
| Fixed                                                                                                                          |                      |                      | -0.178<br>(-1.593)   |
| ListAge                                                                                                                        |                      |                      | -0.116**<br>(-2.281) |
| Subsidy                                                                                                                        |                      |                      | 0.005<br>(0.773)     |
| Constant                                                                                                                       | 0.445***<br>(29.434) | 0.458***<br>(38.822) | -0.977<br>(-1.601)   |
| Observations                                                                                                                   | 3,855                | 3,855                | 3,855                |
| R                                                                                                                              | 0.036                | 0.691                | 0.693                |
| Firm Fixed Effects                                                                                                             | No                   | Yes                  | Yes                  |
| Year Fixed Effects                                                                                                             | No                   | Yes                  | Yes                  |
| R2                                                                                                                             | 0.036                | 0.645                | 0.647                |
| F                                                                                                                              | 144.800              | 73.670               | 11.880               |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |                      |                      |                      |

### 4.1.3 Economic Dividend

Table 6 presents the baseline regression results for H3, examining the effect of the water resource tax reform on the economic dividend of water-intensive firms. Specifically: In column (1), without controlling for fixed effects or including any control variables, a direct regression of *ROE* on *DID* shows that the implementation of the water resource tax reform has a significant positive impact on the economic dividend of water-intensive firms. Subsequently, the model in column (2) introduces firm and time fixed effects, aiming to capture the effect of the water resource tax policy more accurately by controlling for these time-invariant characteristics. The results indicate that the impact of the water resource tax reform on the corporate economic dividend becomes insignificant. In column (3), the model further incorporates firm-level control variables to account for the potential influence of other firm-specific factors on the results. Even so, the significance of the policy effect does not change, remaining insignificant. This supports Hypothesis H3A: the reform had no discernible effect on the economic dividend of water-intensive firms. Two explanations are plausible. First, the reform may require firms to make upfront investments in water-saving equipment, and these outlays need not pay off within the sample period. Second, firms in industries such as liquor and beverage manufacturing face fairly elastic demand, so they cannot fully pass higher water costs on to consumers through prices. Cost pressure therefore stays inside the firm. This conclusion provides an important reference for policy design and implementation: in the process of formulating and implementing policies aimed at environmental protection, the comprehensive impact of the policy on corporate economic activities must be widely considered. This is to ensure that while policy measures promote the achievement of environmental goals, they can also safeguard the stable growth of the corporate economy.

Table 6  
Regression Results for the Economic Dividend

| Variable                                                                                                                                      | ROE                  |                      |                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|-----------------------|
|                                                                                                                                               | (1)                  | (2)                  | (3)                   |
| DID                                                                                                                                           | 0.019***<br>(4.891)  | 0.006<br>(0.872)     | 0.004<br>(0.671)      |
| Size                                                                                                                                          |                      |                      | 0.048***<br>(7.548)   |
| Lev                                                                                                                                           |                      |                      | -0.257***<br>(-9.710) |
| Board                                                                                                                                         |                      |                      | 0.001<br>(0.051)      |
| Top1                                                                                                                                          |                      |                      | -0.000<br>(-0.292)    |
| Fixed                                                                                                                                         |                      |                      | -0.076***<br>(-3.746) |
| ListAge                                                                                                                                       |                      |                      | -0.005<br>(-0.630)    |
| Subsidy                                                                                                                                       |                      |                      | 0.001*<br>(1.743)     |
| Constant                                                                                                                                      | 0.079***<br>(44.573) | 0.081***<br>(46.087) | -0.887***<br>(-6.296) |
| Observations                                                                                                                                  | 3,855                | 3,855                | 3,855                 |
| R                                                                                                                                             | 0.006                | 0.397                | 0.451                 |
| Firm Fixed Effects                                                                                                                            | No                   | Yes                  | Yes                   |
| Year Fixed Effects                                                                                                                            | No                   | Yes                  | Yes                   |
| R2                                                                                                                                            | 0.006                | 0.308                | 0.368                 |
| F                                                                                                                                             | 23.930               | 0.760                | 20.560                |
| Note: Parentheses contain t-statistics adjusted for heteroskedasticity, with *, ** and *** marking significance at the 10%, 5% and 1% levels. |                      |                      |                       |

## 4.2 Parallel Trend Test

In the application of the Difference-in-Differences (DID) model, the validity of a difference-in-differences design rests on the treatment and control groups following parallel trends before the policy. To test whether the water resource tax reform affects the environmental, technological, and economic dividends of water-intensive firms, following Deschênes et al. [7], this paper estimates an event-study specification (models 4–6). The event-study coefficients trace how the three dividends evolved in pilot and non-pilot provinces around the reform, which allows a direct test of whether the two groups were on parallel paths before 2016.

|                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------|
| $HCE_{i,t} = \alpha_0 + \sum_{2012}^{2022} \alpha_k DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (4)$ |
| $REP_{i,t} = \delta_0 + \sum_{2012}^{2022} \delta_k DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (5)$ |
| $ROE_{i,t} = \beta_0 + \sum_{2012}^{2022} \beta_k DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t} \quad (6)$   |

The period immediately before the reform serves as the base period. The interaction-term coefficients measure the gap in each dividend between the treatment and control groups in year  $k$ . Pre-reform coefficients that are jointly indistinguishable from zero are consistent with parallel trends; post-reform coefficients that differ from zero indicate an effect of the pilot.

Throughout, "current" denotes the year of the policy shock, while "pre\_1" and "las\_1" represent the  $i$  year before and after the policy shock, respectively. Panels (A) and (B) show that, for the environmental and technological dividends, none of the pre-policy coefficients differs significantly from zero: the point estimates fluctuate around the zero line and every confidence interval straddles it. The treatment and control groups were therefore on parallel paths before the reform, and the event-study estimates for these two dividends can be attributed to the policy. Panel (C) tells a different story for the economic dividend. Its pre-policy coefficients are close to zero and the intervals cross the zero line, indicating that the parallel trend assumption holds for the pre-reform window as well; what distinguishes this panel is the post-reform path. From the policy year onward the coefficients stay near zero and none is significant, so the reform left the economic dividend essentially unchanged. The environmental and technological dividends therefore pass the parallel trend test, while the economic dividend does not respond to the reform—a pattern consistent with the baseline regressions in Tables 4 to 6.

Because the post-reform window is short, contemporaneous policies may still influence the estimates. The robustness checks below therefore probe how sensitive the baseline results are to alternative explanations.

## 4.3 Robustness Checks

Endogeneity in policy evaluation usually arises from measurement error, omitted variables, and reverse causality. Reverse causality is the least pressing concern here: the dependent variables come from firm-level micro data, whereas the treatment is a nationwide policy decided by central authorities, so individual firms are unlikely to shape its timing or scope. The robustness checks below therefore concentrate on measurement error and omitted variables.

### 4.3.1 Placebo Test

This paper runs a placebo test to gauge how much of the baseline result could be driven by random assignment or omitted variables. Treatment status and policy timing are randomly reassigned, the pseudo-treatment dummy is substituted into the baseline specification, and the procedure is repeated 1,000 times. As Fig. 3 shows, the placebo coefficients center on zero and are far smaller than the baseline estimate; their distribution is approximately normal, and most p-values exceed 0.10. The environmental and technological results are therefore unlikely to be an artifact of random factors.

### 4.3.2 Excluding the Influence of the Environmental Protection Tax

A remaining concern is that other policy shocks coincided with the reform studied here. The Environmental Protection Tax, introduced in 2018, also affected corporate emission control, patenting, and financial performance, so it could contaminate the water resource tax estimates. Following Yao et al. [29], this paper adds the Environmental Protection Tax to models (7)-(9) to separate the two reforms.

Table 7  
Regression Results Excluding Policy Interference

|                                                                                                                        |     |
|------------------------------------------------------------------------------------------------------------------------|-----|
| $HCE_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \alpha_2 ET_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$ | (7) |
| $REP_{i,t} = \delta_0 + \delta_1 DID_{i,t} + \delta_2 ET_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$ | (8) |
| $ROE_{i,t} = \beta_0 + \beta_1 DID_{i,t} + \beta_2 ET_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$    | (9) |

| Variable                                                                                                                              | (1)                     | (2)                  | (3)                   |
|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------|-----------------------|
|                                                                                                                                       | <i>HCE</i>              | <i>REP</i>           | <i>ROE</i>            |
| DID                                                                                                                                   | -5.494***<br>(-21.454)  | 0.359***<br>(8.803)  | 0.006<br>(0.924)      |
| ET                                                                                                                                    | -14.559***<br>(-19.722) | 0.074<br>(1.384)     | 0.010<br>(1.265)      |
| Size                                                                                                                                  | 1.256***<br>(3.265)     | 0.091***<br>(3.319)  | 0.048***<br>(7.521)   |
| Lev                                                                                                                                   | -6.053***<br>(-5.420)   | -0.038<br>(-0.364)   | -0.257***<br>(-9.687) |
| Board                                                                                                                                 | 0.347<br>(0.454)        | -0.143*<br>(-1.653)  | 0.001<br>(0.045)      |
| Top1                                                                                                                                  | -0.109***<br>(-5.937)   | -0.003<br>(-1.581)   | 0.000<br>(-0.297)     |
| Fixed                                                                                                                                 | 3.844***<br>(3.181)     | -0.183<br>(-1.637)   | -0.077***<br>(-3.769) |
| ListAge                                                                                                                               | -0.197<br>(-0.472)      | -0.114**<br>(-2.250) | -0.005<br>(-0.603)    |
| Subsidy                                                                                                                               | -0.442***<br>(-7.469)   | 0.005<br>(0.795)     | 0.001*<br>(1.766)     |
| Constant                                                                                                                              | -3.001<br>(-0.352)      | -0.970<br>(-1.590)   | -0.886***<br>(-6.283) |
| Observations                                                                                                                          | 3,855                   | 3,855                | 3,855                 |
| R                                                                                                                                     | 0.880                   | 0.693                | 0.451                 |
| Firm Fixed Effects                                                                                                                    | Yes                     | Yes                  | Yes                   |
| Year Fixed Effects                                                                                                                    | Yes                     | Yes                  | Yes                   |
| $R^2$                                                                                                                                 | 0.862                   | 0.647                | 0.368                 |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |                         |                      |                       |

| Variable                                                                                                                              | (1)        | (2)        | (3)        |
|---------------------------------------------------------------------------------------------------------------------------------------|------------|------------|------------|
|                                                                                                                                       | <i>HCE</i> | <i>REP</i> | <i>ROE</i> |
| <i>F</i>                                                                                                                              | 111.300    | 10.910     | 18.350     |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |            |            |            |

This paper introduces an interaction term for the Environmental Protection Tax reform ( $ET_{i,t} = treat1_i \times post1_{i,t}$ ) into the original model, aiming to explore the potential impact of this reform on the multiple dividend benefits for water-intensive firms. Specifically, the policy group dummy variable ( $treat1_i$ ) is defined as 1 if the pollutant levy standard in the enterprise's location was raised, covering provinces such as Beijing, Hebei, Jiangsu, Shandong, Henan, Sichuan, Chongqing, Hunan, Guizhou, Hainan, Guangxi Zhuang Autonomous Region, and Shanxi. For the time dummy variable ( $post1_{i,t}$ ), the year 2018 and subsequent years are marked as 1, and other years as 0.

As Table 7 shows, the water resource tax coefficients for the environmental and technological dividends remain significant once the Environmental Protection Tax is controlled for. The multiple dividends are therefore not simply a by-product of that reform.

Even after the Environmental Protection Tax is included, the water resource tax coefficients for environmental protection and technological innovation stay stable and significant, while the Environmental Protection Tax itself is not significant in the firm-level specification used here.

### 4.3.3 Propensity Score Matching Method

Sample selection bias is addressed with a propensity score matching difference-in-differences (PSM-DID) design. Using firm-level covariates and nearest-neighbor, radius, and kernel matching, the treatment and control groups are made comparable on key attributes. A few unmatched observations are dropped and the multi-period DID model is re-estimated; Tables 8–10 report the results. The baseline conclusions are unchanged, which suggests selection bias is not driving them.

Table 8  
PSM Regression Results for the Environmental Dividend

| Variable                                                                                                                       | (1)                   | (2)                   | (3)                   |
|--------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                                                                                                | 1:1                   | Radius Matching       | Kernel Matching       |
| DID                                                                                                                            | -4.056***<br>(-8.182) | -3.068***<br>(-9.850) | -2.875***<br>(-9.347) |
| Size                                                                                                                           | 1.237**<br>(2.388)    | 1.308***<br>(2.991)   | 1.094**<br>(2.504)    |
| Lev                                                                                                                            | -5.066***<br>(-2.975) | -6.043***<br>(-4.763) | -5.315***<br>(-4.162) |
| Board                                                                                                                          | 0.129<br>(0.152)      | 0.494<br>(0.614)      | 0.250<br>(0.304)      |
| Top1                                                                                                                           | -0.049**<br>(-1.966)  | -0.109***<br>(-5.293) | -0.111***<br>(-5.381) |
| Fixed                                                                                                                          | -0.792<br>(-0.463)    | 2.978**<br>(2.128)    | 2.804**<br>(1.973)    |
| ListAge                                                                                                                        | 0.530<br>(0.981)      | -0.190<br>(-0.359)    | 0.155<br>(0.301)      |
| Subsidy                                                                                                                        | -0.391***<br>(-4.978) | -0.419***<br>(-6.182) | -0.444***<br>(-7.127) |
| Constant                                                                                                                       | -9.741<br>(-0.873)    | -6.443<br>(-0.666)    | -1.577<br>(-0.161)    |
| Observations                                                                                                                   | 1,852                 | 3,810                 | 3,851                 |
| R                                                                                                                              | 0.892                 | 0.836                 | 0.837                 |
| Firm Fixed Effects                                                                                                             | Yes                   | Yes                   | Yes                   |
| Year Fixed Effects                                                                                                             | Yes                   | Yes                   | Yes                   |
| R2                                                                                                                             | 0.861                 | 0.811                 | 0.812                 |
| F                                                                                                                              | 15.600                | 28.570                | 28.220                |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |                       |                       |                       |

Table 9  
PSM Regression Results for the Technological Dividend

| Variable                                                                                                                                      | (1)                 | (2)                  | (3)                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|----------------------|
|                                                                                                                                               | 1:1                 | Radius Matching      | Kernel Matching      |
| DID                                                                                                                                           | 0.269***<br>(4.165) | 0.341***<br>(8.469)  | 0.349***<br>(8.747)  |
| Size                                                                                                                                          | 0.105**<br>(2.223)  | 0.082***<br>(2.935)  | 0.097***<br>(3.550)  |
| Lev                                                                                                                                           | 0.179<br>(0.929)    | -0.020<br>(-0.187)   | -0.045<br>(-0.428)   |
| Board                                                                                                                                         | -0.216<br>(-1.462)  | -0.153*<br>(-1.757)  | -0.137<br>(-1.587)   |
| Top1                                                                                                                                          | -0.001<br>(-0.507)  | -0.003*<br>(-1.693)  | -0.003<br>(-1.597)   |
| Fixed                                                                                                                                         | -0.158<br>(-0.777)  | -0.153<br>(-1.355)   | -0.168<br>(-1.508)   |
| ListAge                                                                                                                                       | -0.080<br>(-0.824)  | -0.117**<br>(-2.281) | -0.122**<br>(-2.392) |
| Subsidy                                                                                                                                       | -0.002<br>(-0.240)  | 0.005<br>(0.673)     | 0.001<br>(0.160)     |
| Constant                                                                                                                                      | -1.166<br>(-1.083)  | -0.724<br>(-1.177)   | -1.012*<br>(-1.659)  |
| Observations                                                                                                                                  | 1,852               | 3,810                | 3,851                |
| R                                                                                                                                             | 0.730               | 0.695                | 0.694                |
| Firm Fixed Effects                                                                                                                            | Yes                 | Yes                  | Yes                  |
| Year Fixed Effects                                                                                                                            | Yes                 | Yes                  | Yes                  |
| R2                                                                                                                                            | 0.652               | 0.649                | 0.648                |
| F                                                                                                                                             | 3.090               | 11.090               | 11.910               |
| Note: Parentheses contain t-statistics adjusted for heteroskedasticity, with *, ** and *** marking significance at the 10%, 5% and 1% levels. |                     |                      |                      |

Table 10  
PSM Regression Results for the Economic Dividend

| Variable                                                                                                                              | (1)                   | (2)                   | (3)                   |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                                                                                                       | 1:1                   | Radius Matching       | Kernel Matching       |
| DID                                                                                                                                   | 0.013<br>(1.368)      | 0.004<br>(0.625)      | 0.004<br>(0.662)      |
| Size                                                                                                                                  | 0.043***<br>(3.923)   | 0.046***<br>(7.163)   | 0.048***<br>(7.546)   |
| Lev                                                                                                                                   | -0.294***<br>(-6.292) | -0.252***<br>(-9.180) | -0.257***<br>(-9.702) |
| Board                                                                                                                                 | -0.014<br>(-0.603)    | 0.001<br>(0.095)      | 0.001<br>(0.043)      |
| Top1                                                                                                                                  | 0.000<br>(0.063)      | 0.000<br>(0.007)      | -0.000<br>(-0.301)    |
| Fixed                                                                                                                                 | -0.039<br>(-1.242)    | -0.078***<br>(-3.796) | -0.076***<br>(-3.750) |
| ListAge                                                                                                                               | 0.016<br>(1.186)      | -0.004<br>(-0.458)    | -0.005<br>(-0.671)    |
| Subsidy                                                                                                                               | 0.001<br>(0.767)      | 0.002*<br>(1.907)     | 0.002*<br>(1.759)     |
| Constant                                                                                                                              | -0.784***<br>(-3.306) | -0.858***<br>(-5.995) | -0.888***<br>(-6.300) |
| Observations                                                                                                                          | 1,852                 | 3,810                 | 3,851                 |
| R                                                                                                                                     | 0.502                 | 0.450                 | 0.451                 |
| Firm Fixed Effects                                                                                                                    | Yes                   | Yes                   | Yes                   |
| Year Fixed Effects                                                                                                                    | Yes                   | Yes                   | Yes                   |
| R2                                                                                                                                    | 0.357                 | 0.367                 | 0.368                 |
| F                                                                                                                                     | 6.317                 | 18.530                | 20.590                |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |                       |                       |                       |

# 4.3.4 Changing Fixed Effects

Because the water resource tax is differentiated by province and industry, the specification is re-estimated with industry, province, and year fixed effects. These absorb cross-industry differences in water dependence, provincial differences in industrialization and water endowments, and common time shocks. The specific results are shown in Table 11.

Table 11  
Regression Results with Changed Fixed Effects

| Variable                                                                                                                       | (1)                    | (2)                    | (3)                    |
|--------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------------|------------------------|
|                                                                                                                                | <i>HCE</i>             | <i>REP</i>             | <i>ROE</i>             |
| DID                                                                                                                            | -1.952***<br>(-5.846)  | 0.267***<br>(5.097)    | 0.007<br>(1.036)       |
| Size                                                                                                                           | 0.668***<br>(6.173)    | 0.229***<br>(11.756)   | 0.027***<br>(13.284)   |
| Lev                                                                                                                            | -2.978***<br>(-4.393)  | -0.050<br>(-0.552)     | -0.129***<br>(-9.847)  |
| Board                                                                                                                          | -0.398<br>(-0.908)     | 0.103<br>(1.435)       | 0.009<br>(1.113)       |
| Top1                                                                                                                           | -0.069***<br>(-10.975) | 0.001<br>(1.058)       | 0.000<br>(0.983)       |
| Fixed                                                                                                                          | 2.559***<br>(3.326)    | 0.351***<br>(3.758)    | -0.058***<br>(-4.728)  |
| ListAge                                                                                                                        | 1.047***<br>(5.860)    | -0.077***<br>(-3.327)  | -0.020***<br>(-8.520)  |
| Subsidy                                                                                                                        | -0.320***<br>(-6.861)  | 0.008<br>(1.141)       | -0.001<br>(-0.858)     |
| Constant                                                                                                                       | 2.851<br>(1.489)       | -5.011***<br>(-12.976) | -0.415***<br>(-10.705) |
| Observations                                                                                                                   | 3,855                  | 3,855                  | 3,855                  |
| R                                                                                                                              | 0.771                  | 0.278                  | 0.197                  |
| Firm Fixed Effects                                                                                                             | Yes                    | Yes                    | Yes                    |
| Year Fixed Effects                                                                                                             | Yes                    | Yes                    | Yes                    |
| Province Fixed Effects                                                                                                         | Yes                    | Yes                    | Yes                    |
| $R^2$                                                                                                                          | 0.767                  | 0.264                  | 0.181                  |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |                        |                        |                        |

| Variable                                                                                                                       | (1)        | (2)        | (3)        |
|--------------------------------------------------------------------------------------------------------------------------------|------------|------------|------------|
|                                                                                                                                | <i>HCE</i> | <i>REP</i> | <i>ROE</i> |
| <i>F</i>                                                                                                                       | 50.930     | 40.780     | 35.090     |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |            |            |            |

## 4.4 Heterogeneity Test

The results above average over all firms. Because water endowments differ sharply across provinces and firms at different life-cycle stages respond differently to cost shocks, the average effect may hide offsetting patterns. This section therefore splits the sample by regional water stress and by corporate life-cycle stage.

### 4.4.1 Heterogeneity of Water Resource Endowment

Following Falkenmark and Widstrand [8], this paper uses per capita water resources (the water stress index, WSI) to measure regional water supply-demand pressure. We also draw on the study of Vörösmarty et al. [24] and adopt 1700 m<sup>3</sup>/year as the threshold for determining regional water stress. Based on this criterion, this paper further divides the regions of China into two major categories: non-water-scarce areas and water-stressed areas, as detailed in Fig. 4.

Table 12 reports the split by water endowment. For the environmental dividend the tax produces a significant water-saving effect in both groups, but the effect is larger where water is abundant. The likely reason is that in well-endowed regions resource scarcity is not felt, so water is used casually, efficiency stays low, and an external diseconomy persists. The tax internalizes that externality and gives firms a reason to raise efficiency and cut waste.

The technological dividend also appears in both groups, and here the ranking reverses: the effect is stronger where water is stressed. Firms in these regions operate under evident scarcity, face sharper pressure, and are therefore more willing to cut consumption through innovation and to align with environmental policy. Non-water-scarce regions lag, which is consistent with weaker existing innovation capacity and thinner economic incentives and policy support.

For the economic dividend, only non-water-scarce regions show a significant effect. There the reform may lift performance indirectly, by improving operational efficiency or lowering costs over time. In water-stressed regions, by contrast, firms do innovate, but the upfront cost of new technology is high and payback is slow, so the near-term effect on return on equity is muted.

Table 12  
Regression Results for Water Resource Endowment

| Variable                                                                                                                                      | (1)                   | (2)                 | (3)                   | (4)                 | (5)                   | (6)       |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|-----------|
|                                                                                                                                               | HCE                   | HCE                 | REP                   | REP                 | ROE                   | ROE       |
| Water-stressed Area                                                                                                                           | Non-water-scarce Area | Water-stressed Area | Non-water-scarce Area | Water-stressed Area | Non-water-scarce Area |           |
| DID                                                                                                                                           | -1.198**              | -5.607***           | 0.417***              | 0.164**             | -0.003                | 0.022*    |
|                                                                                                                                               | (-2.230)              | (-10.053)           | (7.983)               | (2.037)             | (-0.344)              | (1.652)   |
| Size                                                                                                                                          | -0.176                | 2.628***            | 0.146***              | 0.048               | 0.044***              | 0.053***  |
|                                                                                                                                               | (-0.307)              | (3.883)             | (3.589)               | (1.202)             | (5.822)               | (4.709)   |
| Lev                                                                                                                                           | -4.526**              | -7.059***           | -0.051                | -0.039              | -0.266***             | -0.251*** |
|                                                                                                                                               | (-2.417)              | (-3.700)            | (-0.342)              | (-0.248)            | (-7.965)              | (-5.651)  |
| Board                                                                                                                                         | -0.320                | 0.668               | -0.181                | -0.095              | -0.020                | 0.027     |
|                                                                                                                                               | (-0.266)              | (0.593)             | (-1.540)              | (-0.691)            | (-0.963)              | (1.148)   |
| Top1                                                                                                                                          | -0.119***             | -0.094***           | -0.005**              | 0.000               | 0.000                 | 0.000     |
|                                                                                                                                               | (-4.683)              | (-2.775)            | (-2.004)              | (-0.120)            | (0.011)               | (-0.820)  |
| Fixed                                                                                                                                         | 1.371                 | 5.085***            | -0.413***             | 0.104               | -0.065**              | -0.104*** |
|                                                                                                                                               | (0.619)               | (2.594)             | (-2.592)              | (0.606)             | (-2.403)              | (-3.098)  |
| ListAge                                                                                                                                       | -1.343*               | 2.360***            | -0.126*               | -0.084              | 0.008                 | -0.022    |
|                                                                                                                                               | (-1.854)              | (2.985)             | (-1.827)              | (-1.029)            | (0.855)               | (-1.508)  |
| Subsidy                                                                                                                                       | -0.369***             | -0.519***           | -0.003                | 0.010               | 0.003**               | 0.000     |
|                                                                                                                                               | (-4.820)              | (-4.482)            | (-0.429)              | (0.793)             | (2.468)               | (-0.134)  |
| Constant                                                                                                                                      | 29.982**              | -40.586***          | -1.789**              | -0.456              | -0.802***             | -0.975*** |
|                                                                                                                                               | (2.271)               | (-2.733)            | (-1.968)              | (-0.507)            | (-4.636)              | (-3.965)  |
| Observations                                                                                                                                  | 2,305                 | 1,550               | 2,305                 | 1,550               | 2,305                 | 1,550     |
| R                                                                                                                                             | 0.857                 | 0.807               | 0.741                 | 0.631               | 0.472                 | 0.467     |
| Firm Fixed Effects                                                                                                                            | Yes                   | Yes                 | Yes                   | Yes                 | Yes                   | Yes       |
| Note: Parentheses contain t-statistics adjusted for heteroskedasticity, with *, ** and *** marking significance at the 10%, 5% and 1% levels. |                       |                     |                       |                     |                       |           |

| Variable                                                                                                                                      | (1)                   | (2)                 | (3)                   | (4)                 | (5)                   | (6)    |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|--------|
|                                                                                                                                               | HCE                   | HCE                 | REP                   | REP                 | ROE                   | ROE    |
| Water-stressed Area                                                                                                                           | Non-water-scarce Area | Water-stressed Area | Non-water-scarce Area | Water-stressed Area | Non-water-scarce Area |        |
| Year Fixed Effects                                                                                                                            | Yes                   | Yes                 | Yes                   | Yes                 | Yes                   | Yes    |
| R2                                                                                                                                            | 0.827                 | 0.762               | 0.687                 | 0.545               | 0.361                 | 0.344  |
| F                                                                                                                                             | 8.130                 | 29.650              | 10.750                | 1.223               | 12.880                | 10.200 |
| Note: Parentheses contain t-statistics adjusted for heteroskedasticity, with *, ** and *** marking significance at the 10%, 5% and 1% levels. |                       |                     |                       |                     |                       |        |

## 4.4.2 Heterogeneity of Corporate Life Cycle

Following the conventional life-cycle classification, the sample firms are divided into three groups—growth, mature, and decline—based on the positive and negative combinations of net cash flows from operating, investing, and financing activities, to further analyze the impact of the water resource tax on the environmental dividend of water-intensive firms.

Table 13 splits the environmental dividend by life-cycle stage. The growth- and mature-stage coefficients are – 3.351 and – 2.996, both significant at the 1% level, so firms at these two stages deliver a clear environmental dividend. In the decline stage the coefficient is 1.339 and insignificant, which means no comparable effect is visible.

Growth- and mature-stage firms have reasons to expand and to accumulate capital, which leaves them room to adjust strategy when policy changes. Mature firms in particular have an interest in protecting market position and brand, and corporate social responsibility of the kind that covers environmental protection serves that interest. For them the tax is an opportunity to demonstrate conservation and burnish their image. They are also better placed to invest in efficient water management systems and technologies, which lowers operating costs and supports competitiveness, producing the observed dividend.

Decline-stage firms show nothing of the kind. Their attention is fixed on cutting costs and keeping existing operations running rather than on innovation or expansion, and that focus pushes environmental and water-saving investment down the list. The incentive the tax creates therefore goes largely unanswered.

Table 13  
Regression Results for the Environmental Dividend by Corporate Life Cycle

| Variable                                                                                                                              | (1)                   | (2)                   | (3)                  |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|----------------------|
|                                                                                                                                       | Growth Stage          | Mature Stage          | Decline Stage        |
| DID                                                                                                                                   | -3.351***<br>(-5.509) | -2.996***<br>(-5.623) | 1.339<br>(0.497)     |
| Size                                                                                                                                  | 1.624**<br>(2.460)    | 0.920<br>(1.571)      | -0.260<br>(-0.065)   |
| Lev                                                                                                                                   | -5.492***<br>(-2.905) | -4.123*<br>(-1.771)   | -10.681<br>(-0.956)  |
| Board                                                                                                                                 | -1.592<br>(-1.183)    | 1.207<br>(0.816)      | 3.760<br>(0.923)     |
| Top1                                                                                                                                  | -0.015<br>(-0.355)    | -0.143***<br>(-5.181) | -0.123<br>(-0.919)   |
| Fixed                                                                                                                                 | -2.153<br>(-0.975)    | 6.567***<br>(2.710)   | -2.122<br>(-0.166)   |
| ListAge                                                                                                                               | -0.153<br>(-0.164)    | 0.324<br>(0.370)      | -0.100<br>(-0.028)   |
| Subsidy                                                                                                                               | -0.246**<br>(-2.435)  | -0.426***<br>(-5.128) | -0.436**<br>(-1.994) |
| Constant                                                                                                                              | -13.830<br>(-0.984)   | -1.051<br>(-0.076)    | 24.380<br>(0.272)    |
| Observations                                                                                                                          | 1,541                 | 1,821                 | 493                  |
| R                                                                                                                                     | 0.875                 | 0.881                 | 0.869                |
| Firm Fixd Effects                                                                                                                     | Yes                   | Yes                   | Yes                  |
| Year Fixd Effects                                                                                                                     | Yes                   | Yes                   | Yes                  |
| R2                                                                                                                                    | 0.828                 | 0.841                 | 0.706                |
| F                                                                                                                                     | 5.975                 | 15.470                | 0.931                |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |                       |                       |                      |

Table 14 turns to the technological dividend. Growth- and mature-stage coefficients are 0.464 and 0.434, both positive at the 1% level, indicating active innovation at these stages. In the decline stage the coefficient is -0.134 and insignificant, so innovative activity there is not evident.

Specifically, during the growth stage, enterprises are typically highly sensitive to changes in the external environment and have strong adaptability, which drives them to seek new opportunities for development through technological innovation. Furthermore, firms in the growth stage often have flexible management mechanisms and a strong sense of innovation, which enables them to quickly adjust their strategies and actively invest in technological innovation when facing the pressure of environmental policies. As for mature firms, due to their strong market competitiveness and ample capital accumulation, they are able to undertake significant R&D investment. Faced with the policy pressure of the water resource tax, these enterprises have not only the ability but also the motivation to invest in the research and development of water-saving technologies and innovation to reduce water consumption and lower the corresponding tax burden. Therefore, the water resource tax effectively promotes innovative activities related to water-saving patents for enterprises in these two stages.

In contrast, firms in the decline stage may be more cautious and conservative in their investment in technological innovation due to differences in their developmental stage and resource allocation strategies. These enterprises may face significant financial pressures and resource constraints, which limit their ability to invest in new technologies and innovate. Under such circumstances, even if there is a need for water conservation, the firms may lack sufficient funds to support the R&D and implementation of related technologies. Furthermore, firms in the decline stage may focus more on cost control and organizational restructuring rather than the development of new technologies. This leads them to strategically de-prioritize large-scale investment in technological innovation, especially when its economic benefits are not apparent. Therefore, during the implementation period of the water resource tax policy, the improvement in the technological dividend for firms in the decline stage is not significant.

Table 14  
Regression Results for the Technological Dividend by Corporate Life Cycle

| Variable                                                                                                                       | (1)                 | (2)                 | (3)                |
|--------------------------------------------------------------------------------------------------------------------------------|---------------------|---------------------|--------------------|
|                                                                                                                                | Growth Stage        | Mature Stage        | Decline Stage      |
| DID                                                                                                                            | 0.464***<br>(6.593) | 0.434***<br>(5.719) | -0.134<br>(-1.075) |
| Size                                                                                                                           | 0.120**<br>(2.294)  | 0.115**<br>(2.260)  | -0.012<br>(-0.072) |
| Lev                                                                                                                            | -0.138<br>(-0.761)  | -0.203<br>(-1.039)  | -0.095<br>(-0.269) |
| Board                                                                                                                          | -0.155<br>(-0.972)  | -0.090<br>(-0.567)  | -0.500<br>(-1.545) |
| Top1                                                                                                                           | 0.000<br>(0.020)    | -0.004<br>(-1.606)  | -0.009<br>(-1.339) |
| Fixed                                                                                                                          | -0.025<br>(-0.131)  | -0.283<br>(-1.464)  | 0.292<br>(0.714)   |
| ListAge                                                                                                                        | -0.105<br>(-1.156)  | -0.109<br>(-1.189)  | -0.178<br>(-0.837) |
| Subsidy                                                                                                                        | 0.025<br>(1.221)    | -0.001<br>(-0.087)  | 0.016<br>(1.047)   |
| Constant                                                                                                                       | -2.088*<br>(-1.782) | -1.311<br>(-1.151)  | 1.945<br>(0.531)   |
| Observations                                                                                                                   | 1,541               | 1,821               | 493                |
| R                                                                                                                              | 0.727               | 0.758               | 0.086              |
| Firm Fixd Effects                                                                                                              | Yes                 | Yes                 | Yes                |
| Year Fixd Effects                                                                                                              | Yes                 | Yes                 | Yes                |
| R2                                                                                                                             | 0.625               | 0.677               | 0.052              |
| F                                                                                                                              | 7.854               | 5.139               | 0.991              |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |                     |                     |                    |

Table 15 covers the economic dividend. The growth- and mature-stage coefficients, 0.003 and  $-0.004$ , are both insignificant, so no economic dividend arises at those stages. The decline stage is different: its coefficient of 0.062 is significant at the 5% level, indicating that an economic dividend does materialize there.

Specifically, firms in the decline stage face the dual pressures of unstable market positions and declining operational efficiency, urgently needing to seek survival and opportunities for transformation through cost control and improved operational efficiency. Against this backdrop, the introduction of the water resource tax policy, acting as an external economic incentive, stimulated these enterprises to strengthen their water resource management and cost-benefit analysis, and produced gains in economic performance within a comparatively short period. In comparison, due to their different business strategies and resource allocation advantages, the response of firms in the growth and mature stages to the water resource tax policy did not manifest as significant growth in economic performance in the short term. Firms in the growth stage, being more focused on expanding market share and business scale, may find it difficult to adjust their business strategies in the short term to respond to the new tax policy. As for mature firms, although they possess a more stable market position and resource advantages, adjustments to their business strategies also require a certain amount of time to be implemented gradually. Therefore, during the implementation period of the water resource tax policy, the improvement in the economic dividend for these enterprises was not significant.

Table 15  
Regression Results for the Economic Dividend by Corporate Life Cycle

| Variable                                                                                                                                      | (1)                   | (2)                   | (3)                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                                                                                                               | Growth Stage          | Mature Stage          | Decline Stage         |
| DID                                                                                                                                           | 0.003<br>(0.255)      | -0.004<br>(-0.434)    | 0.062**<br>(2.303)    |
| Size                                                                                                                                          | 0.045***<br>(4.447)   | 0.041***<br>(3.681)   | 0.099***<br>(3.700)   |
| Lev                                                                                                                                           | -0.236***<br>(-5.533) | -0.219***<br>(-4.794) | -0.512***<br>(-3.977) |
| Board                                                                                                                                         | 0.022<br>(0.796)      | -0.001<br>(-0.024)    | 0.012<br>(0.177)      |
| Top1                                                                                                                                          | 0.001<br>(1.330)      | -0.000<br>(-0.739)    | -0.001<br>(-0.344)    |
| Fixed                                                                                                                                         | -0.148***<br>(-4.643) | -0.038<br>(-1.051)    | -0.054<br>(-0.494)    |
| ListAge                                                                                                                                       | -0.011<br>(-0.680)    | -0.013<br>(-1.077)    | 0.084**<br>(2.114)    |
| Subsidy                                                                                                                                       | -0.001<br>(-0.409)    | 0.003**<br>(2.093)    | -0.000<br>(-0.106)    |
| Constant                                                                                                                                      | -0.837***<br>(-3.773) | -0.741***<br>(-3.012) | -2.142***<br>(-3.533) |
| Observations                                                                                                                                  | 1,541                 | 1,821                 | 493                   |
| R                                                                                                                                             | 0.501                 | 0.557                 | 0.780                 |
| Firm Fixd Effects                                                                                                                             | Yes                   | Yes                   | Yes                   |
| Year Fixd Effects                                                                                                                             | Yes                   | Yes                   | Yes                   |
| R2                                                                                                                                            | 0.312                 | 0.408                 | 0.505                 |
| F                                                                                                                                             | 11.930                | 5.129                 | 4.592                 |
| Note: Parentheses contain t-statistics adjusted for heteroskedasticity, with *, ** and *** marking significance at the 10%, 5% and 1% levels. |                       |                       |                       |

## 5 Mechanism Test

The results so far show that the water resource tax affects the environmental and technological dividends. The next step is to identify the channels through which these effects operate.

### 5.1 The Water Resource Tax

The water resource tax works through firms' own interests. Water resource fees had long been set at low rates, which let firms treat water as a cheap input and led to over-consumption. The reform raised the applicable rates and, by internalizing the cost, tightened the budget constraint on water use and reduced wasteful demand. The water resource tax improves water use efficiency by promoting water-saving technologies and enhancing water conservation awareness. Although R&D for water-saving technology requires substantial capital investment and may not yield immediate results, this can lead to reduced production, higher product prices, and a shift by consumers to lower-cost substitutes, and so reducing consumption of high-water-consumption products by an indirect route [4]. Furthermore, water conservation awareness, by influencing an enterprise's expectations regarding water saving, promotes the adoption of water-saving measures; the expected economic benefits of these actions then transform awareness into actual water-saving behavior [12].

For a water-intensive firm the tax bill moves with the volume abstracted. A higher rate on consumption above the planned quota lifts the marginal cost of water and, with it, total production cost. Firms contain that cost in familiar ways: upgrading water-saving equipment, cutting water use per unit of output, and improving efficiency. The reform thus raises the taxes payable these firms report, and the cost effect is what pushes them toward water-saving technology and management practice.

Based on this, this paper selects the logarithm of corporate water resource taxes and fees as the mechanism variable for the cost burden of taxes and fees to test how the water resource tax, through the mechanism of increasing taxes payable, stimulates water-saving behavior at the firm level and so brings the environmental dividend about. The specific model is as follows:

$$HCE_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$$

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$$SZYS_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$$

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Table 16 reports the estimates. Columns (1) and (2) give DID coefficients of -2.856 and 0.391, negative and positive respectively, each significant at the 1% level, which shows that the reform promotes the environmental dividend. The reform raised collection standards for water resource taxes and fees, and firms responded by adopting water-saving measures to relieve the pressure on their tax burden. Column (3) reports a Sobel test with a Z-statistic of -2.280, negative and significant at the 1% level, and a

Bootstrap test with 1,000 replications whose indirect mediation effect is -9.610, also negative and significant at 1%. The mediating role of water resource taxes and fees (SZYS) is thus supported, and it operates in favour of the environmental dividend.

In short, higher water costs give firms a reason to save water, and that is the route by which the environmental dividend is realized.

Table 16  
Mechanism Test Results for the Water Resource Tax and Environmental Dividend

| Variable                                                                                                                              | (1)       | (2)      | (3)       |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------|----------|-----------|
|                                                                                                                                       | HCE       | SZYS     | HCE       |
| SZYS                                                                                                                                  |           |          | -0.235*** |
|                                                                                                                                       |           |          | (-3.720)  |
| DID                                                                                                                                   | -2.856*** | 0.391*** | -2.764*** |
|                                                                                                                                       | (-9.163)  | (2.886)  | (-8.950)  |
| Size                                                                                                                                  | 0.981**   | 0.729*** | 1.153**   |
|                                                                                                                                       | (2.213)   | (6.208)  | (2.536)   |
| Lev                                                                                                                                   | -5.702*** | -1.085** | -5.957*** |
|                                                                                                                                       | (-4.452)  | (-2.501) | (-4.685)  |
| Board                                                                                                                                 | 0.340     | -0.053   | 0.328     |
|                                                                                                                                       | (0.406)   | (-0.156) | (0.395)   |
| Top1                                                                                                                                  | -0.108*** | 0.013**  | -0.105*** |
|                                                                                                                                       | (-5.182)  | (2.243)  | (-5.038)  |
| Fixed                                                                                                                                 | 2.287     | 1.291*** | 2.591*    |
|                                                                                                                                       | (1.579)   | (2.806)  | (1.781)   |
| ListAge                                                                                                                               | 0.133     | -0.460** | 0.024     |
|                                                                                                                                       | (0.252)   | (-2.543) | (0.047)   |
| Subsidy                                                                                                                               | -0.418*** | 0.007    | -0.416*** |
|                                                                                                                                       | (-6.117)  | (0.272)  | (-6.179)  |
| Constant                                                                                                                              | 0.529     | -1.959   | 0.068     |
|                                                                                                                                       | (0.053)   | (-0.740) | (0.007)   |
| Observations                                                                                                                          | 3,749     | 3,749    | 3,749     |
| R                                                                                                                                     | 0.837     | 0.704    | 0.838     |
| Firm Fixd Effects                                                                                                                     | Yes       | Yes      | Yes       |
| Year Fixd Effects                                                                                                                     | Yes       | Yes      | Yes       |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |           |          |           |

| Variable                                                                                                                              | (1)    | (2)   | (3)       |
|---------------------------------------------------------------------------------------------------------------------------------------|--------|-------|-----------|
|                                                                                                                                       | HCE    | SZYS  | HCE       |
| R2                                                                                                                                    | 0.812  | 0.658 | 0.813     |
| F                                                                                                                                     | 26.050 | 8.144 | 25.770    |
| Sobel Z                                                                                                                               |        |       | -2.280**  |
| Bootstrap                                                                                                                             |        |       | -9.610*** |
| Note: Robust t-statistics are shown in parentheses. Significance levels of 10%, 5% and 1% are denoted by *, ** and ***, respectively. |        |       |           |

## 5.2 R&D Investment

The water resource tax is mandatory, and as such it both signals the government's commitment to water protection and tells the market that conservation and efficiency are being encouraged. By raising tax costs it directs firms' R&D toward water-saving and environmental technology. R&D spending is a precondition for innovation and the material basis on which green technology is turned into market competitiveness, and it has a positive bearing on green innovation [19]. Motivated by the water resource tax, enterprises' R&D momentum is enhanced, and they are more willing to allocate funds to improve technologies to reduce water consumption and pollution emissions. This policy incentive makes enterprises more inclined to invest in developing new water-saving technologies and upgrading existing wastewater recycling and treatment systems. Through these measures, enterprises can reduce water consumption at the front end while strengthening wastewater recycling at the back end, effectively advancing wastewater treatment.

The cumulative effect of this R&D and innovation is a larger stock of water-saving patents and a distinctive market advantage. Financial pressure from the tax is converted into R&D effort. A bigger patent portfolio strengthens the firm's market position, helps it reach scale economies, and supports greener development, while outside investors and market participants tend to favour firms that combine environmental responsibility with innovative capability.

Based on this, this paper selects the logarithm of corporate R&D investment as the mechanism variable to test how the water resource tax, through the mechanism of R&D investment, stimulates water-saving behavior at the firm level and so brings the technological dividend about. The specific model is as follows:

$$HCE_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$$

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$$R\&D_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \lambda X_{i,t} + \mu_i + \varphi_t + \epsilon_{i,t}$$

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Table 17  
Mechanism Test Results for R&D Investment and Water-saving Patents

| Variable                                                                                                                       | (1)                  | (2)                   | (3)                  |
|--------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------|----------------------|
|                                                                                                                                | REP                  | R&D                   | REP                  |
| R&D                                                                                                                            |                      |                       | 0.047***<br>(2.743)  |
| DID                                                                                                                            | 0.370***<br>(8.495)  | 0.197***<br>(3.675)   | 0.361***<br>(8.288)  |
| Size                                                                                                                           | 0.113***<br>(3.737)  | 0.725***<br>(14.166)  | 0.079**<br>(2.461)   |
| Lev                                                                                                                            | -0.056<br>(-0.489)   | -0.628***<br>(-4.017) | -0.027<br>(-0.234)   |
| Board                                                                                                                          | -0.161*<br>(-1.770)  | -0.011<br>(-0.088)    | -0.161*<br>(-1.772)  |
| Top1                                                                                                                           | -0.003<br>(-1.621)   | 0.002<br>(0.649)      | -0.003*<br>(-1.676)  |
| Fixed                                                                                                                          | -0.162<br>(-1.264)   | 0.506**<br>(2.569)    | -0.185<br>(-1.459)   |
| ListAge                                                                                                                        | -0.131**<br>(-2.424) | -0.242***<br>(-3.649) | -0.119**<br>(-2.215) |
| Subsidy                                                                                                                        | 0.006<br>(0.870)     | 0.005<br>(0.514)      | 0.006<br>(0.828)     |
| Constant                                                                                                                       | -1.370**<br>(-2.099) | 2.036*<br>(1.854)     | -1.465**<br>(-2.260) |
| Observations                                                                                                                   | 3,596                | 3,596                 | 3,596                |
| R                                                                                                                              | 0.697                | 0.865                 | 0.698                |
| Firm Fixd Effects                                                                                                              | Yes                  | Yes                   | Yes                  |
| Year Fixd Effects                                                                                                              | Yes                  | Yes                   | Yes                  |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |                      |                       |                      |

| Variable                                                                                                                       | (1)    | (2)    | (3)      |
|--------------------------------------------------------------------------------------------------------------------------------|--------|--------|----------|
|                                                                                                                                | REP    | R&D    | REP      |
| R2                                                                                                                             | 0.649  | 0.843  | 0.649    |
| F                                                                                                                              | 11.980 | 29.990 | 11.620   |
| Sobel Z                                                                                                                        |        |        | 2.198**  |
| Bootstrap                                                                                                                      |        |        | 5.210*** |
| Note: Heteroskedasticity-robust t-statistics appear in parentheses. *, ** and *** mark the 10%, 5% and 1% significance levels. |        |        |          |

Table 17 reports the two-equation estimates. The DID coefficient in column (1) is 0.370 and significant at the 1% level, so the reform raised water-saving patent output; the coefficient on R&D investment in column (2) is 0.197 and also significant at 1%, confirming that the tax lifted corporate research spending. Column (3) gives a Sobel Z of 2.198, positive and significant at the 5% level, and a Bootstrap indirect effect of 5.210 based on 1,000 draws, significant at 1%. The mediation running from the tax through R&D investment to water-saving patents therefore holds, and the sample covers 3,596 firm-year observations once R&D disclosure requirements reduce the panel.

The two mechanisms are distinct in character. The cost channel in Section 5.1 works by making water more expensive and so compels firms to economize; the innovation channel here works by making water-saving technology worth developing, which turns a compliance cost into a durable asset. That distinction matters for policy design, because a tax that only raises the price of water will reach its limits once low-cost conservation measures are exhausted, whereas a tax that also stimulates research generates returns that persist after the reform itself is absorbed into production costs.

## 6 Conclusions and Recommendations

Treating the water resource fee-to-tax reform as a quasi-natural experiment, this study applies a multi-period DID model to the multiple dividends accruing to water-intensive firms in the pilot provinces. Three results stand out. Water use efficiency improves—an environmental dividend, since higher water costs give firms a reason to economize. Water-saving patenting increases—a technological dividend, plausibly channelled through R&D investment. And return on equity does not respond, so no economic dividend is detectable: outlays on water-saving R&D may not pay off within the sample window, and firms in beverage-type industries face elastic demand and close substitutes, which prevents them from passing the tax on to consumers.

Water endowments differ across regions, and splitting the sample into non-water-scarce and water-stressed areas shows that the environmental dividend appears in both, though it is larger where water is not scarce; the technological dividend likewise appears in both, but is more pronounced where water is stressed; and the economic dividend is significant only where water is not scarce. Splitting firms by life-

cycle stage tells a related story. For growth- and mature-stage firms the environmental and technological dividends are the more significant, and no economic dividend is evident, whereas for decline-stage firms the economic dividend is the more pronounced while the environmental and technological dividends lose significance. The mechanism tests indicate that the reform promotes the environmental dividend by making water dearer and so inducing conservation, and achieves the technological dividend by encouraging R&D investment and strengthening innovation. In water-intensive industries the tax can therefore promote water-saving innovation and improve water use efficiency, but economic incentives for firms need strengthening.

Based on the above conclusions, this paper proposes the following policy recommendations:

First, the pilot should be extended nationwide without delay. The tax delivers environmental and technological dividends and steers water-intensive firms towards conservation, which makes nationwide rollout the logical next step. Until the tax is levied everywhere, moreover, firms in pilot provinces or in provinces with higher rates may move to regions of comparable endowment where the tax has not been introduced or the rate is lower, producing “water resource usage leakage.” Three listed water-intensive firms moved their operations out of pilot provinces over this period: one from Hebei to Qinghai in 2016, one from Shanxi to Jiangxi in 2022, and one from Beijing to Hunan in 2020. Leakage of this kind is not a technical loss but a relocation of consumption driven by differences in provincial tax policy. Since a cubic metre consumed in one province draws on the same national resource as a cubic metre consumed in another, total national water use does not fall and the conservation objective is missed. China should therefore move promptly to evaluate the pilot—jointly with water resources, finance and taxation departments—so that the experience can be summarized and the reform extended nationwide.

Second, the base tax rate should be unified. Water is basic to both production and daily life, so rate differences carry real socio-economic weight. Provinces differ in endowment, which argues for differentiated rates; yet devolving rate-setting power to local governments may undercut the conservation objective. China should therefore establish a unified national base rate, adjusted on a defined basis. The differential classifications already used across pilot regions are largely consistent—rates vary by economic development or water endowment, by whether a user is connected to public supply networks, and by whether the source is a non-over-exploited, over-exploited or severely over-exploited groundwater area—so these can serve as the adjustment factors. The calculation is: Tax Rate = Base Tax Rate × Water Scarcity Coefficient A (per capita water resources) × Water Source Coefficient B (surface or groundwater, and whether over-exploited) × Industry Coefficient C (urban public water supply, agricultural and rural domestic use, industrial and commercial use, special industries, and other sectors).

Third, revenue should be earmarked for its designated purpose. Before the reform, fees were special-purpose local revenue used mainly for water management, conservation and the running costs of grassroots water departments. Once the pilot began, the tax flowed into the local general budget, leaving those departments short of funds. Collection in the pilot regions works through taxpayer self-assessment, verification of consumption by water resource departments, and collection by tax

authorities. With funding thin at the grassroots, water resource departments may struggle to verify consumption in a timely way, and management and conservation work suffers. China should therefore allow water resource tax revenue to be earmarked for the exclusive use of water resource departments, which would fund cooperation between water resources, taxation and other departments, strengthen collection and administration, shape how firms view water use, encourage R&D and improve efficiency.

Fourth, disclosure of water resource tax and water consumption information needs strengthening. Transparency matters for efficient water management and for effective public oversight, and it can both set an example for other firms in an industry and push the whole sector towards more sustainable practice. Yet several leading water-intensive firms, despite high market share, strong innovation capacity, good reputation, a stated commitment to social responsibility and sustainable development, and mature accounting systems, have not yet disclosed their water resource tax payments or water consumption in their annual or social responsibility reports; four such firms, anonymised here as firms A to D, therefore cannot serve as models for firms in non-pilot regions. Government should strengthen the disclosure mechanism in three ways. It should establish mandatory disclosure requirements, obliging water-intensive firms to report their tax payments and water consumption clearly so that the information becomes transparent and comparable. It should work with industry associations and academic experts to develop unified disclosure standards and guidelines that ensure consistency. And it should build a sound supervision and penalty mechanism, imposing strict penalties on firms that fail to disclose as required. Measures of this kind would strengthen disclosure on water resource tax and water consumption, support the scientific and standardized management of water resources, and help secure their sustainable use and protection.

Fifth, the tax should be written into the Water Law or the Resource Tax Law as soon as possible. Pilot provinces diverge on matters such as taxable objects and taxpayers, so simply assembling the various reform documents into a national statute would be unlikely to command consensus. Some clauses of the Interim Measures for Water Resource Tax used in the pilot provinces were carried over from the Water Law—the purpose, the taxable objects and the taxpayers among them—while the Resource Tax Law contains only implicit clauses on water resource taxation and does not specify a concrete path. Once the tax is implemented nationwide it should therefore be written into the Water Law or the Resource Tax Law, refining and summarizing the consensus reached during the pilot and stating clearly what the water resource tax covers. Such an approach would draw on the pilot experience, ensure the policy is scientifically grounded and effective, and give firms firmer legal ground for standardizing their water use.

## **Declarations**

### **Ethics approval and consent to participate**

Not applicable. This study does not involve human participants, human data or human tissue, or animals.

## **Consent for publication**

Not applicable. This manuscript does not contain any individual person's data in any form.

## **Availability of data and material**

The data that support the findings of this study are available from public sources. Firm-level financial and governance data are drawn from the China Stock Market & Accounting Research (CSMAR) database and the Wind database, and patent data are obtained from the enterprise patent authorization information released by the China National Intellectual Property Administration (CNIPA). Derived datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

## **Competing interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## **Authors' contributions**

A.L. and Y.C. conceived and designed the study; A.L., Y.C., and Y.H. performed data collection, data cleaning, and statistical analysis; A.L. and Y.C. wrote the main manuscript text; Y.H. prepared figures and tables; Y.Z. provided supervision, validated the results, and revised the manuscript critically for important intellectual content; All authors reviewed and approved the final manuscript.

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## **Authors' information**

Not applicable.

## **Footnotes**

1. To determine the standard for high water-consuming industries, we comprehensively referred to the "Guidelines on Industry Classification of Listed Companies" (2012 Revision) and the "14th Five-Year Plan for Building a Water-Saving Society," while also incorporating the research findings of scholars such as Yao Peng et al. Based on the above standards and research, this paper selects the following

12 industries as the research subjects for high water-consuming industries: ferrous metal mining and processing, non-ferrous metal mining and processing, food manufacturing, manufacture of liquor, beverages and refined tea, tobacco products, papermaking and paper products, printing and reproduction of recording media, petroleum processing, coking and nuclear fuel processing, manufacture of raw chemical materials and chemical products, smelting and pressing of ferrous metals, smelting and pressing of non-ferrous metals, and production and supply of electricity and heat.

2. As some enterprises did not disclose their water resource consumption data, we adopted an estimation method for these companies. First, we calculate the average industrial water use coefficient based on the industrial operating water costs of all high water-consuming enterprises within a province; then, this coefficient is applied to the target enterprise's operating costs to estimate its water resource consumption. The rationale for this method is that industrial water consumption in high water-consuming industries typically accounts for more than 80% of the total industrial water consumption.
3. For missing data, this paper uses data from the resource tax or other relevant tax items within the 'taxes payable' account as a supplement.

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## Figures

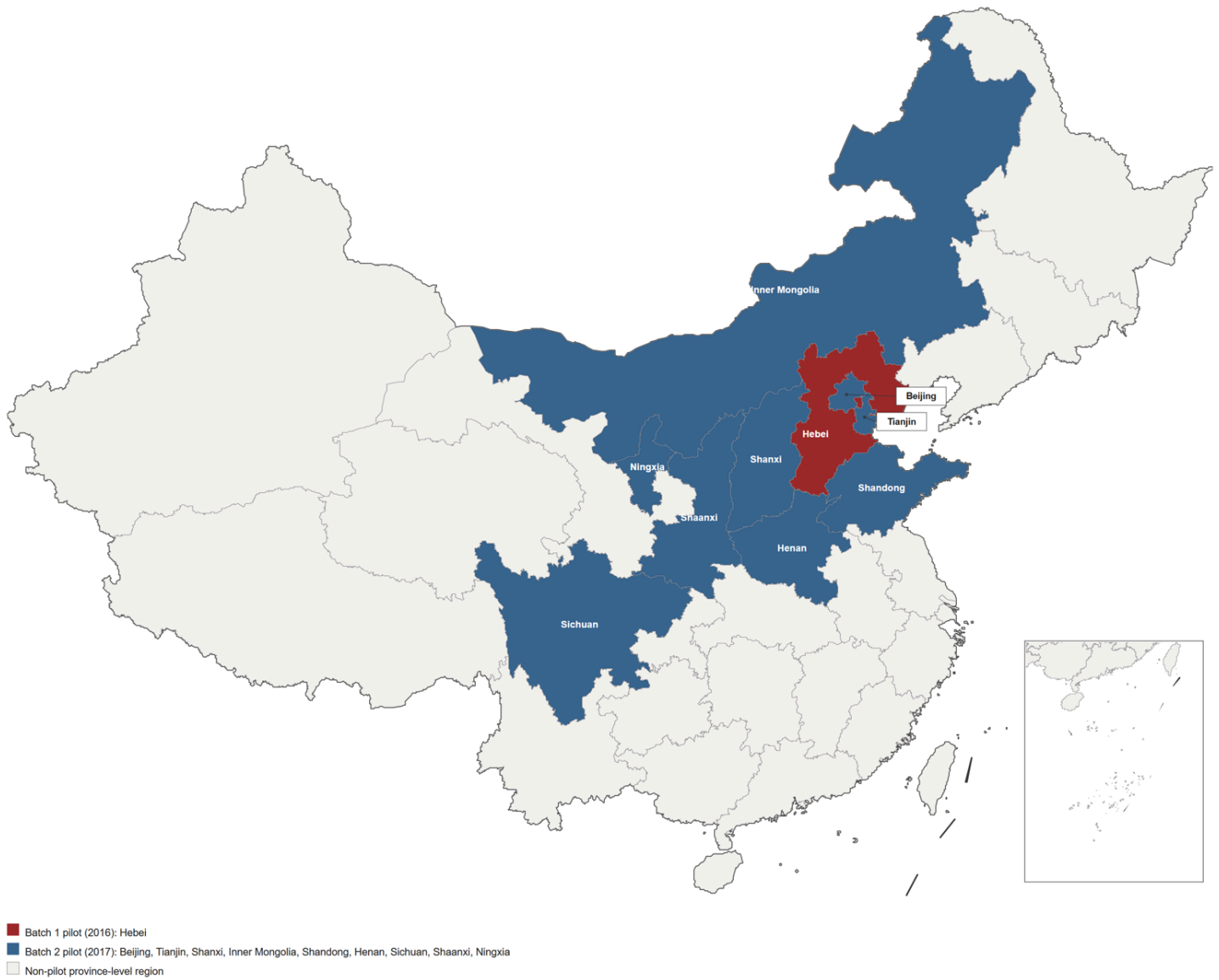


Figure 1

Pilot Provinces for Water Resource Tax in China

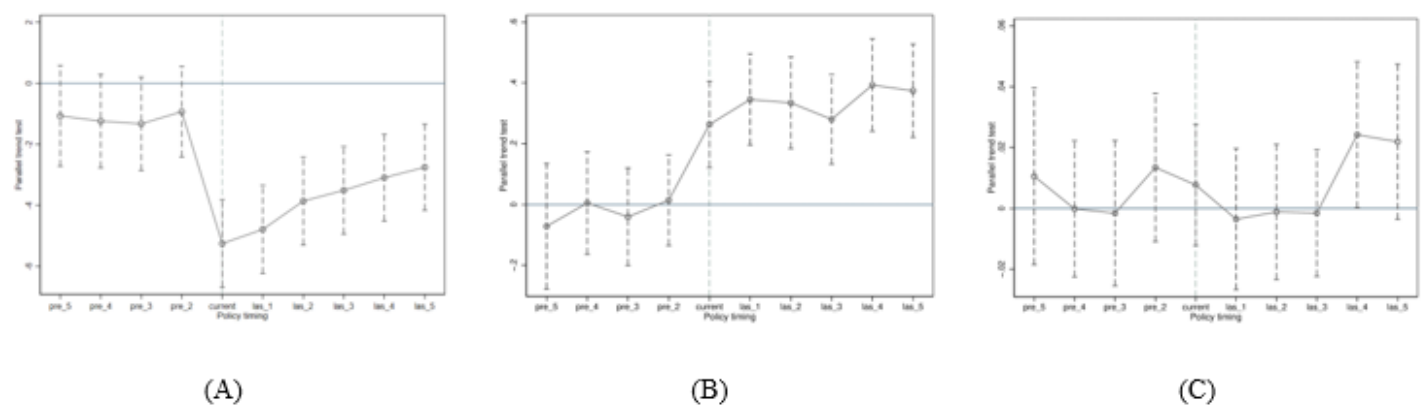


Figure 2

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Parallel trend tests for the (A) environmental dividend, (B) technological dividend, and (C) economic dividend.

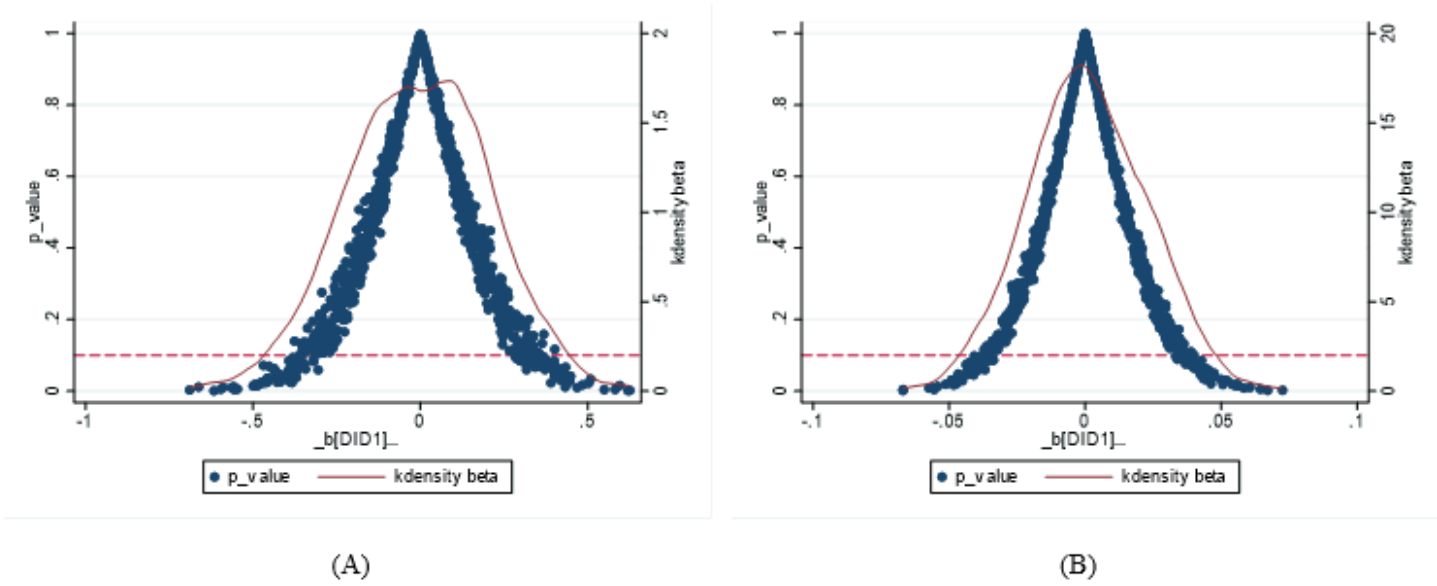


Figure 3

Placebo tests for the (A) environmental dividend and (B) technological dividend.

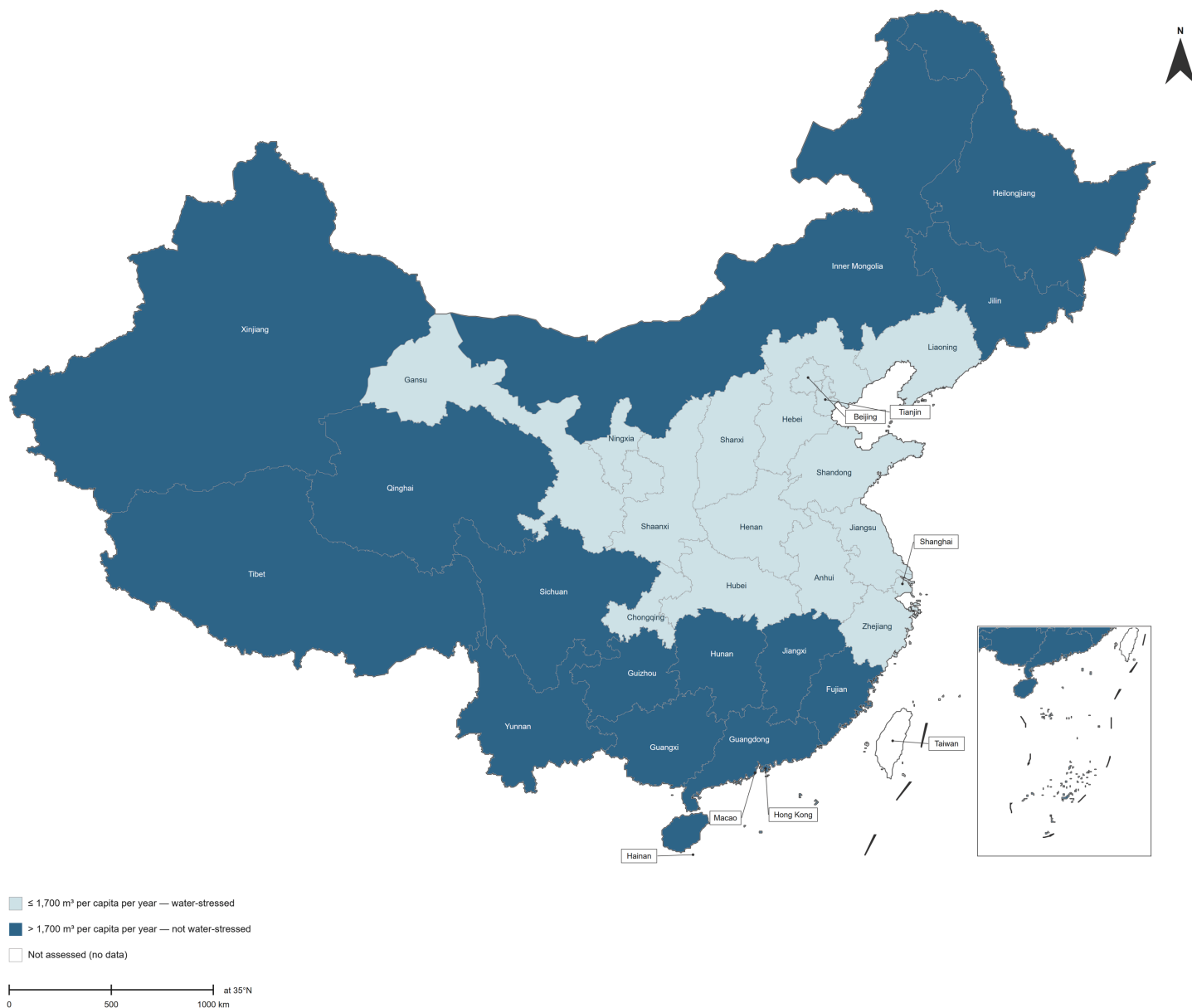


**Figure 4**

**Non-water-scarce and Water-stressed Areas**

# Supplementary Files

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