

Incremental vs. Stock: Evaluating the Impact of VAT Credit Refunds on Corporate Productivity with Evidence from Difference-in-Differences and Machine Learning Heterogeneity Analysis

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ABSTRACT This paper re-examines the effects of incremental and stock value-added tax (VAT) credit refunds on enterprise total factor productivity (TFP). Based on updated panel data from Shanghai and Shenzhen listed companies covering both the incremental-refund window and the stock-refund window, a difference-in-differences (DID) model is used to identify average productivity effects. The results show that both refund policies significantly improve corporate TFP, and the updated estimates support the interpretation that tax refunds operate through R&D investment, financing constraints, productive investment, and firm-level absorptive capacity. The effects vary across regions and firms: fiscal pressure, marketization, profitability, growth, ownership, and innovation-related capacity help explain heterogeneous responses. To connect DID estimates with firm-level heterogeneity, Logistic Regression, Random Forest, and XGBoost models are further applied. Feature-importance and SHAP analyses show that ROA, ownership, growth, leverage, capital expenditure, financing constraints, and intangible assets are key predictors of policy response. The findings provide evidence for precision-oriented fiscal policy and are relevant to capital-intensive advanced manufacturing sectors, including optical communication and electromagnetic equipment industries.

INDEX TERMS VAT credit refund, total factor productivity, DID, machine learning, advanced manufacturing

I. INTRODUCTION

CHINA's recent reforms to its value-added tax (VAT) credit refund system simplify the procedures for businesses to claim credits. This improvement is intended to boost corporate liquidity, ease financial burdens, and support a more vibrant market. The VAT credit refund policy is an essential part of China's tax policy, aimed at encouraging company investment and stimulating economic development and industrial structure improvement [1]. Existing findings show that VAT refund proportion increases greatly export volume and export performance and benefits to overall development [2]. A major fiscal policy enacted in 2019 involved substantial cuts to taxes and fees to stimulate the economy. Designed to be both comprehensive and targeted, its core objectives included reducing the tax burden on the manufacturing industry and supporting small and micro enterprises. Those methods will boost the vitality of mar-

ket entities and spur supply-side structural reforms and industrial transformation and upgrades [1]. As VAT is in all sectors of the national economy, and directly associated with the activities of a huge number of market players, it became a key instrument of China's macro control system and the main content of tax and fee reduction work. After the implementation of the VAT credit refund policy, it optimizes the enterprise's tax burden structure, strengthens the company's market confidence, but also gives birth to many new questions in local fiscal management.

Total factor productivity (TFP) serves as the primary driver and sustainable source of economic growth. China's economic strategy during its recent transition period increasingly centered on boosting Total Factor Productivity (TFP) and fostering innovation. This reflected a fundamental shift toward a growth model driven primarily by productivity gains, moving beyond factor accumulation. But, at present,

the growth rate of TFP in Chinese enterprises shows a decreasing trend, so it is necessary to further speed up the technological progress by means of technological innovation and organizational innovations. At the same time, the share of resource allocation efficiency is also still small, which calls for deepening the reform of institutions, breaking through the bottleneck of improving enterprise TFP [3].

Refunding the enterprise's accumulated input VAT, VAT credit refund policy directly increased the cash flow of enterprises and alleviated the financing constraints of enterprises. Previously, before the policies were implemented, the government was able to retain all the operating funds of the companies at no cost through the tax retention policy, which not only caused the companies to bear excessive pressure but also restricted the company's investment. Tax refunds release liquidity greatly reducing the actual tax load on firms improving firm capital structures leading to the expansion of productive capacity (e.g. purchasing of equipment, expanding factories) and more optimal resourcing of the factors leading to an improvement in TFP. And the policy also lowers the burden of taxation on corporate, the money released provides the necessary supports for enterprise technological revolution. Specifically, the refunded funds may be used for R&D activities and the purchase of advanced equipment, thereby supporting technological improvement and manufacturing efficiency. And the demand for innovation and equipment upgrade also appeals high-end talents, meanwhile the knowledge spillover of such talents and upgrading of management capability make the transformation of innovations faster, creating a cycle of "capital investment - technology upgradation - talent gathering - innovation consolidation", thus promoting TFP. However, there remains a gap in the research concerning the mechanisms through which the VAT credit refund policy affects enterprise total factor productivity (TFP), particularly in terms of separately analyzing the respective impacts of incremental and stock VAT credit refunds on TFP.

Therefore, this paper adopts the DID method to study the impact of VAT credit refund policies, specifically treating incremental and stock VAT credit refunds as policy shocks. The updated empirical results show that both policies increase enterprise TFP. Mechanism tests indicate that the policy effect is related to R&D investment, financing constraints, and productive investment rather than simple liquidity expansion. Heterogeneity tests further show that local fiscal pressure, regional marketization, firm absorptive capacity, and ownership structure shape the strength of policy transmission. On this basis, the paper adds a machine learning module to identify which firms are more likely to become high-response firms after the policy. This design keeps the average-effect DID framework as the main causal identification strategy, while using machine learning to explain cross-firm differences in policy response.

This paper adds to the study done prior in terms of 3 main parts. First of all, it is conducive to the effect verification of tax policy. So far, analysis of how tax policies

shape enterprise TFP has been largely limited to cases of VAT transformation and the "BT to VAT" reform. This paper comprehensively assesses the policy effects of the VAT credit refund policy from the perspective of enterprise TFP, extending policy effects to different TFP levels, and providing new perspectives for both theoretical and practical research. And it gives policymakers who make alterations to the tax system a more detailed theoretical backdrop. Second, this paper supplements literature on enterprise TFP related research. It analyzes the TFP on regional, time, and space to fully understand the current situation and ongoing trends of TFP among Chinese companies. It also analyzes TFP from the perspective of allocation efficiency and emerging quality productive forces, which makes the analysis of enterprise productivity more comprehensive. Third, this paper explains the different impacts of incremental and stock VAT credit refunds, it compares the distinctive impact of these two types of refund policy on enterprise TFP. Incremental VAT credit refund mainly focuses on current investment incentives, which directly promotes enterprise innovation and efficiency improvements, and the stock VAT credit refund mainly alleviates historical financial burdens and improves shortterm corporate financial situations. Through analyzing the different effects of these kinds of refund policies, this paper can further understand the special role played by those policy tools for supporting high-quality development and TFP of enterprises. In addition to the baseline DID framework, this study further introduces a data-driven analysis to identify heterogeneous firm-level policy responses. While the DID estimates capture the average effect of VAT credit refund policies on enterprise productivity, the supplementary machine learning analysis is used to distinguish which firms are more likely to exhibit stronger post-policy productivity improvement. By combining average treatment effect identification with heterogeneous response recognition, the paper extends the conventional policy evaluation framework toward a more targeted and precision-oriented analysis of tax policy effectiveness.

II. POLICY BACKGROUND AND LITERATURE REVIEW

A. VAT CREDIT REFUND POLICY

Value-added tax (VAT), refers to the tax levied on the value created by taxpayers during the course of production and operations. The commonly used name for this type of tax is goods and services tax in various countries. Generating over 30% of total tax revenue in more than 170 countries, the VAT has become a cornerstone of modern fiscal systems. So, VAT is a main element of tax revenues for most nations. Its extensive application makes VAT an important element of the world's tax system, it affects the economic structure and taxation reform around the world by covering various types of commodities and services.

In the last few years, with the structural modification of China's economy and the increase of enterprise cost, VAT reform has entered a deeper phase. The government focused on the issue of retained VAT — capital deposits from over

time when the input VAT exceeds output VAT. These VAT credits essentially represent taxes that enterprises pay but cannot deduct from their income, which has remained fixed in the capital chain for a long time. And what's more, it is bound to aggravate enterprises' financial stress and impede the resource distribution process, and so limit the overall level of operational efficiency as well as sustainable economic growth. In response to these difficulties, the government has carried out a number of reforms in order to improve corporate liquidity, which includes the VAT credit refund policy.

Initially, in 2011-2018, China began piloting the VAT credit refund policy in the integrated circuit industry. The scope gradually broadened, and in 2014, there was a refund of VAT credits on naphtha and fuel oil purchased by enterprises for ethylene and aromatic chemical production. By 2015 the application was to large passenger aircraft and engine development projects. Then the incremental VAT credit refund policy was tested in 2018 - 2021, applied to 18 major industries including manufacturing industry and modern service industries such as R&D industry and power grid companies, providing refunds according to retained tax credit. On April 1, 2019 began the major reform of VAT credits in China, which is a new measure that allows enterprises meeting certain conditions in specific industries to claim a 60 % refund of their incremental VAT credits.

June 2019 saw the expansion of full rebate of additional VAT credit into advance manufacturing sectors that include non-metallic minerals, and general and special equipment, and the computers and communications and electronic devices. Between 2020 and 2021, eligibility was extended to pandemic-related material producers and to firms in pharmaceuticals, chemical fibers, transportation equipment, electrical machinery, and instrumentation. In March 2022, the Ministry of Finance and the State Taxation Administration issued Announcement No. 14, launching a one-time refund of stock VAT credits accumulated before March 2019 for qualifying small and micro enterprises across all industries and granting a 100 % monthly refund of incremental credits to firms in designated sectors. Medium- and large-scale enterprises in other industries continued to receive 60 % of incremental credits monthly. At this point by July 2022, the full refunded sectors were broadened to seven sectors as well to include wholesale and retail, as well as agriculture, forestry, animal husbandry, and fishery industries. And it's expanded, with the policy covering the 13 from the 19 groups in CSRC, which include the industries of manufacturing, science research and utility. Since 2023, the VAT credit refund policy has become more institutionalized and regularized, but this paper only interprets the estimated results as post-policy productivity effects rather than permanent effects. Incremental refunds only refer to incremental surpluses of excess input VATs, stock refunds refer to the elimination of historical credit balances. Such a gradual expansion indicates policymakers' determination to alleviate liquidity burdens on small, micro,

and manufacturing enterprises, so as to strengthen market confidence and stabilize growth.

The existing evidence connects tax reform to higher TFP. Liu & Mao (2019), Zhou et al. (2022) observe gains from shifting from a pro-distribution to a consumption-based VAT system, with Yu & Qi (2022) attributing improved efficiency to switching from a business tax to a VAT. Yao et al. (2022) shows that increased management expenses increase TFP, increases in staff decrease TFP. Cui et al. (2023) demonstrate that headline rate cuts and additional input deductions boost TFP, especially for asset-light firms in northeastern provinces. Yu et al. (2023) found that a stronger institutional environment increases the productivity effect of VAT relief. Cheng et. al (2024) attributes the increase to greater R&D and investment in human capital and better capital allocation which calls for a smaller spread between manufacturing and other sectors' rates. but no one studies the causal effect of VAT credit refunds for TFP.

B. FACTORS AFFECTING TFP

Total Factor Productivity (TFP) is how much extra output is produced, affected by many things [11]. Specifically, TFP is the efficiency of production activities over a certain period, which reflects the part of production increases that do not involve increased use of capital and labor. This concept measures the residual output — that is, the portion not attributable to capital and labor inputs. TFP increasing means that the business is improving the efficiency of resource use in production, applying new technology and managing activities when producing goods and services. The increase in the efficiency on production resulting from the developments is another of the reasons for the economy's development [12].

In recent years, the rapid development of the digital economy is also changing the factors of TFP. The digital economy with information technology as its economic model has raised social productivity via high-tech updates and mass use. This is a fast development of new technology, such as 5G of mobile network, AI, blockchain, and cloud computing [13][14]. And these technologies not only change traditional production model, and improve production efficiency greatly by transmitting information faster, using resources better and making the market more connected.

The exploration of factors influencing TFP in enterprises is important to understand how to suit the new normal of China's economic development and achieve a better quality of economic development [15]. First, most of the previous work is based on the study of impact on TFP through technological progress. A positive correlation was observed across the 65 countries: each 1% rise in per capita R&D investment was linked to a 0.16% increase in TFP [16]. Digital technology innovation inside companies can improve TFP through two main channels: improving through technological progress directly and an indirect effect achieved by empowering production factors and elevating management efficiency [17]. The above is based on the

newly created provincial panel data from 1998 to 2018 by several studies to examine the impact of a few R&D types on China's TFP: basic, applied and experimental. The results show experimental research and development has crucial role for TFP growth in China during this period, but there is no support for basic and applied R&D as for contributions [18].

Second is the existing studies, they study the impact on TFP from the perspective of resource allocation efficiency. Through building a factor optimization model and assessing the distortion in factor resource allocation and its impact on the TFP in the major industries. Rectifying capital allocation distortions potentially improves overall efficiency, and so TFP [19]. In addition, through measuring the TFP losses caused by resource mismatches under various ownership types, different regional types, industrial types, and overall industrial scales respectively, it can be found that there is a strong relationship between resource mismatch and regional economic development levels [20]. The calculations showed that the TFP loss resulting from the resource misallocation problem with mismatched "low tax rate and high refund rate" vs "high tax rate and low tax rate" could be offset if multi-tax effect could be eliminated; on average, this could cause an increase in TFP of 1.645% yearly [21].

Lastly, some scholars state that economic agglomeration has a positive impact on TFP [22]. From the perspective of data element agglomeration, some studies use structured testing methods to quantitatively research how data integration affects changes in the Industrial structure: The results show that the unionization of data elements with an industrial sector results in greater labor productivity and TFP[23].

III. THEORETICAL ANALYSIS AND HYPOTHESES

Tax incentive theory believes that reasonable tax incentive can improve the economy by changing corporate behaviors and efficiently using resources [24]. Tax incentives pertain to the state employing tax methods to encourage certain projects or units, so as to assist the sound growth of the country's economy. Deferred VAT is an important tax incentive policy and embodies the essence of tax incentive theory. Traditional vat credit refunds: When a company's input value-added tax is more than their output value-added taxes, the company can save the extra value-added tax credit, then they can use it in the next period. If that credit can't be deducted right away though, then the company must wait for a long time to get those funds back.

Stock VAT credits are the unutilized credits of stocks before the implementation of the policy. With these stock credits refunded, an enterprise can get timely cash inflows, sharply cutting its need for external funds in the short run, and easing the difficulties caused by capital lack. Refunding of stock credits also frees up internal working capital, which improves operational efficiency. The VAT credit refund policy allows companies to make better use of their money, quickly answer the calls of the market and environmental

changes, making for better resource allocation and greater production efficiency. This policy can increase enterprises' cash flow as well as decrease dependence on external financing. Before the policy was implemented, enterprises bore higher funding costs and made lower investments in R&D and innovation, which hindered their innovation capacity and productivity [25].

China implemented a production VAT system in the 1994 tax system reforms which allowed businesses to carry forward unused tax credits for usage in following periods [4]. The original intent behind the VAT credit refund policy is to reduce the tax interference with companies' business operations and enhance tax system's fairness and efficiency as a whole. VAT credit refund system can ease the tax pressure for enterprises, which could provide an opportunity for enterprises to get more funds for further investment and operation. These reforms greatly increased enterprise growth and market competitiveness [6]. especially short-term refund of stock credit provides a great economic help to companies which help company to grow and expand and invest and revitalizes it by not increasing debt. Through this policy, it gives the enterprises greater adaptability to face changes in the market, and also a better risk resistance ability to deal with various challenges from the market, enabling the enterprises to alter its production and operational policies in a more adaptable way, and have a better output efficiency and resource allocation level.

Furthermore, refunds of stock VAT credit will benefit the overall financial situation of enterprises. Having enough money, companies can better control their money flow and don't have to rely on high-priced sources to get cash. the economic effect of the VAT credit refund policy is also great considering that there are quite a few businesses and the total amount of accumulated VAT credits is considerable. Scholars noticed that the VAT credit refund policy gave strong money help to companies by making their cash better, letting them put more money into new ways of thinking and discovering, and this helped make a better way to do things [26][27][28]. VAT credit refund can reduce enterprises' financing constraints, create a good production and operation environment, and promote tax system institutionalization [29]. More than 80 percent of Chinese listed firms have considerable VAT credits [4]. This implies that the policy benefits more than 80 percent of the businesses right away because of its adoption. And specifically speaking, the total sum of VAT tax credits generated by all Chinese enterprises in 2018 is over RMB 1 trillion. This important digit not only indicates the reduction of all the tax burden on enterprises after the reform, but also shows the great impact and large role of "VAT credit refund" as an economic phenomenon. Due to the fact that external financing faces higher interest rates and fees, the increase in cash flow reduces companies' financing needs and financial costs. tax refunds can be seen as a benefit for SMEs that find themselves in financial trouble, since they can use their investment in technology and marketing. Based on the above analysis, this paper

proposes the following hypothesis:

H1: The refund of stock VAT credits has a promoting effect on the improvement of the TFP of enterprises.

The incremental VAT credit refund can make enterprises get VAT credit refunds for new investment more quickly, thus greatly improving their cash flow. The main benefit of this policy is it can give them short period working capital. This can help enterprises increase their capital investment, especially in key areas like improving product technology, upgrading equipment, and investing in R&D. This growth in cash flow directly eases the financial pressure of enterprises, making them more willing and eager to invest and make bigger investment. The enterprises will usually use the incremental VAT credit refunds towards the purchase of new equipment as well as constructing new production facilities, building new production line, which would lead to improvements in productivity and technology. Innovations to new technologies and updates to equipment effectively increase production capacity and competitiveness in the market for total factor productivity (TFP). Also, by increasing liquidity with the refund of increased VAT credit, companies can spend more on hiring and training the best possible employees, which raises the overall quality of employees and improves productivity. The research of [30] and [31] show that highly skilled employees contribute to higher productivity, which enhances innovation capabilities, backing up the liquidity benefits afforded by the VAT rebate policy. Thus, the incremental VAT credit refund policy not only offers companies with more finance but also improves efficiency in allocating production factors, strengthens technology, and makes technological innovation stronger, which also contributes to TFP [32].

Existing economics research has pointed out that R&D investment, technology adoption, and advanced division of labor are important factors affecting TFP improvement for enterprises [33]. Technological innovation and resource allocation are key factors in promoting TFP [34]. Incremental VAT credit refund policy drives firms to boost their investments in technological improvement and enterprise equipment upgrade, utilizing more fully the present available production elements for the whole level of production. Through its promotion of ongoing technological innovation, the policy not only encourages good capital allocation but also supports steady productivity increases within enterprises. In other words, in this situation, the implementation of the incremental VAT credit refund policy can allow enterprises to speed up the dynamic adjustment of production factors, thus further improving TFP.

Furthermore, it has obvious short term dynamic effects on enterprise TFP with the incremental VAT credit refund policy. It can quickly mobilize enterprise funds and help optimize production factors allocation and resource utilization efficiency. Enterprises can enhance their financial use efficiency in the short term when they secure financial assistance, improve production processes, reduce resource waste and improve productivity [2]. Especially in the capital-

intensive industries, this policy calls for companies to invest in new equipment as well as do process transformation, so it brings about noticeable rise in production efficiency and tech abilities over a short period of time. The short-term adjustment of resources can enable companies to better adapt to market changes and challenges and better survive in a fiercely competitive environment.

In short, when the incremental tax-credit refund occurs, it alters the short term production factor distribution, i.e., production factor utilization and resource use efficiency. The companies will be able to put more money into technology and equipment improvements as well as research and development because of this policy, which will bring about big improvements in productivity very soon. This policy is implemented by the enterprises and thus helps the organizations in the optimal usage of the resources available and the production efficiency. It also provides to such enterprises with more market responsiveness and competitiveness. Thus, the incremental VAT credit refund policy has a significant positive effect on improving TFP of enterprise and is worthy of wider promotion in different industries.

Based on the above analysis, this paper proposes the following hypothesis:

H2: The refund of incremental VAT credits has a promoting effect on the improvement of the TFP of enterprises.

IV. RESEARCH DESIGN

A. SAMPLE SELECTION AND DATA SOURCES

This paper has selected companies listed on China's Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) as the research objects, with a period from 2013 to 2024. To ensure the consistency and reliability of various financial data, companies of the financial industry, companies with serious missing variable values, ST companies and delisted companies were excluded. In order to eliminate the influence of extreme values, continuous variables are winsorized by 1% up and down. The data used in this paper comes from the CSMAR database. The treatment and control groups are defined separately for the incremental VAT credit refund policy and the stock VAT credit refund policy. For the incremental refund analysis, Treat is defined according to the industries covered by MOF and STA Doc. [2018] No. 70. For the stock refund analysis, Treat is defined according to the industries and firms covered by the large-scale 2022 stock VAT credit refund arrangement. The corresponding Post variables are also set separately according to the relevant policy years.

B. VARIABLE CONSTRUCTION AND MODEL DESIGN

1) VAT Credit Refund

For the incremental VAT credit refund policy, Treat is defined according to the industries covered by MOF and STA Doc. [2018] No. 70. Post equals 1 for 2018 and subsequent years, and 0 otherwise. In the event-study specification, 2017 is used as the omitted base year.

For the stock VAT credit refund policy, the policy shock is identified around the large-scale 2022 stock VAT credit refund reform. Treat is defined according to the industries and firms covered by the 2022 stock refund arrangement. Post equals 1 for 2022 and subsequent years, and 0 otherwise. In the event-study specification, 2021 is used as the omitted base year.

2) TFP

This article references existing literature and employs the LP method [35] and the OP method [36] to measure the total factor productivity of listed companies. Firstly, the contribution ratios of capital and labor are estimated using equation (1):

$$\begin{aligned} \ln Y_{i,t} = & \beta_0 + \beta_k \ln K_{i,t} + \beta_l \ln L_{i,t} \\ & + \beta_a \text{Age}_{i,t} + \beta_s \text{SOE}_{i,t} + \beta_e \text{EX}_{i,t} \\ & + \sum_m \delta_m \text{Year}_m + \sum_n \lambda_n \text{Province}_n \quad (1) \\ & + \sum_k \zeta_k \text{Industry}_k + \varepsilon_{i,t}. \end{aligned}$$

Wherein, Y denotes the annual output; K , the capital input; L , the labor input; Age , a proxy for corporate maturity; SOE , a dummy variable capturing state ownership; EX , a binary indicator of export engagement; Year , Province , and Industry are sets of temporal, regional, and sectoral dummies; $\varepsilon_{i,t}$ is the stochastic disturbance. Output is gauged by the natural logarithm of operating revenue; capital, by the log of net fixed assets; labour, by the log of total employees; investment, by cash outlays for fixed, intangible, and other long-term assets. Under the OP specification, Age and $\ln K$ serve as state variables, $\ln L$ as the proxy, $\ln L$ together with Year , Province , and Industry as free variables, EX and SOE as controls, and delisting or ST^*/ST status as exit indicators. In the LP framework, intermediate input—computed as operating costs plus selling, administrative, and financial expenses less depreciation, amortisation, and staff remuneration—functions as the proxy. The resulting productivity measures are designated TFP_LP and TFP_OP , respectively.

3) Model Setting

The net effect of the VAT credit refund policy is evaluated by evaluating the difference in time trends between the treatment group and the control group before and after the implementation of the policy. At the same time, the annual fixed effects and firm fixed effects are controlled. Specifically:

$$\begin{aligned} \text{TFP}_{i,t} = & \beta_0 + \beta_1 \text{Treat}_i \times \text{Post}_t + \sum \text{Controls}_{i,t} \quad (2) \\ & + \sum \text{Firm}_i + \sum \text{Year}_t + \varepsilon_{i,t}. \end{aligned}$$

TFP refers to total factor productivity. The connotations of Treat and Post are introduced separately in the section

on VAT credit refunds. Growth (annual operating income growth rate), ROA (the ratio of net income to total assets), Lev (the ratio of total liabilities to total assets), Liquid (the ratio of current assets to current liabilities), Cash (the ratio of net cash flow from operating activities to total assets), Turnover (asset utilization efficiency, i.e. the turnover rate of current assets), Size (the natural logarithm of the number of employees), TobinQ (the ratio of market value to total assets), Intangible (the ratio of intangible assets to total assets), Age (the natural logarithm of the number of years since the establishment of the enterprise), Board (the natural logarithm of the number of directors), Indep (ratio of independent directors, i.e., the number of independent directors/number of directors), Top1 (equity concentration, i.e., the shareholding ratio of the largest shareholder), and SOE (ownership type; if the enterprise is a state-owned enterprise, the value is 1; otherwise it takes the value of 0). Data comes from the CSMAR database.

4) Data-Driven Analysis Design

To further identify heterogeneous firm-level responses to VAT credit refund policies, this paper supplements the baseline DID framework with a data-driven analysis. Traditional DID interaction terms can test pre-specified heterogeneity dimensions, such as fiscal pressure, marketization, ownership, and absorptive capacity. However, they are less suitable for ranking the relative importance of multiple firm characteristics or capturing nonlinear interactions among these characteristics. Therefore, the machine learning analysis is used as a supplementary tool, not as a substitute for DID, to identify high-response firms and connect firm-level predictors with the mechanisms tested in the DID framework. Specifically, a binary classification target is constructed based on firms' post-policy productivity improvement. Let $\Delta \text{TFP}_i^{\text{post}}$ denote the post-policy change in total factor productivity for firm i . The response indicator is defined as

$$Y_i = \begin{cases} 1, & \text{if } \Delta \text{TFP}_i^{\text{post}} > \text{Median}(\Delta \text{TFP}^{\text{post}}), \\ 0, & \text{otherwise.} \end{cases} \quad (3)$$

Where $Y_i = 1$ indicates a high-response firm and $Y_i = 0$ indicates a low-response firm. This setting allows the analysis to move beyond average treatment effects and examine which firm characteristics are associated with stronger policy gains.

Based on this classification task, three models are implemented, namely Logistic Regression, Random Forest, and XGBoost. Let X_i denote the vector of firm characteristics, including profitability, leverage, liquidity, cash flow, growth, R&D intensity, ownership, fiscal pressure, and marketization level. For Logistic Regression, the probability that firm i is classified as a high-response firm is written as

$$P(Y_i = 1 | X_i) = \frac{1}{1 + \exp[-(\alpha + \beta' X_i)]}. \quad (4)$$

Random Forest and XGBoost are further used to capture potential nonlinear relationships and interaction effects among firm characteristics. Model performance is evaluated by Accuracy, Precision, Recall, F1-score, and AUC. To improve interpretability, feature importance is reported to identify the most influential predictors, and SHAP values are employed to further examine the direction and magnitude of each variable's contribution to the prediction of heterogeneous policy responses.

Figure 1 summarizes the revised empirical logic. The DID model identifies the average policy effect, mechanism tests explain why the policy affects TFP, heterogeneity tests show where and for whom the effect is stronger, and the machine learning analysis predicts firm-level high-response patterns using the same economic variables.

V. EMPIRICAL ANALYSIS

A. DESCRIPTIVE STATISTICS

Table 1 reports the descriptive statistics after updating the sample. TFP_OP and TFP_LP represent enterprise TFP calculated using the OP and LP methods, respectively. The updated sample contains 21,600 firm-year observations. The mean value of TFP_OP is 11.051, and the mean value of TFP_LP is 12.448, indicating that the two productivity measures are close in direction but differ in level. The descriptive results also show variation in financial leverage, cash holdings, R&D investment, financing constraints, and regional characteristics, which provides a basis for the following DID, mechanism, heterogeneity, and machine learning analyses.

Table 2 reports the updated baseline DID estimates. Columns (1) to (4) present the results for the stock VAT credit refund policy, while columns (5) to (8) present the results for the incremental VAT credit refund policy. Across both TFP_OP and TFP_LP specifications, the $Treat \times Post$ coefficient remains positive and statistically significant after adding controls and fixed effects. This indicates that both types of VAT credit refund policies improve enterprise TFP. The updated results are also consistent across different model settings, suggesting that the baseline conclusion is not driven by a single estimation specification.

Using column (2) as an example, the coefficient of the stock VAT credit refund is 0.055. Relative to the mean value of TFP_OP, this implies an economically meaningful improvement in firm productivity. Total factor productivity of enterprises shows differences overall and is determined by control variables. This article uses the two-way fixed effect model, which makes for a more accurate estimation. $Treat \times Post$ still has a positive significant correlation coefficient when explaining the core variables at 5%, both before and when control variables are included, thus showing that the implementation of the stock VAT credit refund policy has a certain contribution to the productive performance of enterprises. So, it supports hypotheses 1 and 2 of the study.

B. ROBUSTNESS TESTING

1) Parallel Trends Test

In order to further test the parallel trends before the implementation of the policy and the possible time lag of the policy, this paper refers to the practice of Wu et al. (2021). Taking 2017, i.e. the year before the implementation of the incremental VAT credit refund policy, as the benchmark, the paper adds the interaction term generated by $Treat$ and $Year$ in each year of the sample period to the baseline DID model. The specific model is as follows:

$$TFP_{i,t} = \beta_0 + \sum_{\substack{t=2013 \\ t \neq 2017}}^{2019} \beta_t Treat_i \times Year_t + \sum Controls_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (5)$$

Taking 2021 as the omitted base year for the stock VAT credit refund policy and 2017 as the omitted base year for the incremental VAT credit refund policy, this paper estimates the dynamic DID model by interacting the treatment indicator with year dummies. The updated event-study figures report the yearly coefficients and 90% confidence intervals for TFP_OP and TFP_LP.

Figures 2-5 report the updated parallel-trends tests. Before the implementation of each VAT credit refund policy, the estimated coefficients are close to zero and their confidence intervals generally cover zero, indicating that the treatment and control groups do not show systematic pre-policy divergence. After the policy year, the coefficients turn positive and become more pronounced, which supports the interpretation that the VAT credit refund policies improve enterprise TFP. These results provide the key precondition for using DID to estimate the average treatment effect.

2) Placebo Test

This paper further conducts placebo tests to examine whether the baseline findings are driven by random policy assignment or other unobserved shocks. The sample is randomly processed 1,000 times, and the distribution of placebo t-statistics is compared with the true t-statistic from the main regression. Figures 6-9 show that the true t-statistics are far away from the placebo distribution, while the placebo statistics are concentrated around zero. This result suggests that the positive effect of VAT credit refund policies on TFP is unlikely to be generated by random factors.

3) Replacing the Explained Variable

Table 3 reports the robustness test using alternative measures of TFP. The dependent variable is replaced by TFP calculated using alternative OLS and FE approaches, and the specifications are estimated with and without control variables. The coefficients of $Treat \times Post$ remain positive and statistically significant across the stock-refund and incremental-refund models. This indicates that the baseline conclusion is robust to alternative productivity measurements.

high response patterns using the same economic variables.

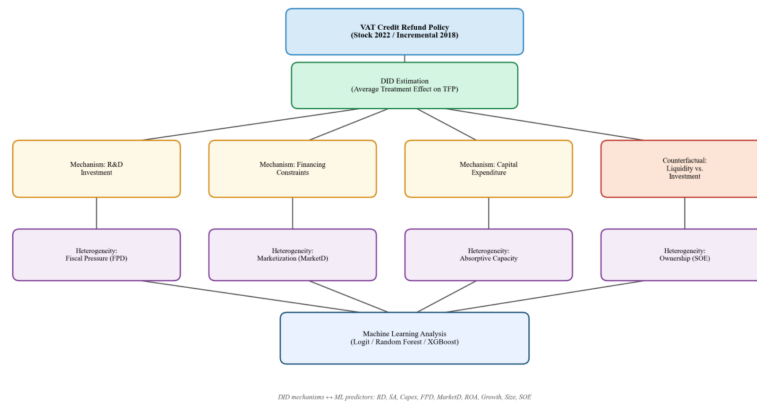


FIGURE 1. Analytical framework linking DID, mechanism tests, and ML heterogeneity analysis

TABLE 1. Descriptive statistics

Variables	Obs	Mean	SD	P25	Median	P75
TFP_OP	21600	11.051	0.816	10.492	11.048	11.619
TFP_LP	21600	12.448	0.843	11.878	12.446	13.031
Size	21600	7.893	1.16	7.098	7.889	8.673
Intangible	21600	0.052	0.04	0.017	0.048	0.079
Age	21600	3.02	0.307	2.813	3.019	3.228
Board	21600	2.309	0.242	2.144	2.309	2.476
Indep	21600	0.381	0.07	0.334	0.38	0.428
Top1	21600	0.337	0.137	0.241	0.336	0.43
SOE	21600	0.427	0.495	0	0	1
Growth	21600	0.149	0.348	-0.088	0.15	0.387
ROA	21600	0.032	0.054	-0.004	0.032	0.068
Lev	21600	0.453	0.18	0.33	0.451	0.571
Liquid	21600	2.15	1.115	1.297	2.12	2.921
Cash	21600	0.042	0.054	0.006	0.042	0.079
Turnover	21600	24.548	27.982	0.5	14.689	41.818
RD	21600	0.04	0.024	0.02	0.038	0.057
SA	21600	-2.808	0.042	-2.835	-2.808	-2.78
Capex	21600	0.06	0.03	0.04	0.06	0.081
FPD	21600	0.5	0.5	0	0.5	1
MarketD	21600	0.5	0.5	0	0.5	1

TABLE 2. Baseline DID estimates of VAT credit refunds on TFP

Variables	Stock VAT credit refund				Incremental VAT credit refund			
	(1) TFP_OP	(2) TFP_OP	(3) TFP_LP	(4) TFP_LP	(5) TFP_OP	(6) TFP_OP	(7) TFP_LP	(8) TFP_LP
Treat × Post	0.055*** (29.37)	0.055*** (29.37)	0.056*** (25.61)	0.056*** (25.55)	0.093*** (55.93)	0.093*** (55.88)	0.100*** (51.04)	0.100*** (50.93)
Size		-0.005 (-1.15)		0.001 (0.30)		-0.001 (-0.41)		-0.001 (-0.15)
Intangible		-0.029** (-2.33)		0.011 (0.78)		-0.015 (-1.41)		0.009 (0.74)
Age		-0.002 (-1.40)		0.001 (0.76)		-0.001 (-0.98)		0.004** (2.57)
Growth		0.001 (0.43)		-0.003 (-0.86)		-0.001 (-0.25)		-0.002 (-0.64)
ROA		0.028 (1.15)		-0.023 (-0.80)		0.002 (0.11)		-0.032 (-1.24)
Lev		0.033** (2.00)		-0.004 (-0.21)		0.024 (1.62)		0.024 (1.40)
Cash		0.025 (1.04)		0.003 (0.10)		0.023 (1.08)		0.012 (0.46)
Turnover		-0.000 (-0.53)		0.000 (1.27)		-0.000 (-0.32)		-0.000 (-0.12)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12600	12600	12600	12600	16200	16200	16200	16200
R ²	0.064	0.065	0.049	0.050	0.162	0.163	0.139	0.139

Note: The incremental VAT credit refund policy and the stock VAT credit refund policy correspond to different implementation windows. Therefore, the empirical design separately estimates the two policy shocks and reports the results in parallel. The difference in sample periods and policy timing is retained in the updated modelling and figure design.

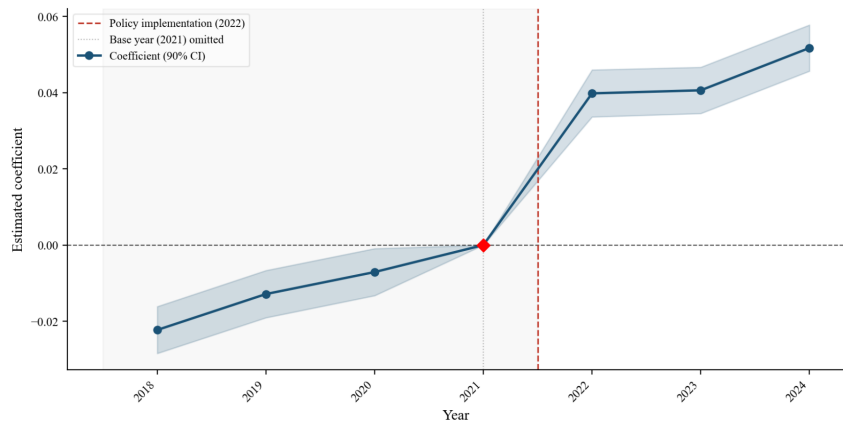


FIGURE 2. Parallel trends test for stock VAT credit refund — TFP_OP

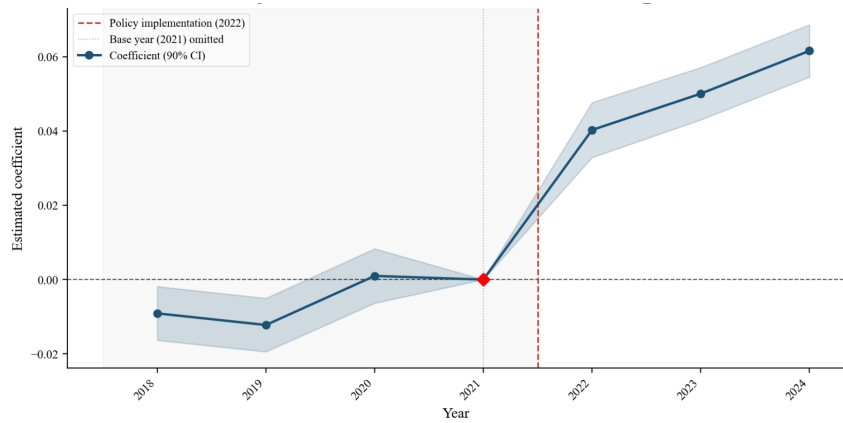


FIGURE 3. Parallel trends test for stock VAT credit refund — TFP_LP

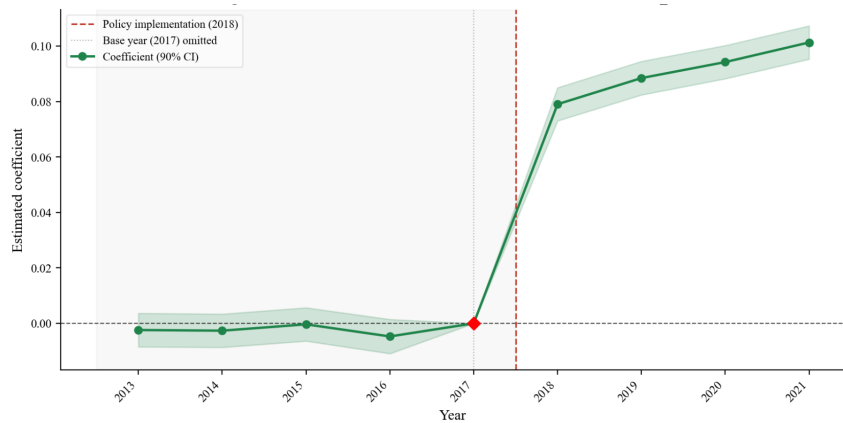


FIGURE 4. Parallel trends test for incremental VAT credit refund — TFP_OP

To distinguish productive investment from a pure liquidity explanation, Table 4 reports counterfactual tests. The results support the interpretation that VAT credit refunds improve TFP mainly by encouraging productive investment and improving resource allocation, rather than only by increasing short-term liquidity.

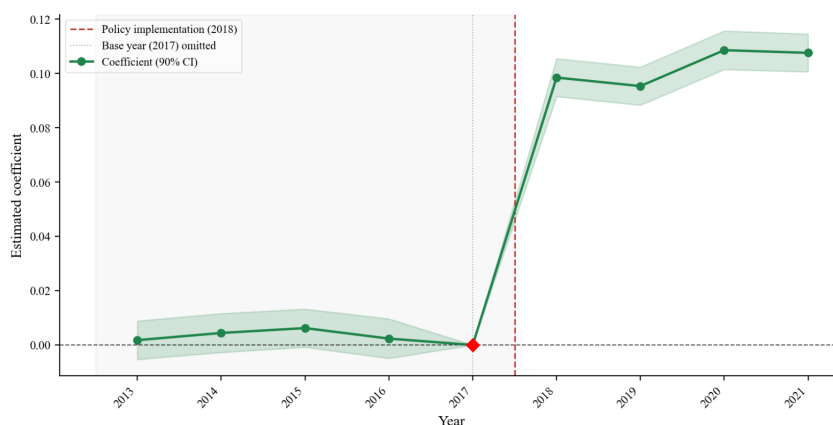


FIGURE 5. Parallel trends test for incremental VAT credit refund — TFP_LP

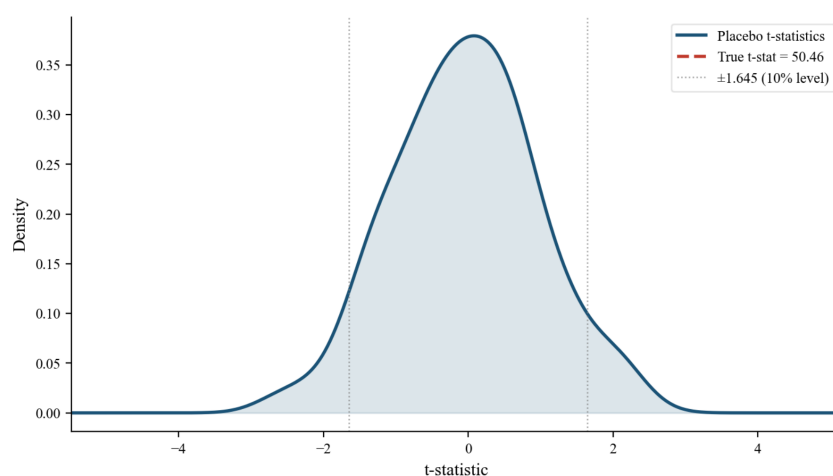


FIGURE 6. Placebo test for stock VAT credit refund — TFP_OP

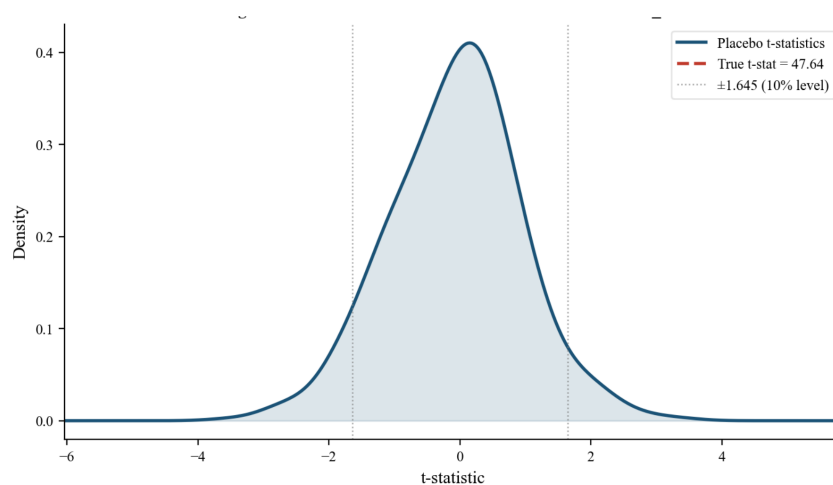


FIGURE 7. Placebo test for stock VAT credit refund — TFP_LP

C. MECHANISM ANALYSIS

1) R&D Input

Firstly, both the incremental and stock VAT credit refund policies may enhance total factor productivity by increasing

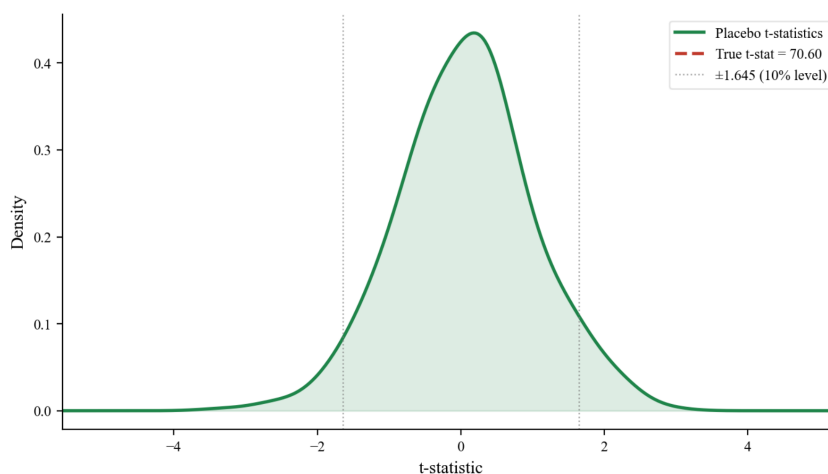


FIGURE 8. Placebo test for incremental VAT credit refund — TFP_OP

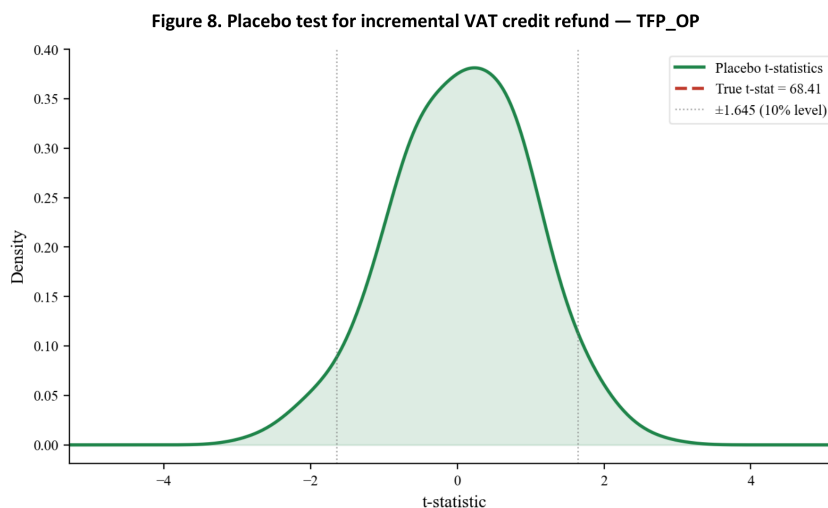


FIGURE 9. Placebo test for incremental VAT credit refund — TFP_LP

TABLE 3. Robustness test: alternative measures of TFP

Variables	Stock VAT credit refund				Incremental VAT credit refund			
	(1) TFP_OLS	(2) TFP_OLS	(3) TFP_FE	(4) TFP_FE	(5) TFP_OLS	(6) TFP_OLS	(7) TFP_FE	(8) TFP_FE
Treat × Post	0.054*** (4.55)	0.054*** (4.52)	0.050*** (4.20)	0.050*** (4.26)	0.085*** (8.03)	0.085*** (8.00)	0.106*** (9.94)	0.106*** (9.89)
Size		-0.041 (-1.55)		0.023 (0.86)		-0.014 (-0.62)		0.016 (0.67)
Intangible		0.043 (0.54)		-0.180** (-2.26)		0.036 (0.52)		-0.105 (-1.51)
Age		0.012 (1.10)		-0.004 (-0.34)		0.006 (0.63)		0.025*** (2.67)
Growth		-0.001 (-0.04)		-0.020 (-1.12)		-0.006 (-0.37)		-0.009 (-0.60)
ROA		0.294* (1.85)		-0.157 (-0.99)		0.153 (1.10)		-0.067 (-0.48)
Lev		-0.092 (-0.86)		0.259** (2.45)		-0.066 (-0.71)		0.236** (2.51)
Cash		0.052 (0.34)		0.097 (0.62)		0.077 (0.56)		-0.240* (-1.73)
Turnover		0.000 (1.04)		-0.000 (-0.07)		0.000 (0.05)		-0.000 (-0.13)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12600	12600	12600	12600	16200	16200	16200	16200
R ²	0.002	0.003	0.001	0.003	0.004	0.004	0.006	0.007

research and development (R&D) investments, thereby fostering technological innovation within enterprises. In R&D,

companies often need to purchase a large amount of research equipment, recruit specialized staff, and purchase patented

TABLE 4. Counterfactual tests: liquidity injection versus productivity-enhancing investment

Dependent Variable	Stock VAT credit refund		Incremental VAT credit refund	
	(1) w/o controls	(2) w/ controls	(3) w/o controls	(4) w/ controls
RD – R&D investment	0.003*** (16.06)	0.003*** (16.08)	0.006*** (32.98)	0.006*** (32.81)
N	12600	12600	16200	16200
R ²	0.020	0.021	0.063	0.064
Capex – Capital expenditure	0.004*** (3.84)	0.004*** (3.89)	0.004*** (4.21)	0.004*** (4.15)
N	12600	12600	16200	16200
R ²	0.001	0.002	0.001	0.002
Lev – Leverage (debt repayment proxy)	-0.003*** (-2.95)	-0.003*** (-2.96)	-0.005*** (-5.93)	-0.005*** (-6.01)
N	12600	12600	16200	16200
R ²	0.001	0.001	0.002	0.003
Cash – Cash holdings	0.001 (1.15)	0.001 (1.12)	-0.006*** (-9.37)	-0.006*** (-9.44)
N	12600	12600	16200	16200
R ²	0.000	0.002	0.005	0.006
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

technology, which leads to an explosion of the number of expenses during the product development process, leading to a lot of input tax credit. But before the product is finished and placed into production, there are no physical goods on hand to sell, so there is less output tax credit at first. According to the interim regulations on VAT, this part of the input tax can only be used for carryover deduction in the future. Consequently, with substantial capital tied up, the speed of R&D output diminishes, further inhibiting the generation of sufficient output tax credits in subsequent periods. The cycles make the companies unwilling to participate in R&D activity, increasing the companies' tax payment as well as investments made by the company during the period of research work. The implementation of the incremental VAT credit refund policy will be conducive to R&D companies to reduce the capital tied up in the earlier stages of development, leading companies to increase investment in R&D, speed up the progress of R&D, improve the speed of product development, thereby establishing an advantage for themselves in the market and driving overall total factor productivity.

This suggests that the cash-flow improvement brought by the VAT credit refund policy may increase enterprise investment in hardware facilities and research equipment [38]. Compared with developed countries, Chinese enterprises still face insufficient innovation investment and relatively weak innovation intensity, which may reduce their competitiveness in global innovation competition [39]. VAT credit refund policies help reduce firms' tax burden and improve operating cash flow [9]. With better cash-flow conditions, enterprises may have stronger incentives to invest in innovation. The refunded funds can be used to develop new products and improve technological and process capabilities. These innovation activities may raise firms' technological level and strengthen their market competitiveness. Therefore, the refund policy can reduce financial pressure when firms expand business activities, especially in technological

innovation and R&D.

2) Financing Constraints

The VAT credit refund policy can help enterprises alleviate financing constraints (Liu & Zhang, 2024; Wang et al., 2024). On the one hand, the policy directly increases firms' internal funds through VAT credit refunds. In the short term, it provides enterprises with more flexible working capital. This internal funding support can reduce capital shortages and improve cash-flow conditions. Positive cash-flow shocks may also encourage firms to invest more in equipment upgrading, R&D innovation, production expansion, and economies of scale [9]. By improving the allocation of financial resources and technology inputs, the policy may further increase total factor productivity [42]. Enterprises can therefore make greater investments in technological improvement, process upgrading, and equipment renewal, which helps them maintain competitiveness in a changing innovation environment.

Affecting TFP through the stock VAT credit refund can mainly be divided into two aspects of corporate financing channels – internal and external financing. Internal financing refers to the reliance on a company's internal surplus, which is characterized by relatively low financial risks, lower costs, and few restrictive factors. External finance means obtaining funds from banks and other financial institutions, individuals, institutions, and so on, and it is further divided into debt and equity financing, which have higher capital costs and place pressure on enterprises to repay debts or pay dividends. The incremental VAT credit refund has an important role in alleviating corporate financing constraints [18], for internal funding sources – the VAT credit refund policy enhances enterprises' confidence in further investment and upgrading transformation by refunding incremental VAT credit refunds. Stable amounts of refunds might prompt firms to switch out old equipment; stir economies of scale; help with allocating and using technologies more efficiently;

TABLE 5. Mechanism test: VAT credit refunds and R&D investment

Variables	Incremental (1) RD	Incremental (2) RD	Stock (1) RD	Stock (2) RD
Treat × Post	0.006*** (32.98)	0.006*** (32.81)	0.003*** (16.06)	0.003*** (16.08)
Size		0.000 (0.02)		-0.001 (-1.41)
Age		-0.000 (-0.88)		-0.000 (-0.07)
Growth		-0.001*** (-3.15)		-0.001* (-1.82)
ROA		-0.004 (-1.59)		-0.004 (-1.57)
Lev		-0.000 (-0.13)		0.001 (0.63)
Cash		0.000 (0.09)		-0.001 (-0.30)
N	16200	16200	12600	12600
R ²	0.063	0.064	0.020	0.021
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

and increase firm value so as to attract investors, thus raise total factor productivity. In regards to external financing, the VAT credit refund policy means that the government is supporting the enterprise, this creates a stronger credit assurance based on signally theory[29]. It conveys positive messages to banks, financial institutions, securities markets etc., dispelling external investors' worries, drawing social capital to enterprises, and reducing the difficulty of external financing acquisition for enterprises. This also promotes the agglomeration of production factors, thus increasing total factor productivity [43].

After confirming the baseline productivity effect, this paper further examines the economic mechanisms through which VAT credit refund policies affect TFP. Tables 5 and 6 separately test the R&D investment channel and the financing constraint channel. Table 5 shows that VAT credit refunds are associated with higher R&D investment, indicating that tax refunds can support innovation-related inputs. Table 6 shows that VAT credit refunds reduce financing constraints measured by the SA index, suggesting that the policy improves firms' internal funding conditions. These mechanism tests explain why the refund policy can be transformed into productivity improvement rather than remaining only as short-term liquidity support.

TABLE 6. Mechanism test: VAT credit refunds and financing constraints

Variables	Incremental (1) SA	Incremental (2) SA	Stock (1) SA	Stock (2) SA
Treat × Post	-0.018*** (-14.43)	-0.018*** (-14.44)	-0.013*** (-9.16)	-0.013*** (-9.09)
Size		0.004* (1.66)		0.003 (0.98)
Age		-0.004*** (-4.10)		-0.008*** (-6.49)
Growth		0.001 (0.65)		0.001 (0.36)
ROA		0.004 (0.23)		-0.025 (-1.34)
Lev		0.006 (0.59)		0.021* (1.68)
Cash		-0.011 (-0.71)		-0.030 (-1.63)
N	16200	16200	12600	12600
R ²	0.013	0.014	0.007	0.011
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

D. HETEROGENEITY TEST

1) Local Fiscal Pressure

The refund amount of VAT credits needs to be shared by governments at all levels, so the core lies in the cross-regional transfer of VAT tax burden [44]. Under the VAT system, the tax burden often shifts from one region to another. This cross-regional transfer leads to the inconsistency between the taxpayer's refund location and the tax collection location. The core purpose of the VAT credit refund policy is to reduce the tax burden of enterprises, release the liquidity of corporate funds, and then promote the innovation and production efficiency of enterprises. However, if local finances are under great pressure, local governments may scale down tax refund support for enterprises or postpone the payment of the refunds, which will reduce the positive impact of the stock VAT credit refund policy on the TFP of enterprises. Therefore, local fiscal pressure not only affects the implementation of the VAT credit refund policy, but also may weaken the positive incentive effect that this policy should have brought, thereby reducing the TFP of enterprises. In consideration of the above, this paper constructs the variable FPD. When the fiscal pressure is greater than the median value, its value is 1; otherwise, its value is 0.

Table 7 reports the heterogeneity test based on local fiscal pressure. The interaction term between Treat × Post and FPD captures whether fiscal pressure changes the policy effect. The updated results show that fiscal pressure weakens the productivity effect of VAT credit refunds. This means that in regions with greater fiscal pressure, the transmission from tax refunds to enterprise productivity may be less effective, possibly because local fiscal constraints affect policy implementation intensity and the broader business environment.

TABLE 7. Heterogeneity test: local fiscal pressure

Variables	Stock VAT credit refund		Incremental VAT credit refund	
	(1) TFP_OP	(2) TFP_LP	(3) TFP_OP	(4) TFP_LP
Treat × Post	0.073*** (60.50)	0.076*** (55.45)	0.131*** (110.85)	0.136*** (103.51)
FPD	0.004 (1.56)	-0.000 (-0.17)	0.005** (2.24)	0.005** (2.08)
Treat × Post × FPD	-0.014*** (-10.75)	-0.013*** (-8.69)	-0.025*** (-19.25)	-0.027*** (-18.52)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	12600	12600	16200	16200
R ²	0.260	0.231	0.480	0.445

2) Marketization Index

Due to differences in geographical environment, economic structure, cultural background and policy orientation, the degree of marketization varies significantly in different regions. On the one hand, in an environment with a high degree of marketization, the incremental VAT credit refund policy can guide enterprises to use the refunded money to optimize resource allocation more effectively. Since the improvement of the degree of marketization means that the allocation of market resources is more inclined to the market mechanism, enterprises can more flexibly adjust the mode and direction of resource allocation according to changes in market demand and their own strategic needs. Regions with a high degree of marketization usually have a more complete market environment and a sounder market mechanism [45]. On the other hand, a higher degree of marketization means more developed financial markets and more diversified financing channels. Developed financial markets provide enterprises with more financing opportunities, and enterprises can obtain the financial support they need for development through diversified financing channels. In these regions, enterprises can obtain R&D funds at a lower cost through multiple channels, which provides strong support for their technological innovation and production efficiency improvement. Therefore, this paper constructs the variable MarketD. When the marketization index is greater than the median value, MarketD takes the value of 1; otherwise it takes the value of 0.

Table 8 reports the heterogeneity test based on regional marketization. The interaction term between Treat×Post and MarketD captures whether the policy effect is stronger in more market-oriented regions. The updated results show that a higher degree of marketization strengthens the productivity effect of VAT credit refunds. This indicates that a better market environment helps firms allocate refunded funds more efficiently and convert tax relief into productivity gains.

TABLE 8. Heterogeneity test: regional marketization

Variables	Stock VAT credit refund		Incremental VAT credit refund	
	(1) TFP_OP	(2) TFP_LP	(3) TFP_OP	(4) TFP_LP
Treat × Post	0.055*** (45.87)	0.056*** (41.41)	0.096*** (83.32)	0.100*** (77.93)
MarketD	-0.007** (-2.40)	-0.010*** (-3.12)	-0.009*** (-3.56)	-0.015*** (-5.00)
Treat × Post × MarketD	0.022*** (16.56)	0.027*** (17.80)	0.046*** (36.20)	0.045*** (31.58)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	12600	12600	16200	16200
R ²	0.269	0.245	0.508	0.466

E. ECONOMIC CONSEQUENCES

The VAT credit refund policy was implemented, which eased financial burdens for enterprises and allowed for more working capital to be accessed. This working capital helps the enterprise get rid of its temporary capital shortage, as well as provides the necessary financial support for the development of the enterprise and new technology. Based on existing studies, it is shown that the stability and liquidity of an enterprise's capital chain are important characteristics for an enterprise's long-term development. In high financial pressure environments, enterprises can greatly improve their competitiveness in the market by replenishing working capital [4]. VAT Credit Refund policy brings more money into enterprises, it reduces the company's tax bill, which is especially important for areas without many funds. These regions see companies generally encounter bigger financing costs and financial stress. Thus, the capital infusion from the refund policy plays a crucial role: it allows firms to improve their financial structure and operational efficiency, thereby enhancing market value. [32].

The policy has also driven a marked increase in production efficiency, especially within manufacturing and technology-intensive sectors. The funds received for additional VAT refunds are often used to improve equipment, make more goods, and invest more in new technological developments. This sort of investment would result in more technology in R&D and production. This investment directly increases TFP. Literature shows that a company's production efficiency is positively correlated with its technological innovation strength, upgrading of equipment, and R&D investments [33]. VAT credit refund policy can provide additional funds for enterprises, encouraging them to invest more in new technologies and equipment, which can improve production efficiency, enhance innovation capabilities, enable companies to stand out from the competition in the market and capture a larger market share [32]. Thus, in this paper, an analysis is carried out using the market value Tobin's Q of listed companies, which is the proportion of market value to total assets. Table 9 further examines firm absorptive capacity and ownership-related heterogeneity. The results compare policy effects across firms with different profitability, R&D intensity, growth, and ownership characteristics. The updated evidence suggests that firms with stronger absorptive capacity are more likely to convert

tax refunds into TFP improvement. This also provides an empirical bridge to the machine learning analysis, because

the same firm-level characteristics are later used to predict heterogeneous policy response.

TABLE 9. Heterogeneity test: firm absorptive capacity

Variables	ROA		R&D Intensity		Growth		Ownership	
	High	Low	High	Low	High	Low	Non-SOE	SOE
Treat × Post (Stock)	0.064*** (24.54)	0.058*** (21.97)	0.064*** (23.34)	0.054*** (20.38)	0.065*** (24.24)	0.064*** (24.02)	0.058*** (23.54)	0.050*** (17.61)
Treat × Post (Incremental)	0.101*** (43.20)	0.094*** (40.36)	0.101*** (41.93)	0.092*** (39.09)	0.105*** (43.80)	0.096*** (40.64)	0.099*** (45.05)	0.085*** (33.19)
N (Stock)	6300	6300	6300	6300	6300	6300	7217	5383
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

F. SUPPLEMENTARY ANALYSIS OF HETEROGENEOUS POLICY EFFECTS

To further explore firm-level heterogeneity in policy responses, this paper supplements the baseline DID analysis with a machine learning classification exercise. Table 10 reports the predictive performance of Logistic Regression, Random Forest, and XGBoost. The results show that Logistic Regression achieves the highest Accuracy, F1-score, and AUC among the three models, while Random Forest and

XGBoost also show strong predictive performance. Since XGBoost can capture nonlinear relationships and provide interpretable feature-importance and SHAP results, it is further used to visualize the key predictors of heterogeneous policy responses. This suggests that nonlinear relationships and interaction effects among firm characteristics are relevant for identifying heterogeneous policy responses. Therefore, the subsequent interpretation focuses on the XGBoost model.

TABLE 10. Predictive performance of machine learning models for heterogeneous policy response

Model	Training N	Test N	Accuracy	Precision	Recall	F1-score	AUC
Logistic Regression	693	297	0.818	0.813	0.824	0.819	0.908
Random Forest	693	297	0.801	0.816	0.777	0.796	0.897
XGBoost	693	297	0.808	0.797	0.824	0.811	0.888

Table 11 further summarizes how the DID variables, mechanism tests, and machine learning predictors are connected. This table is added to make clear that the machine learning module is not an independent add-on, but an

extension of the DID-based mechanism and heterogeneity analysis.

TABLE 11. Linkage between DID mechanisms and machine learning predictors

DID / Mechanism Component	ML Predictor(s)	Interpretation
Financing constraints channel	SA, Lev, Cash	Firms with tighter pre-policy liquidity show larger TFP gains from VAT refunds via internal funding relief
Innovation investment channel	RD	Higher R&D intensity signals absorptive capacity to convert tax relief into productivity-enhancing innovation
Local fiscal pressure heterogeneity	FPD	Regions under greater fiscal pressure delay or reduce refund disbursement, dampening the treatment effect
Regional market environment	MarketD	More market-oriented regions facilitate efficient reallocation of refunded capital, amplifying the TFP effect
Profitability & operational efficiency	ROA	Profitable firms face fewer distortions and are better positioned to translate liquidity gains into output growth
Firm growth and expansion capacity	Growth	Fast-growing firms exhibit stronger demand for investment, leading to higher marginal productivity of refunded capital
Scale and resource base	Size	Larger firms benefit from economies of scale when reinvesting refund proceeds into equipment or R&D
Ownership-related rigidities	SOE	State-owned enterprises exhibit weaker policy transmission due to softer budget constraints and lower innovation incentives
Capital expenditure channel	Capex	Evidence of productive investment confirms the productivity-enhancing vs. liquidity injection distinction

Figure 10 presents the updated feature importance results of the XGBoost model. The most important predictors include SOE, ROA, Growth, Lev, Capex, SA, Intangible, Size, FPD, MarketD, RD, Cash, and Turnover. These variables correspond to the paper's DID mechanisms and heterogeneity dimensions, showing that the machine learning module is not separated from the empirical framework but is used to extend it from average effects to firm-level response differences.

Figure 11 further reports the updated SHAP summary plot, which provides additional evidence on the direction of heterogeneous policy responses. Firms with stronger profitability, higher growth potential, and more innovation-related capacity are more likely to be classified as high-response firms, suggesting that financially healthier and more capable firms are better positioned to transform tax relief into productivity gains. By contrast, ownership structure, fiscal pressure, financing conditions, and local institutional environment may weaken or strengthen policy transmission. Taken together, these results extend the conventional average-effect analysis by showing not only whether VAT credit refund policies work, but also for which firms they work better and why.

VI. CONCLUSION AND IMPLICATIONS

This paper studies the effect of implementation of stock VAT credit refund and incremental VAT credit refund policy on total factor productivity of enterprise. A difference-in-differences model is used in the empirical study, and the effect of VAT credit refunds policy on total factor productivity is verified. The findings show that the effect of VAT credit refund on total factor productivity is positive. It can be seen that the implementation of stock VAT credit refund measures and incremental VAT credit refund measures has a significant positive impact on the total factor productivity of enterprises. The updated evidence shows a significant post-policy improvement in total factor productivity, suggesting that the VAT credit refund policy can promote enterprise production efficiency during the observed sample period. The heterogeneity results show that local fiscal pressure weakens the productivity effect of VAT credit refunds, while regional marketization strengthens the policy effect. This suggests that the effectiveness of VAT credit refunds depends not only on firm-level liquidity relief, but also on the local fiscal and institutional environment. In contrast, areas with higher levels of marketization experience more pronounced effects from these refunds. The economic effects indicate that the improvements to production brought about by both stock and incremental refunds raise the market value of enterprises. Beyond the average treatment effect identified by the DID results, the supplementary machine learning analysis further shows that firm-level policy responses differ substantially across enterprises. In particular, profitability, R&D intensity, firm growth, and fiscal pressure are important characteristics for identifying high-response firms. This implies that the implementation of VAT credit

refund policies should place greater emphasis on differentiated and precision-oriented support. Synthesizing findings on how the VAT refund policy, local fiscal pressures, and marketization levels affect TFP—and how these effects vary across regions, industries, and firm types—we propose the following recommendations:

Optimize the VAT credit refund policy and bolster support over the long term. This research shows that VAT credit refund policy greatly improves total factor productivity and especially helps in places with great fiscal strain and high marketization, it substantially eases financial burden for enterprises. In 2018, the VAT credit refund policy was implemented, it is also the first large-scale nationwide reform of VAT refunds by China, an important breakthrough in the process of tax reform. Unlike the previous ones, which were industry-specific or regional, had a timeline, and were smaller in scope compared to the vastness and wide range encompassing all industries and companies, the reform is unique when compared to every previous reform before it. This was a major adjustment to China's tax system and brought more tax flexibility to companies all over the country, especially the reduction of tax burden and improve the enterprise's cash flow, this would have a huge economic impact. But the policy is not very effective across different areas and kinds of companies, so we need the policy to solve the long-term and adaptable issues. Therefore, we need to further improve the strategic design under the current policy framework. A more stable supporting mechanism is needed to help enterprises convert tax relief into innovation investment and productivity improvement. One side of it, creating different kinds of supporting mechanism to improve the policy precision. Tailored refund plans need to be formulated, which is in line with the financial conditions, company type and industry feature of each region so as to provide proper resource distribution. For instance, in areas with substantial fiscal pressure and high marketization, refund efforts could be intensified to assist local enterprises in stabilizing cash flow and alleviating financial burdens; conversely, in regions with favorable fiscal conditions, enterprises could be encouraged to allocate refund funds toward R&D innovation and technological upgrades. Besides that, more tax subsidy can be given to technology enterprises, innovative enterprises and small and medium-sized enterprises so as to strengthen technology investment and upgrade industry. Differential, support and it will stop the resource sharing, which can guarantee that the implementation is reasonable.

On the other hand, reinforcing the stability and continuity of the policy is essential. Enterprise's long-term investment decisions have a good policy environment, frequent policy changes will affect people's production and investment decisions. So we suggest that for tax related policies to have a long term roadmap so that the VAT refund policy is always there, no matter how much it can change. Cutting back on the number of times policies change enables companies to form clear ideas about what the tax landscape will look like ahead, which helps them plan finances better

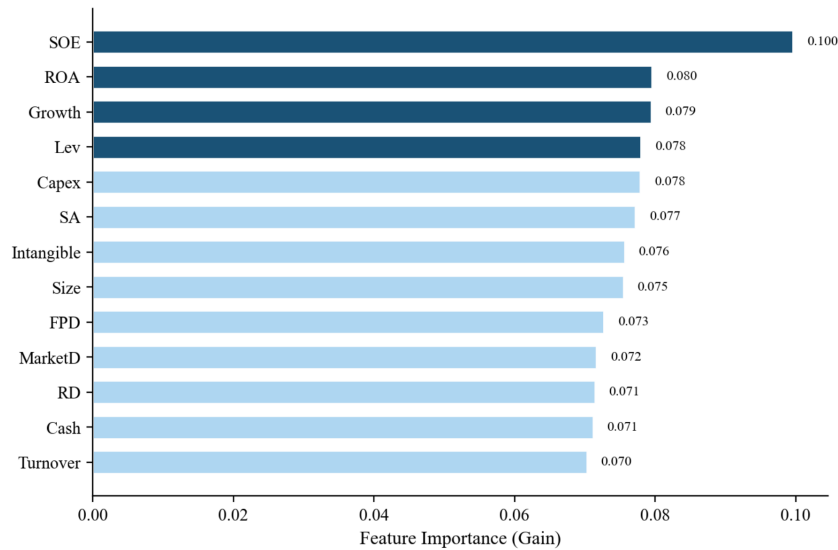


FIGURE 10. Feature importance of XGBoost for heterogeneous policy response

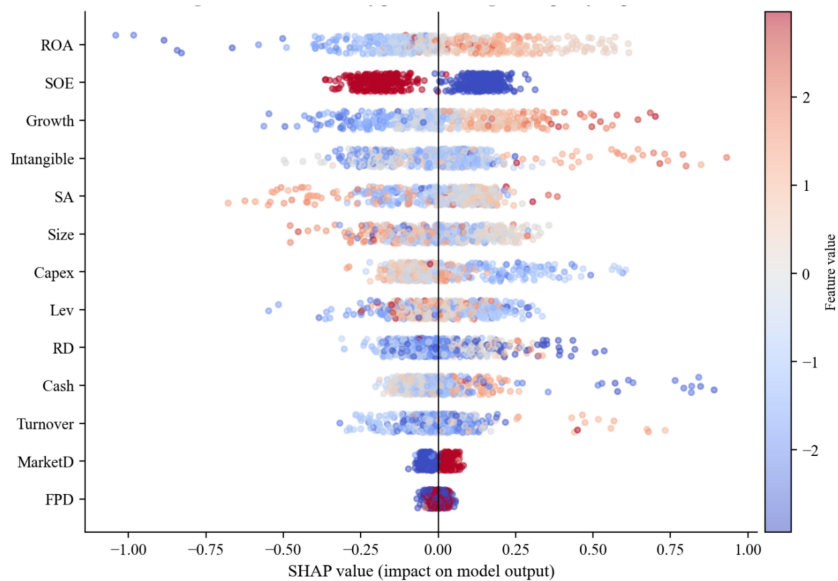


FIGURE 11. SHAP summary plot for heterogeneous policy response

for long-term growth. Refund amount adjustments can be conveyed via regular updates, which let enterprises plan their finances ahead of time based on policy changes and thus guaranteeing stable production activities.

Continue with “synchronized” tax and fee cuts and speed up tax reforms. A lot of research shows that the VAT credit refund policy helps ease the financial pressure on companies and increase total factor productivity. But the results of policies differ from region to region and kind of company. Therefore, we must continue to promote the simultaneous implementation of ‘Tax Reduction’ and ‘Fee Reduction’, and continue to optimize the tax structure to help enterprises accumulate more capital and invest more

in innovation. Comprehensive tax cuts and improvements to corporate tax and fee structures will reduce business expenses and enhance market competitiveness; regions with high fiscal burden and high degree of marketization need more active tax-cut policies to alleviate corporate burdens. To push for reforms and improvements to the tax system, so as to achieve the digitization and intelligence of tax administration, this will make sure that tax policies can be carried out in an efficient and fair manner. Moreover, we should also flexibly adjust tax system according to various financial pressure and marketization level to improve the flexibility and effectiveness of policy. Therefore, it is necessary to strengthen the regulation of a variety of fees

levied on enterprises, and at the same time, implement constant tax cuts, so as to alleviate the overall burden on enterprises and enhance their vitality.

Promote the reform of enterprise fee management to reduce the burden on enterprises even further: In their operations, companies have to deal with tax burdens and lots of other fees and charges like management and industry regulations. These fees lack transparency, they are unreasonable and it causes companies to have unclear and opaque tax-fee burdens. This results in higher operational costs. In this way, the government's efforts should also be strengthened in terms of managing enterprise-attached fees, to strictly manage fee standards and increase transparency, eliminate arbitrary charges, truly allowing the reduction and exemption of taxes to benefit enterprises, especially small and micro-enterprises, and so on. In addition, the regular release of reports on the company's tax burden can also pay attention to changes and data support for the next time.

AUTHOR CONTRIBUTIONS

Conceptualization, Minghui Liu and Yongchun Guo; methodology, Minghui Liu; software, Yongchun Guo; validation, Minghui Liu and Yongchun Guo; formal analysis, Minghui Liu; investigation, Yongchun Guo; resources, Yongchun Guo data curation, Yongchun Guo; writing—original draft preparation, Minghui Liu; writing—review and editing, Minghui Liu; visualization, Minghui Liu; supervision, Minghui Liu; project administration, Yongchun Guo. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

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REFERENCES

- [1] Y. Zhang, Z. Bai, and C. Findlay, "Value-added tax reform and service exports: Evidence from China," *The Journal of International Trade & Economic Development*, vol. 33, no. 4, pp. 551-573, 2024, doi: 10.1080/09638199.2023.2199437.
- [2] Y. Li and M. Meng, "Value-Added Tax Retention and Refund, Local Government Subsidies and Digital Transformation of Manufacturing Enterprises," *Tax Research*, vol. (08), pp. 30-38, 2024, doi: 10.19376/j.cnki.cn11-1011/f.2024.08.007.
- [3] G. Shen and M. Meng, "Value-Added Tax Retention and Refund, Local Government Subsidies and Digital Transformation of Manufacturing Enterprises: New Data, New Methods and New Findings," *China Economic Quarterly*, vol. 24, no. 04, pp. 1048-1065, 2024, doi: 10.13821/j.cnki.ceq.2024.04.02.
- [4] Y. Liu and J. Mao, "How Do Tax Incentives Affect Investment and Productivity? Firm-Level Evidence from China," *American Economic Journal: Economic Policy*, vol. 11, no. 3, pp. 261-291, 2019, doi: 10.1257/pol.20170478.
- [5] Q. Zhou, T. Li, and L. Gong, "The effect of tax incentives on energy intensity: Evidence from China's VAT reform," *Energy Economics*, vol. 108, Art. no. 105887, 2022, doi: 10.1016/j.eneco.2022.105887.
- [6] J. Yu and Y. Qi, "BT-to-VAT reform and firm productivity: Evidence from a quasi-experiment in China," *China Economic Review*, vol. 71, Art. no. 101740, 2022, doi: 10.1016/j.chieco.2021.101740.
- [7] D. Yao, L. Jiang, and F. Wang, "Management Expenses, Transaction Costs and Enterprise Total Factor Productivity—A Quasi-Experimental Study Based on the "Business Tax to VAT" Reform," *World Economy Papers*, vol. (02), pp. 36-56, 2022, doi: 10.3969/j.issn.0488-6364.2022.2.sjjwh202202003.
- [8] H. Cui, B. Wang, and W. Wang, "Can Reducing Value-Added Tax Rates Improve Enterprise Total Factor Productivity? Accounting Research," 2023;(02):133-148, doi: 10.3969/j.issn.1003-2886.2023.02.010.
- [9] H. Yu, K. Shen, and L. Sun, "Research on the Impact of VAT Reduction on Regional Manufacturing Productivity," *Finance & Trade Research*, vol. 34, no. 06, pp. 45-56, 2023, doi: 10.19337/j.cnki.34-1093/f.2023.06.005.
- [10] X. Cheng, Z. Liu, and H. Xiu, "Can Value-Added Tax Reduction Improve the Total Factor Productivity of Manufacturing Enterprises? — An Empirical Study Based on the VAT Rate Reduction Event," *Journal of Beijing Technology and Business University (Social Sciences)*, vol. 39, no. 01, pp. 65-77, 2024, doi: 10.12085/j.issn.1009-6116.2024.01.006.
- [11] C. Syverson, "What Determines Productivity? Journal of Economic Literature," 2011;49(2):326-365, doi: 10.1257/jel.49.2.326.
- [12] C. Cobb and P. Douglas, "A Theory of Production," *The American Economic Review*, vol. 18, no. 1, pp. 139-165, 1928.
- [13] S. Nambisan, K. Lyytinen, A. Majchrzak, and M. Song, "Digital Innovation Management: Reinventing Innovation Management Research in a Digital World," *MIS Quarterly*, vol. 41, no. 1, pp. 223-238, 2017, doi: 10.25300/misq/2017/41:1.03.
- [14] X. Luo, W. Zhang, and H. Li, "Cloud computing capability: Its technological root and business impact," *Journal of Organizational Computing and Electronic Commerce*, vol. 28, no. 3, pp. 193-213, 2018, doi: 10.1080/10919392.2018.1480926.
- [15] C. Du and Y. Xue, "R&D Alliance, Open Innovation and the Improvement of Enterprise Total Factor Productivity," *Quantitative Economics and Technical Economics Research*, vol. 41, no. 12, pp. 111-132, 2024, doi: 10.13653/j.cnki.jqte.20240926.005.
- [16] C. Bravo-Ortega and Á. García, "R&D and Productivity: A Two Way Avenue? World Development," 2011;39(7):1090-1107, doi: 10.1016/j.worlddev.2010.11.006.
- [17] X. Ke and Z. Xu, "The Impact of Enterprise Digital Technology Innovation on Total Factor Productivity—Based on the Dual Paths of Factor Structure Optimization and Management Efficiency Improvement," *Western Forum*, vol. 34, no. 05, pp. 50-64, 2024, doi: 10.3969/j.issn.1674-8131.2024.05.004.
- [18] Y. Zhou and S. Dahal, "Has R&D contributed to productivity growth in China? The role of basic, applied and experimental R&D," *China Economic Review*, vol. 88, Art. no. 102281, 2024, doi: 10.1016/j.chieco.2024.102281.
- [19] T. Ren, X. Sun, and X. Chu, "The Impact of Capital Allocation Distortion in Key Industries on China's Total Factor Productivity," *Economics and Management Research*, vol. 41, no. 01, pp. 63-77, 2020, doi: 10.13502/j.cnki.issn1000-7636.2020.01.005.
- [20] W. Wang and Z. Niu, "A Multi-dimensional Study on the Impact of Resource Misallocation on China's Industrial Total Factor Productivity," *Quantitative Economics and Technical Economics Research*, vol. 36, no. 03, pp. 20-37, 2019, doi: 10.13653/j.cnki.jqte.2019.03.002.
- [21] B. Liu, E. Kou, and L. Yang, "Multi-rate VAT, Resource Misallocation and Total Factor Productivity Loss," *Economic Research Journal*, vol. 54, no. 05, pp. 113-128, 2019.
- [22] A. Otsuka, "Regional determinants of total factor productivity in Japan: Stochastic frontier analysis," *The Annals of Regional Science*, vol. 58, no. 3, pp. 579-596, 2017, doi: 10.1007/s00168-017-0808-7.
- [23] X. Chen and W. Xu, "Data Elements, Transportation Infrastructure and Industrial Structure Upgrading—An Analysis Based on a Quantitative Spatial General Equilibrium Model," *Management World*, vol. 40, no. 04, pp. 78-98, 2024, doi: 10.19744/j.cnki.11-1235/f.2024.0046.
- [24] D. Jorgenson, "Capital Theory and Investment Behavior," *The American Economic Review*, vol. 53, no. 2, pp. 247-259, 1963.
- [25] Y. Liu and C. Geng, "The Impact of Intergovernmental Burden Sharing of Export Tax Rebates on Product Exports," *China Economic Quarterly*, vol. 16, no. 03, pp. 1011-1030, 2018, doi: 10.13821/j.cnki.ceq.2017.02.08.

- [26] J. Yu and C. Wan, "VAT Retention and Refund, Financing Constraints and Enterprise Total Factor Productivity," *Fiscal Science*, vol. (01), pp. 104-118, 2022, doi: 10.19477/j.cnki.10-1368/f.2022.01.013.
- [27] S. Li, Z. Jin, and Y. Xie, "Value-Added Tax Neutrality and Enterprise Total Factor Productivity—A Study Based on the VAT Refund Reform," *Economic Review*, vol. (02), pp. 59-74, 2023, doi: 10.19361/j.er.2023.02.05.
- [28] X. Li, "The Effect of Value-Added Tax Refunds on the Total Factor Productivity of Manufacturing Enterprises," *Tax Research*, vol. (11), pp. 112-117, 2023, doi: 10.19376/j.cnki.cn11-1011/f.2023.11.011.
- [29] S. Yue and C. Xiao, "Can VAT Retention and Refund Alleviate Enterprise Financing Constraints? — Empirical Evidence Based on Cash-Cash Flow Sensitivity," *Finance & Trade Economics*, vol. 44, no. 01, pp. 51-67, 2023, doi: 10.19795/j.cnki.cn11-1166/f.2023.01.003.
- [30] S. Alnahedh, S. Bhagat, and I. Obreja, "Employment, Corporate Investment, and Cash-Flow Risk," *Journal of Financial and Quantitative Analysis*, vol. 54, no. 4, pp. 1855-1898, 2019, doi: 10.1017/S0022109019000437.
- [31] P. Bacchetta, K. Benhima, and C. Poilly, "Corporate Cash and Employment," *American Economic Journal: Macroeconomics*, vol. 11, no. 3, pp. 30-66, 2019, doi: 10.1257/mac.20150191.
- [32] P. Wang, Y. Liu, and M. Cui, "Research on the Impact of Value-Added Tax Refund Policy on Enterprise Green Innovation Efficiency," *Tax Research*, vol. (08), pp. 39-47, 2024, doi: 10.19376/j.cnki.cn11-1011/f.2024.08.014.
- [33] D. Comin and B. Hobijn, "An Exploration of Technology Diffusion," *American Economic Review*, vol. 100, no. 5, pp. 2031-2059, 2010, doi: 10.1257/aer.100.5.2031.
- [34] L. Li, Y. Bao, and J. Liu, "Research on the Impact of Intelligence on China's Manufacturing Total Factor Productivity," *Studies in Science of Science*, vol. 38, no. 04, pp. 609-618+722, 2020, doi: 10.16192/j.cnki.1003-2053.2020.04.006.
- [35] J. Levinsohn and A. Petrin, "Estimating Production Functions Using Inputs to Control for Unobservables," *The Review of Economic Studies*, vol. 70, no. 2, pp. 317-341, 2003, doi: 10.1111/1467-937X.00246.
- [36] G. Olley and A. Pakes, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, vol. 64, no. 6, pp. 1263-1297, 1996, doi: 10.2307/2171831.
- [37] Y. Wu, C. Lv, and C. Ni, "Tax Neutrality of VAT, Enterprise Investment and Enterprise Value—A Study Based on the "VAT Refund" Reform," *Management World*, vol. 37, no. 08, pp. 180-194, 2021, doi: 10.19744/j.cnki.11-1235/f.2021.0115.
- [38] W. Cai, X. Shen, B. Li, et al., "Innovation Incentive Effect of Value-Added Tax Refund Policy," *Financial Studies*, vol. (05), pp. 31-48, 2022, doi: 10.19477/j.cnki.11-1077/f.2022.05.005.
- [39] D. Zhou, B. Min, and X. Liang, "The Early-life Political Event Experience of the Chair of the Board and the Firm's Innovation Decision," *Australian Accounting Review*, vol. 31, no. 3, pp. 186-212, 2021, doi: 10.1111/auar.12331.
- [40] J. Yu, H. Zhao, and C. Zhu, "Tax Reduction Incentives and Corporate Environmental, Social and Governance Performance—A Quasi-Natural Experiment Based on VAT Retention and Refund," *Contemporary Finance and Economics*, vol. (10), pp. 44-57, 2023, doi: 10.13676/j.cnki.cn36-1030/f.20230906.001.
- [41] C. Liu and N. Zhang, "The Incentive Effect of Value-Added Tax Refunds on Enterprise Green Technology Innovation," *Journal of Zhongnan University of Economics and Law*, vol. (03), pp. 57-69, 2024, doi: 10.19639/j.cnki.issn1003-5230.2024.0029.
- [42] J. Mao, J. Cao, and C. Yang, "The Impact of "Business Tax to VAT" Reform on Enterprise Innovation Behavior—Mechanism Analysis and Empirical Test," *Tax Research*, vol. (07), pp. 12-19, 2020, doi: 10.19376/j.cnki.cn11-1011/f.2020.07.002.
- [43] S. Yang, P. Zhang, and J. You, "Research on the Incentive Effect of Tax Preferences on Enterprise Total Factor Productivity—Based on the Background of Supply-side Structural Reform," *Tax Research*, vol. (04), pp. 104-109, 2019, doi: 10.19376/j.cnki.cn11-1011/f.2019.04.021.
- [44] B. Sun, "Research on the Reform of Fiscal Burden Sharing Mechanism for VAT Retention and Refund," *Macroeconomic Research*, vol. (11), pp. 25-34+47, 2023, doi: 10.16304/j.cnki.11-3952/f.2023.11.002.
- [45] M. Huang, L. Yang, and H. Wang, "Construction of a Unified National Market and Carbon Emissions from the Perspective of Market Factors—Empirical Evidence from China's 15 Major Urban Agglomerations," *Finance Theory & Practice*, vol. 46, no. 01, pp. 103-110, 2025, doi: 10.16339/j.cnki.hdxbcjb.2025.01.013.