Investment Tax Credits and Innovation

Shaowei Ke[1], Yao Lu[2], Xinzheng Shi[3], Yeqing Zhang[4]

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Abstract

This paper investigates the effects of the investment value-added tax credit reform in China in 2004 on firms' innovation behaviors. The difference-in-difference-in-differences (DDD) estimation results show that the reform significantly increases firms' capital expenditures on fixed assets; however, it decreases R&D investment, resulting in lower innovation. More importantly, the results show that the negative impacts of the reform on innovation are stronger for financially more constrained firms, non-SOE firms, and domestic firms. These findings suggest that financial constraints may cause some unintended consequences of investment tax credits.

JEL Classification: O31, O32, G31.

Keywords: Value-added tax reform; capital expenditure; innovation; financial constraints

[1] Assistant Professor in Economics, Department of Economics, University of Michigan, shaoweik@umich.edu.
[2] Associate Professor in Finance, School of Economics and Management, Tsinghua University, (86)13691288499, luyao@sem.tsinghua.edu.cn.
[3] Associate Professor in Economics, School of Economics and Management, Tsinghua University, (86)13439315025, shixzh@sem.tsinghua.edu.cn.
[4] Ph.D. Candidate in Finance, School of Economics and Management, Tsinghua University, (86)18810669907, zhangyq3.15@sem.tsinghua.edu.cn.

1. Introduction

Technology is the engine of productivity growth for firms. Firms can improve their technologies either by externally purchasing existing technology advancing machines and equipment or by internally pursuing innovations. The governments of many countries have implemented the investment tax credits (ITC), such as the Tax Reform Act of 1986 in U.S., to stimulate fixed investment. A large number of studies have shown that such investment tax credits can effectively reduce the price of capital goods relative to other factors, and enhance capital expenditures on fixed assets (e.g., Hall and Jorgenson, 1967; Abel, 1982; Brock, 1988; Sen and Turnovsky, 1990). However, little is known about how ITC effects firms' internal innovation and their technology adoption strategies. To fill this gap, in this paper, we investigate how firm innovation responds to 2004 value-added tax (VAT) reform in China, an investment tax credit reform.

In 2004, the government implemented the VAT reform in China. This reform was introduced to avoid double taxation and mitigate firms' burden of taxation, further encourage firms to invest in fixed assets, especially equipment investment. Before the reform, investment in fixed assets cannot be deductible when calculating a firm's VAT base, called production-type VAT. The VAT reform converts the original production-type VAT into the standard consumption-type VAT in six industries in three northeastern (NE) provinces of China in 2004. After the VAT reform, the expenditure on fixed assets (excluding structures) can be deducted from the VAT base for firms in the pilot regions and industries. As a result, the reform reduces the relative prices of purchasing fixed assets.

We provide a simple theoretical model to illustrate how the 2004 VAT reform affects firms' innovation behaviors depends on the elasticity of substitution between purchasing external technologies and internal innovation. First, investment in technology advancing machines and equipment and internal innovative activities can both improve firm productivities (Howitt and Aghion, 1998). As a result, there are substitution effects between these two inputs. The VAT reform decreases the relative price of fixed asset investment for affected firms, but leaves the price of innovative inputs unchanged, which may make firms more likely adopt more advanced technology by purchasing technology advancing machines and equipment externally than internal innovation. The negative impacts of the investment tax credits on innovation are stronger for firms which have more flexibility and incentives to reallocate inputs between ordinary investment and innovative investment, such as financially more constrained firms. Second, as discussed before, the 2004 VAT reform can reduce the cost of capital expenditure, and thus may increase firms' investment in fixed assets. When firms have access to capital, the decrease in the price of physical capital induces the firm to upsize, associated with an increase in the demand for all input factors, including internal innovation and external technology acquisition. Thus, the reform may have positive effects on firms' innovation activities, since innovation is normally considered as risky activities. These competing effects leave an important empirical research question to examine.

Examining the impacts of the 2004 VAT reform has two advantages for the identification issues. First, the 2004 VAT reform pilot provides an exogenous variation, which has been acknowledged by previous studies (e.g., Zhang, Chen, and He, 2018; Liu and Lu, 2015). Second, the reform is implemented only in a subset of manufacturing industries in Chinese northeastern region, allowing us to construct the treatment and control groups of firms. By comparing the post-reform investment in fixed assets and innovation outputs between firms in the affected industries and northeastern area (i.e., the treatment firms) and those in non-northeastern areas or non-eligible industries (i.e., the control firms), we can identify the effect of the 2004 VAT reform pilot on firms' technology adoption strategies using a triple-difference approach. Such triple-difference approach allows us to control for the time trend of firms in both different industries and different locations.

In this paper, we use a firm-level panel dataset covering 2001 through 2007 from the Annual Survey of Industrial Firms (ASIF) to identify the effect of the 2004 value-added tax reduction on manufacturing firm innovation strategies. We find that the 2004 VAT reform pilot has a positive effect on firm investment in fixed assets. Specifically, we find that affected firms increase investment in fixed assets by 13.81% more on average, compared to unaffected firms. Then using the patents as the measure of firm innovation, we find that the 2004 VAT significantly decreases innovation. Specifically, our results show that 2004 VAT reform leads to a 13.19% decrease in patent quantity. The increase in capital expenditure and the decline in innovation together suggest that there is substitution between investment in physical capital and innovative investment, which is consistent with the "substitution effect". In other words, the reduction in relative cost of physical capital provides affected firms with more incentives to purchase technology advancing machines and equipment externally than to cultivate innovation internally.

We further test some heterogeneous effects of the VAT reform on innovation to examine the roles of financial constraints. We firstly construct an index, directly measuring firms' financial constraint level. We find that the VAT reform pilot has a more substantial negative effect on innovation for firms which is more financially constrained. Then we also test the heterogeneous effects of the VAT reform on innovation for SOEs vs. non-SOEs and firms with foreign ownership vs. solely domestically owned firms. We find that the VAT reform pilot has more substantial negative effects on innovation for non-SOE firms and solely-domestic owned firms, respectively. Since non-SOEs tend to be more financially constrained than SOEs and solely-domestic owned firms tend to be more financially constrained than multination firms, these findings also support the idea that financial constraints play important roles in crowding out internal innovation when the investment tax credit reduces the cost of purchasing physical capital.

One key concern on our specification is that the selection of industries and location of the reform is non-random, which will bias our estimation. To address this concern, we first control for a full set of province*year, industry*year, and firm fixed effects throughout the whole paper to control for province specific-shocks, industry specific-shocks, and time-invariant unobservable factors. In addition, we use the propensity score (PS) to match treatment and control groups of firms and re-estimate the results with the PS-matched sample. Besides, our results are also robust to the placebo tests regarding reform time and pilot firms and alternative samples. We also introduce R&D expenditure to verify that innovative inputs respond to the 2004 VAT reform similar to innovation output. All these results are consistent with our baseline results.

Our paper relates to three literatures. First, our paper contributes to the literature on investment tax credits. Investment tax credits are normally considered as an effective tool to lower the price of capital, stimulate firm investment, and boost economic growth (e.g., Abel, 1982; Sen and Turnovsky, 1990). Zhang, Chen, and He (2018) and Liu and Lu (2015) examine the same VAT reform pilot as this paper and find the positive effect of the VAT reform on firm investment in physical capital. However, Goolsbee (1998) documents that real investment can hardly respond to changes in the cost of capital because much of the benefit of investment tax incentives does not go to investing firms but rather to capital suppliers through higher prices. Besides, some studies focus directly on R&D tax credits, which provides direct subsidies to R&D expenditures, and have shown that it can increase R&D intensity (e.g., Bloom et al., 2002; Rao, 2016). However, Thomson (2015) argues that the elasticity of R&D

investment with respect to tax-price varies substantially between firms due to the endogeneity to the current choice of investment. This paper contributes the literature by showing that there might be some unintended consequences on reducing firms' internal innovation of the investment tax credits.

This work also contributes to a growing literature that examines firms' strategies of technology adoption, especially the choice between pursuing innovation internally and sourcing existing technology externally. A large strand of research argues whether there is substitutability or complementarity between internal or external sourcing (Arora and Gambardella, 1990; Rosenberg, 1990; Veugelers and Cassiman, 1999). More recently, Bernstein (2015) documents that firms that went public changed their composition of projects from innovative ones to conventional ones and had more incentives to acquire external technologies through M&As. The findings of this paper show that investment tax credits might also shape firms' technology adaptation strategies by changing the relative costs of purchasing external innovation and cultivating internal innovation.

Third, this paper contributes to the papers which shed light on the role of financial constraints on investment sensitivity. The relation between financing and investment has attracted researchers' attention for long time, whereas do not present consistent findings. Fazzari, Hubbard, and Petersen (1988) argue that for constrained firms, the sensitivity of investment to firms' cash holdings is larger compared to unconstrained firms. However, Kaplan and Zingales (1997) report evidence which contradicts the finding of Fazzari, Hubbard, and Petersen (1988), and show that investment-cash flow sensitivities for financially constrained firms are less than those for unconstrained firms. Recently, Zwick and Mahon (2017) focus on the heterogeneous effects of tax policy on investment behavior by financial constraints, and find that small firms face larger financial constraints, and thus respond to the policy more substantially. Our paper contributes to this topic by showing that financial constraints can affect the spillover effects of investment tax credit on firms' innovative investment.

Finally, this paper is closely related to Zhang, Chen, and He (2018) and Cai and Harrison (2017). Both of them examine the impacts of the 2004 VAT reform in China on firms' investment behaviors. Our findings are more consistent with Zhang, Chen, and He (2018), showing positive impacts of the reform on firm investment, but are differ from Cai and Harrison (2017), which find no significant impacts of the 2004 VAT reform in China. Our results differ from Cai and Harrison's (2017) mainly for two reasons. First, Cai and Harrison's (2017) only use the sample of affected industries to estimate the difference-in-differences estimation to identify the effects, while we use the full sample covering both affected and unaffected industries to estimate a triple-difference estimation to identify the effects. Second, their specification differs from ours. Specifically, they employ the difference-in-differences (DID) estimate with firm and year fixed effects to identify the effects of the reform, while we employ difference-in-difference-in-differences (DDD) estimation with firm, province*year, and industry*year fixed effects to identify the effects of the reform. Our specification controls for time-variant industry and location unobserved effects. The DID analysis in Cai and Harrison (2017) removes the innovation trend specific to the ineligible industries, and the remaining difference captures the innovation trend specific to NE regions that might come from changes other than the VAT reform. Compared to DID method, our DDD method removes the innovation trend specific to NE regions in general, and the remaining difference reflects the extra innovation of eligible firms in the NE region. Thus, our DDD method is more effective than their DID method.

The rest of this paper organizes as follows. Section 2 introduces the background of China's Value-added Tax reform. Section 3 provides the theoretical framework. Section 4 discusses the data and methodology of the whole research. Section 5 presents the empirical results. Finally, section 6 concludes.

2. Institutional Background of the 2004 Value-added Tax Reform in China

The value-added tax (VAT) has been widely adopted by more than 130 countries around the world. It is a tax that is charged on the added value at each stage of production, transaction, or labor services. Specifically, VAT liabilities are calculated based on the differences between sales revenues and the sum of the costs of production inputs, employee wages and the purchasing value of fixed assets used in production in most countries.

China adopted the VAT policy at the first time in 1994[5]. At that time, to increase government tax revenues and also release the economic overheating by discouraging investment, the government required that the purchasing value of fixed assets used in production is not deductible from sales revenues while calculating the VAT liabilities. Under this policy, the value of fixed assets is taxed twice. One is charged from fixed asset producers as their sales products, and the other one is charged from fixed asset purchasers (i.e. users). The VAT becomes the most important tax source in China and accounts for 35% to 45% of national tax revenue at that time.

With the changes of economic environments and the government financial situation, the original VAT policy became not suitable anymore in China. First, the economic overheating had been reversed. Chinese economy confronted new challenges, demanding for production automation and technology upgrading and improvement. As a result, stimulating investment in fixed assets, such as purchasing new machines and equipment, became important. Second, the government fiscal revenues had been significantly increased to a great extent compared to 1994. For the above reasons, the government decided to enact the new VAT policy by allowing firms to deduct the purchasing value of fixed assets for production (excluding structures) from sales revenue when calculating VAT liabilities in 2004. This

[5] In 1994, mainland China implemented a tax sharing reform and the VAT was part of the reform.

reform can reduce firms' tax burdens and also encourage the adoption of technology embodied in machines and equipment by increasing purchasing fixed assets.

The VAT reform pilot issued by the Chinese Ministry of Finance and the State Administration of Taxation became effective on September 12, 2004 for firms in six industries in three northeastern provinces of China. The six industries include: equipment manufacturing; automobile manufacturing; petroleum, chemical, and pharmaceutical manufacturing; agricultural product processing; metallurgy; and ship building. The three northeastern provinces are Heilongjiang, Jilin, and Liaoning. This reform pilot applied to purchasing transactions completed after July 1, 2004. "Decision of the Ministry of Finance and the State Administration of Taxation on Issues on the Expansion of Deduction of the Value-Added Taxation in the Northeastern Provinces" was announced by the government on September 14th in 2004 and stipulated the scope of the deduction. First, the purchase of fixed assets on production including accepting donations and physical investment, is able to be deduct. Second, the material or labor cost of fixed assets manufactured or constructed by an enterprise itself can be deducted. Third, fixed assets acquired through lease financing can be deducted when the lessor pays VAT following regulations. Fourth, labor cost related to transportation and installation of fixed assets is able to be deducted only if these services are supplied by the fixed asset sellers. After the first pilot, the reform was expanded to another 26 cities in six provinces located in central China in 2007, and finally to all industries and provinces of China in early 2009.

The VAT rate consists of a standard rate of 17%, a reduced rate of 13% for agricultural production, and a zero rate for some export enterprises. After the VAT reform, the cost of purchasing fixed assets (excluding structures) can be deducted from the value-added tax base when the value-added tax is calculated. Thus, under the new VAT regulation starting from 2004, the cost of investment in fixed assets is reduced by a substantial scale.

3. Theoretical Framework

In this section, we develop a simple theoretical framework to demonstrate how the VAT reform affects firms' choices of technology adoption through changing the relative prices of input factors. We create a framework where the aim of a firm was to maximize its productivity with three input factors: innovation investment, fixed assets and labor. Suppose a firm is choosing two types of projects to invest. The first one is non-innovative projects with existing technology embodied in machinery and equipment and labor inputs; and the second one is innovation projects which generate returns through long-term innovation and the introduction of new products.

The VAT reform leads firms located in northeast of China in the six affected industries to experience a large decrease in the relative price of fixed assets. It is reasonable that the decrease in the cost of purchasing fixed assets increases firms' investment in fixed assets because of the price elasticity. If the machines and equipment become cheaper with other factors unchanged, firms would buy more machines and equipment to make profits through operating non-innovative projects with existing technology embodied in machines and equipment, rather than explore new technology by innovation activities, considering innovation as an input factor of production other than fixed assets. The impact of the VAT reform on technology enhancing strategies and innovation decisions depends on firms' financial constraints and the elasticity of substitution between non-innovative, ordinary investment and innovative investment. If investment in purchasing machines and equipment and investment in innovation are substitutes in pursuing advanced technologies, then the VAT reform could cause the decrease in innovative inputs, thus a decline in firm innovation.

We consider a framework where the aim of a firm was to maximize its profits under financial constraints. Suppose a firm's final output comes from two kinds of investment: non-innovative, ordinary investment and innovative investment. Similar to Acemoglu and Autor (2011), we assume a nested Constant Elasticity of Substitution (CES) production function[6] $(\beta N^{\rho}+(1-\beta)R^{\rho})^{\frac{1}{\rho}}$ in order to illustrate the potential substitution effect between non-innovative projects (*N*) and innovation projects (*R*).

In addition, we assume that firms are price takers in both input and output markets, facing the cost of capital equal to c_K per unit of fixed assets, a wage rate of c_L per unit of labor, and the cost of innovation equal to c_R per unit of innovation input, with the output price standardized as one. The total cost of all input factors is no more than the total investment, *I*. The profit function of a firm with three input factors (capital, labor and innovation) is given as follows:

$$\underset{\{K,L,R\}}{Max}\left[\beta\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}}+(1-\beta)R^{\rho}\right]^{\frac{1}{\rho}}-c_K K-c_L L-c_R R \tag{1}$$

subject to the budget constraints,

$$c_K K+c_L L+c_R R=I. \tag{2}$$

In model (1), $\sigma=\frac{1}{1-\rho}$, which is always larger than zero, governs the elasticity of substitution between ordinary, non-innovative production ($N(K,L)=\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{1}{\psi}}$) and innovation production (*R*) outputs.[7] Ordinary and non-innovative production is a function of two types of inputs, physical capital (*K*) and labor (*L*). The implications of the switch to consumption-type VAT for factor inputs and project choices can be derived simply by interpreting the profit maximization of the firm and investigating how its optimal decisions change in response to a decline in the relative price of fixed assets (c_K).

[6] The CES function is the most extensively used functional form in economics literature for analyzing the relationships between a set of input factors (e.g., Acemoglu et al., 2012).

[7] If σ is zero, the production is a Leontief type where the output is produced by using non-innovative and innovative inputs; if σ is between 0 and 1, non-innovative and innovative projects are complements; if σ is 1, the case is the Cobb-Douglas production; if σ is larger than 1, then non-innovative and innovative projects are substitutes; and when σ goes infinity, non-innovative and innovative projects are perfect substitutes.

After taking the first-order conditions and differential regarding c_K (see Appendix 1), we derive

$$\frac{\partial R}{\partial c_K} = \frac{\rho}{(1-\rho)\left[(1+X)\frac{c_K}{R}+\frac{c_R}{K}\right]} = \frac{\sigma-1}{\left(1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)\frac{c_K}{R}+\frac{c_R}{K}} \tag{3}$$

When $\sigma > 1$, which means innovative and non-innovative projects work as gross substitutes and the elasticity of substitution is larger than 1, $\frac{\partial R}{\partial c_K} > 0$.

Prediction 1. 2004 VAT reform increases the amount of investment in physical capital and decreases the amount of innovative investment when the elasticity of substitution between ordinary investment and innovative investment is greater than 1.

Different Firms might be differentially affected by the investment tax credits. In our model, the magnitude of the elasticity of substitution between ordinary investment and innovative investment is pivotal in understanding the response of innovative investment decisions to investment tax credits. It gauges the ease with which firms can cut R&D spending and acquire new machinery and equipment, and determines how firms' usage of capital, labor, and R&D inputs respond to policy changes that affect factor prices. Consider that there are two types of firms facing different magnitudes of the elasticity of substitution $i = H, L$. The elasticity of substitution of firms is denoted by σ_i, $i = H, L$. The firms with a higher σ may respond to investment tax credits to a larger extent, whereas the firms with a lower σ (e.g., $\sigma = 1$) show less significant substitution effects between ordinary investment and innovative investment.

Prediction 2. The negative impacts of the investment tax credits on innovation are stronger for firms which have more flexibility and incentives to reallocate inputs between ordinary investment and innovative investment, such as financially more constrained firms.

Why look at firms with different financial constraints? First, financially more constrained firms usually have smaller-size assets, especially physical assets, thus might face a lower adjustment cost and allocate inputs among different tasks with more flexibility. Second, financially constrained firms are intended to increase the tangibility of their assets to enhance their credit capacity (Almeida and Campello, 2007). However, comparing with machinery and equipment, innovation requires more intangible inputs such as hiring more researchers and scientists (Hall, 2010). As a result, the negative effects of investment tax credits on internal innovation might be more significant for financially constrained firms than financially unconstrained firms.

4. Data and Methodology

4.1 Sample Construction

Our sample is constructed as a firm level panel data. The data are taken from the Annual Survey of Industrial Firms (ASIF). The survey is conducted by the National Bureau of Statistics of China (NBS). It consists of all the State-Owned Enterprises (SOEs) and non-SOEs with annual sales in excess of 5 million yuan (around US$650,000). The data cover the information of firm characteristics and the information from financial balance sheets collected at the end of calendar year. By the end of 2007, the ASIF collected the information of more than 330,000 firms in manufacturing industries, making up around 95% of the nation’s industrial output. Thus it is considered as the most comprehensive firm-level panel dataset of Chinese manufacturing industries. Since the VAT pilot took place in 2004, our sample covers from 2001 to 2007, which includes three years before and after the regulatory shock.

Following Zhang, Chen, and He (2018), to get our final regression sample, we take the following steps. First, we exclude firms located in the 26 cities of central China to eliminate the effect of the VAT reform in 2007. We also exclude firms in the mining, electricity, and utility sectors, because firms in these industries sectors were covered by the 2009 VAT reform. Next, we exclude observations in which variables have error values, such as zero or negative sales or outputs. Third, we eliminate firms which change locations or industries during the sample period to avoid the potential selection bias. Finally, in order to reduce the effects of outliers, we winsorize all continuous variables at the top and bottom 1% of its distribution for each year-province combination. Our final sample consists of a total number of 981,273 firm-year observations associated with 256,350 firms.

[Insert Table 1 Here]

Table 1 presents the sample description by years, regions and industries. The total number of firms reported in Column (1) increases as time goes by. Column (2) reports the number of observations in the northeastern region. Column (3) reports the percentage of firms in the six affected industries in northeastern (NE) region. Firms in affected industries account for 83% in firms in the NE region, which is similar to the data presented by Zhang, Chen, and He (2018). The definition of the industry eligibility of industries is based on the detailed guideline of the Ministry of Finance and State Administration of Taxation and the manufactory firms' 2- or 3-digit industry code defined by the 2004 industry classification.[8] The six broadly defined affected industries include: (1) equipment manufacturing[9]; (2) automobile manufacturing[10]; (3) petroleum, chemical, and pharmaceutical manufacturing[11]; (4) agricultural product processing[12]; (5) metallurgy[13]; and (6) ship building[14]. The unaffected industries primarily include tobacco, metal and non-metal mineral products industries[15].

[8] Industry classification and industry codes were revised in 2003 in the ASIF database. We adjust all firm industry codes to the new classification and codes, because the eligible industries of the 2004 VAT reform were defined based on the new industry code system.

[9] 2-Digit (3-digit) industries in equipment manufacturing consist of Ordinary machinery manufacturing (35), Special equipment manufacturing (36), Railway transport equipment manufacturing (371), Aerospace and aeronautic equipment manufacturing (376), Other transportation equipment manufacturing (379), Electric machines and apparatuses manufacturing (39), Computer and communication equipment manufacturing(40),and Instruments, cultural and office machinery manufacturing (41).

[10] 2-Digit (3-digit) industries in automobile manufacturing consist of Automobile manufacturing (372).

[11] 2-Digit (3-digit) industries in petroleum, chemical, and pharmaceutical manufacturing consist of Refined petroleum products (251), Nuclear fuel processing (253), Raw chemical materials and chemical products (26), Medical and pharmaceutical products (27), Chemical fibers (28), Rubber products (29), and Plastic products (30).

[12] 2-Digit (3-digit) industries in agricultural product processing consist of Smelting and pressing of ferrous metals (32) and Smelting and pressing of nonferrous metals (33).

[13] 2-Digit (3-digit) industries in metallurgy consist of Agricultural and by-product processing (13), Food production (14), Beverage production (15), Textile (17), Garments manufacture (18), Leather, furs, down and related products (19), Timber processing, bamboo, and straw products (20), Furniture manufacturing (21), Paper making and paper products (22), and Crafts work and other manufacturing (42).

[14] 2-Digit (3-digit) industries in ship building consist of Ships and floating equipment manufacturing (375).

[15] 2-Digit (3-digit) industries in unaffected industries consist of Tobacco products processing (16), Printing and record medium reproduction (23), Cultural, education, sports article production (24), Coking (252), Nonmetal mineral products (31), Metal products (34), Motorcycle manufacturing (373), Bicycle manufacturing (374), Transportation equipment repairing (378), and Waste recycling and processing (43).

4.2 Innovation Variables

Following a large body of recent literature (e.g., Aghion, Van Reenen, and Zingales, 2013; Fang, Tian, and Tice, 2014; Seru, 2014), we use patent information to measure firm innovation outcome. We choose patent information instead of R&D investment as the primary measure of innovation, because patents are the comprehensive outcome of innovative inputs and can be transformed into productivity in a more direct way. In addition, R&D expenditures are not included in the ASIF Database. Thus R&D investment information is not available for us as the innovation measure.

We obtain patent data from Baiten Website[16], where we can search the patent information of firms. The data presented in this website come from the Chinese National Intellectual Property Administration (CNIPA) of the P.R.C.[17], the official institution for patent application management in China. Rich patent information is disclosed to public through the CNIPA, including the application ID, application date, granting ID, granting date, applicants, investors, classification number, and patent types.

Based on the patent law of China, there are three different types of patents: invention patents, utility model patents, and design patents. Different types of patents reflect different levels of innovativeness, investigation period, protection period, and investigation mechanisms. Specifically, invention patents are required to show a significant technology improvement, need to go through a complex approval process, and have the longest protection period. Utility model patents are not as innovative as invention patents, and can be granted for new applications of existing technologies (Fang, Lerner, and Wu, 2017). Design patents focus on the new design of the shape, color, and graphic pattern of products, and hence it is least innovative among the three types of patents.

Following previous papers, we construct four firm innovation measures. The first one is the logged value of one plus total number of patent applications filed (and eventually granted) by firm *i* in a given

[16] For more information, see the Baiten Web site: http://www.baiten.cn/ (accessed Dec 26, 2018).
[17] For more information, see the CNIPA Web site: http://www.sipo.gov.cn/ (accessed Dec 26, 2018).

year t, $LnPat_t$. This measure reflects only the quantity, but not quality of innovation. However, we cannot obtain the quality information due to the absence of citation data in CNIPA website. To address this issue, we construct the following three variables based on the degree of innovativeness of patents. Thus, our second innovation variable is the logged value of one plus the number of invention patent applications filed (and eventually granted) by firm i in a given year t, $LnPat\_inv_t$, following Tan et al. (2015). Due to its highest inventiveness level, invention patent can be proxied for high quality innovation. Our third and four measures of innovation are $LnPat\_utl_t$ and $LnPat\_des_t$. They are defined as the logged value of one plus the number of utility model patent and design patent applications filed (and eventually granted) by firm i in a given year t, respectively. In sum, we capture both the quantity and quality of firm innovation by examining the number of all patents and three different categories of patents.

Following the innovation literature, we use the number of successful patent applications (eventually granted in the following years), rather than the number of patents granted in the given year for two reasons. First, the application year is year when a firm produces the innovation output, and thus it can better capture the actual time of innovation (e.g., Hall, Jaffe and Tratjenberg, 2001; Griliches, Pakesn and Hall, 1988). Second, it takes time for the government to approve patent applications, and there are variations in approving time among different patent applications.

Finally, we match the patent information using patent applicants to the ASIF database. All innovation measures are set to zero if a firm doesn't apply any patent successfully in a given year. Our patent data of the sample firms include all patents granted by the end of 2014, because the latest patent data used in the paper is in 2011 and we give a three year window between application and granting dates of patents[18].

4.3 Control Variables

Following previous studies (e.g., Fang, Tian, and Tice, 2014; Tan et al, 2015), we control for

[18] The time lag between the application date and the grant date of a patent in China is 2 to 3 years for invention patents, 5 to 13 months for utility patents and design patents on average in our data.

several firm-specific time-varying variables that are known to affect firms' innovation strategies.

They are defined as follows: (1) Firm size, $LnAssets_{i,t}$, measured as the natural logarithm of total assets for firm i in year t adjusted by the price index[19] based on RMB in 1998, the beginning year of the whole ASIF database. On the one hand, according to the Schumpeterian hypothesis (1942), firms with larger sizes might have an advantage over external financing for risky R&D and perform scale economies in R&D outputs, resulting in better innovation results; on the other hand, firms with larger sizes might undermine the efficiency in R&D due to the lack of managerial control and excessive bureaucratic control, resulting in worse innovation results (e.g., Acs and Audretsch, 1988; Holmstrom, 1989; Lerner, 2006). (2) Firm debt, $Debt_{i,t}$, defined as the book value of debt divided by the book value of total assets. Firms with high leverage ratios are discouraged to invest in risky and long-term innovation projects compared to investment in physical assets, because lenders could not share the potential upside benefits from innovation projects (e.g., Hall, 2002; Heider and Ljungqvist, 2015). (3) Return on assets, $ROA_{i,t}$, defined as operating income divided by the book value of total assets. Firm profitability reflects the capability of generating internal funds when the capital market is imperfect, thus higher profitability can reduce the possibility of financial constraints and improve investment in innovation projects (e.g., Cohen, 2010). (4) Firm age, $LnFirmAge_{i,t}$, measured as the natural logarithm of one plus firm i's age in year t. Startups are more nimbler than older firms when they decide to invest in innovation projects and older firms often have additional layers of bureaucratic management, resulting in lower efficiency of innovation (Adelino, Ma and Robinson, 2017). (5) State ownership, $State\ Share_{i,t}$, measured as the proportion of capital owned by the state sector in the total paid-in capital. Compared to state-owned firms, private firms perform better in technological innovation due to better interest alignments between controlling and minority shareholders and higher stock price informativeness (Tan et al., 2016). The detailed definitions of all variables can be found in

[19] The price index comes from the Chinese Annual Statistical Yearbooks.

Appendix 2.

4.4 Summary Statistics

Table 2 presents summary statistics for the key variables used in the paper. To mitigate the effect of outliers, we winsorize all continuous variables at the 1^{st} and 99^{th} percentiles for each year-province combination. Our sample firms on average generate 0.072 total patents (Pat_{t+1}) per year one year ahead. The number of the three types of patents are 0.003, 0.023, and 0.026, respectively. The number of patents increases to a large extent when we focus on innovative outcomes in four years ahead, denoted as Pat_{t+4}, Pat_inv_{t+4}, Pat_utl_{t+4}, and Pat_des_{t+4}, which means that the innovation level is increasing during our sample period on average. For example, the average of Pat_{t+4} grows to 0.144. In addition, the number of patents shows skewness, and thus we use the natural logarithm of one plus the number of patents as the main innovation outcome measure in our analysis.

We also present the summary statistics of the firm-year level control variables. On average, a firm in our sample has book value of assets of 52.763 million in 1998 RMB, ROA of 0.067, leverage ratio of 0.578, and firm age of 9.110, and state share of 0.061. These firm-year characteristics are similar to those reported in other studies using the ASIF database as the data source (e.g., Zhang, Chen, and He, 2018).

[Insert Table 2 Here]

4.5 Identification Strategy: The DDD Estimation

The 2004 VAT reform pilot in China offers a natural experiment to examine the impacts of investment tax credit on firm behaviors with the trip-difference estimation model. The tax reform affected the cost of fixed asset investment only for the firms located in northeast regions (NE) belonging to the six eligible industries in 2004; however, the cost of fixed asset investment of the NE firms in ineligible industries or non-NE firms are unaffected.

A straightforward way to evaluate the effect of the VAT reform on firm innovation is to estimate the difference in firm innovation for affected firms between the pre-reform period and post-reform period. This method could control for the time-invariant firm characteristics. However, this method fails to control for time trend effects. A better way to estimate the effects is using a control group and comparing the change in innovation for affected firms with that of firms which are not affected by the VAT reform to control for the time trends. The second difference is the differences between the NE region vs. non-NE region firms in differences between before and after the reform in firm innovation. This difference across regions (NE region vs. non-NE region) allows us to control for region-specific time trends, because region-specific patterns affect in both NE firms and non-NE firms. The third difference is the difference in the second difference mentioned before between eligible industries and ineligible industries. This across industries (eligible industries vs. ineligible industries) difference allows us to control for industry-level specific time trend. The triple-difference methodology thus can allow us well control for region level and industry level specific time trend before and after the reform.

To examine the short- and long-run impact of changes in investment tax credits on firm innovation strategies, we estimate the following triple difference estimation model:

$$y_{i,t+1(4)} = \beta \times NE_{prov} \times Eind_{ind} \times Post2004_t + Controls_{i,t} + \lambda_i + \lambda_{prov,t} + \lambda_{ind,t} + \varepsilon_{i,t+1(4)}. \quad (4)$$

The subscript i indicates firms and t indicates years. In addition, the subscript $prov$ indicates provinces or province-equivalent municipal cities[20] and the subscript ind indicates industries which are classified based on the 3-digit industry code in the ASIF dataset. The dependent variable $y_{i,t+1(4)}$ represents one of our innovation measures ($LnPat_{i,t+1(4)}$, $LnPat\_inv_{i,t+1(4)}$, $LnPat\_utl_{i,t+1(4)}$, and $LnPat\_des_{i,t+1(4)}$), the logarithm of one plus the number of successful (total, invention, utility model, and design) patent applications filed by firm i either in year $t+1$ or $t+4$. We define the one-year effect of the VAT policy as a short-run effect while the four-year effect as a long-run effect. On the one hand, most papers (e.g., Hsu, Tian, and Xu, 2014; and Acharya and Xu, 2017) in the innovation literature use the patent information one year ahead. On the other hand, following Tan et al. (2016),

[20] Province-equivalent municipal cities in China include Beijing, Chongqing, Shanghai and Tianjin.

we use patent information in 4 year ahead to measure the long-term effect.[21] $Post2004_t$ is an indicator which equals to one for post-reform period, year 2005-2007, and zero otherwise.[22] The results are also robust, if we define the year of 2004 as the first post reform year. $Eind_{ind}$ is an indicator, which is equal to 1 if firm i belongs to one of the six affected industries, and 0 otherwise. NE_{prov} is also an indicator, which is equal to one, if firm i is located in the northeastern region of China during the sample period, and 0 otherwise.

Our main parameter of interest in model (1) is the coefficient β on the interaction among NE_{prov}, $Eind_{ind}$, and $Post2004_t$. This parameter tells us whether affected firms and unaffected firms differ in changes in their innovation outcomes after the VAT reform. Under the null that the VAT reform does not affect firms' innovation behaviors (i.e. $\beta = 0$). We expect β to be negative if the VAT reform have a negative effect on firms' internal innovation activities.

In addition, λ_i represents firm fixed effects to control for firm-level unobserved factors; λ_{prov*t} and λ_{ind*t} represent province- and industry-year fixed effects, respectively, to account for province- and industry-specific events in a given year that could affect innovation. In other words, we control λ_{prov*t} and λ_{ind*t} to capture time-varying, province-level unobserved heterogeneity and time-varying, industry-level unobserved heterogeneity. $\varepsilon_{i,t+1}$ is the heteroskedasticity-robust standard errors clustered at the firm level, since the innovation activities are firm-level behaviors. We also cluster the standard errors by province-industry level as robustness checks, since the reform is at province-industry level. All these results are robust. We include only the interaction term $NE_{prov} \times Eind_{ind} \times Post2004_t$ in the regression, but not the binary variables themselves, since these three terms are absorbed by firm, industry-year, and province-year fixed effects, respectively. In addition,

[21] Our baseline results do not change if the patent variables two or three years ahead are used as the dependent variables. The VAT reform were implemented around the whole country in early 2009, so we do not use the patent variables five or more years ahead as the dependent variables.

[22] The reform was implemented in September, 2004. Considering the purchase of fixed assets is time-consuming, we refer year 2005 as the first post-reform year. To address the potential bias due to the definition of post-reform indicator, we delete the observations in 2004 in the robustness test in Section 5.3.3.

according to the existing literature, we further add a vector of firm-level time-variant control variables ($Controls_{i,t}$) to the model specification to test if the baseline result is driven by other omitting time-variant factors.

In a nutshell, our identification stems from a triple-difference estimation strategy: Affected provinces versus unaffected provinces; affected industries versus unaffected industries; before versus post the policy change. The above specification is appropriate only if two conditions are satisfied. First, we need to show that the results are not driven by the difference in the trend of outcome variables prior to the VAT reform. Figure 1 plots the differences in number of successfully applied patents between eligible and ineligible firms around the 2004 VAT reform. The vertical axis is $(Y_{NE\text{-}Eind} - Y_{NE\text{-}nonEind}) - (Y_{nonNE\text{-}Eind} - Y_{nonNE\text{-}nonEind})$, which is the each year difference in the gap of average number of patents of NE relative to the non-NE regions between the eligible and ineligible industries over the period from 2001 through 2007. The figure depicts that the relative difference in differences between eligible and ineligible industries is quite small over 2001–2004, while it drops significantly after 2005. This graphical prereform trends suggest that the parallel trends assumption is valid. We further replace the post-reform indicator that we used in the baseline model with a series of year dummies and run regressions to prove the parallel assumption. Then, we confirm that the potential nonrandom selection of pilot firms has no significant impacts on our main results by constructing a PSM sample and replicating the baseline regressions. We address these issues in the robustness check section (Section 5.3) after presenting our baseline results.

[Insert Figure 1 Here]

5. Empirical Results

5.1 Baseline Results

Table 3 provides the main triple-difference results examining the effect of the 2004 VAT reform on firm-level innovation using Equation (4). In Panel A, we examine the effect of the 2004 VAT reform by using the innovation outcomes one year ahead.

[Insert Table 3 Here]

The results reported in Table 3 show that the 2004 VAT reform has significant negative effects on the number of patent applications filed (and eventually granted) for affected firms, suggesting that there is a decline in innovation in affected firms. The dependent variable of Column (1) is the innovation measure, $LnPat_{t+1}$ and the estimated coefficient on the independent variable of interest, the interaction term $NE_{prov}\times Eind_{ind}\times Post2004_t$, is -0.0089 and significant at the 1% level (t-statistics = −2.98), suggesting that the 2004 VAT reform reduces the number of total patents of a firm by 13.19%[23]. In Column (2), the estimate of coefficient on $NE_{prov}\times Eind_{ind}\times Post2004_t$ is −0.0087 and significant at the 1% level as well. The estimated results of these control variables also show that firms with larger size, higher profitability, younger age, and less state ownership tend to do more internal innovation.

The results reported in Columns (3) to (5) are consistent with those reported in Column (2). The key variable of interest—the interaction term among *NE*, *Post2004*, and *Eind*—are negative and significant, indicating that the 2004 VAT reform decrease the number of invention patents regardless of their innovativeness level. Comparing the magnitudes of estimated coefficients of the three types of patents shows that the estimated coefficient of $LnPat\_des_{t+1}$ is smaller than $LnPat\_inv_{t+1}$ or $LnPat\_utl_{t+1}$,[24] suggesting that the impacts of VAT reform is stronger for high innovativeness level of patents, which may require more capital inputs and longer development period.

Overall, the results reported in Table 3 suggest that the 2004 VAT reform appears to have a significant negative effect on firm innovation. The negative effects of the reform are more prominent for innovation activities requiring more inputs and longer investigation and investment period. In sum, these findings are consistent with the "substitution effect".

[23] Specifically, $d[Ln(1+y)]/dx = [1/(1+y)]dy/dx$, and x represents the interaction among NE_{prov}, $Eind_{ind}$, and $Post2004_t$ in this case. When we increase x from zero to one, $dy = (1+y)[Ln(1+y)]$. The change in number of patents (dy) from its mean value (0.072) is then equal to 0.0089*(1+0.072) = 0.0095, which accounts for 13.19% of the mean value of the number of patents.

[24] The p-value of test the equality of the estimates of key coefficients in Columns (3) and (5) is 0.076, and that in Columns (4) and (5) is 0.070, both of which are significant in 10% level.

5.2 Heterogeneous Effect Analyses by Financial Constraints

Our findings so far suggest that the decrease in relative price of fixed assets hinders firm internal innovation activities because the purchase of machinery and equipment and the internal innovative investment are two substitutes for firms to improve technology and productivity. According to previous literature, firms with different level of financial constraints may respond to different extent to investment tax credits. For example, Zwich and Mahon (2017) show that the investment response to tax incentives on equipment investment is stronger for financially constrained, cash-poor firms than financially unconstrained firms when the tax credits could generate immediate cash flows. Fazzari, Hubbard and Peterson (1988) show that financial constraints can increase firms' cash holding to their investment sensitivity. Thus, financial constraints are inevitable and critical for understanding the impacts of investment tax credits on firm behaviors including their innovation activities.

In this section, in order to examine how internal innovation of firms respond to investment tax credits interacts under different financial constraint conditions, we examine several heterogeneous effects of the 2004 VAT reform on firm innovation.

5.2.1 Interacting with the Financial Constraint Index

In this section, we analyze an interactive effect of the 2004 VAT reform with one financial constraint index on firm innovation. We divide the sample by the median of a financial constraint index in 2004 to examine the effect of firms' financial constraints on the baseline results in Section 5.1, and then compare the estimated coefficients of the two groups. As discussed in early sections, we expect that the effect of investment tax credits on innovation is stronger when firms are more financially constrained.

Following Hadlock and Pierce (2010), our financial constraint index is measured based on firm size and age, denoted as the SA index. The SA index equals to $-0.737*Size + 0.043*Size^2 - 0.040*Age$, where *Size* is the logged value of book assets, and *Age* is the number of years since the firm was established. Both *Size* and *Age* are measured in 2004 and winsorized at 1% level when we calculate this index. The reason why we choose this index is threefold. First, SA index is more exogeneous because its value does not count on any endogenous variables such as cashflow and leverage. Second, computing SA index does not need dividend information and Q, thus it is easy to be computed for non-listed firms. Third, SA index is more stable over time compared to other traditional measures (e.g., KZ index). Different from Hadlock and Piece (2010), we use the number of years the firm is established, rather than the number of years since the firm became a publicly listed firm, because most our sample firms are not publicly listed firms.[25]

[Insert Table 4 Here]

The results reported in Table 4 show the effect of the 2004 VAT reform on firm innovation for the groups of high and low financially constrained firms. We find that the coefficients of $NE_{prov} \times Eind_{ind} \times Post2004_t$ using two subsamples are different to a large extent, indicating that the difference of the response to the 2004 VAT reform between the two groups of firms is evident. The Columns (1) and (2) show that the estimated coefficient estimate of $NE_{prov} \times Eind_{ind} \times Post2004_t$ on the logged value of the total number of patents successfully applied in year $t+1$ for the group of financially more constrained firms is −0.0109 significant at 5% level, while that for the group of financially less constrained firms is −0.0033 and statistically insignificant. In sum, the analysis shows that financially more constrained firms are significantly more responsive to the investment tax credits.

5.2.2 State-owned Firms verses Domestic Private Firms

In this section, we examine the heterogeneous effects of the 2004 VAT reform on firm innovation regarding the state ownership. Firms with different types of ownership, such as state-owned enterprises (SOEs) and domestic private-owned enterprises, may confront different innovation incentives and financial constraints in China, therefore differ in response to the investment tax credits. Zhang, Chen,

[25] Hadlock and Piece (2010) find that firm size and age, two relatively exogenous firm characteristics, are particularly useful predictors of financial constraint levels, and they propose a measure of financial constraints that is based solely on firm size and age, and perform better than other traditional financial constraint measures, such as the Kaplan and Zingales (KZ) index.

and He (2018) also find that the increase in fixed investment for affected firms is largely driven by the domestic private firms. In addition, SOEs may have easier access to bank loans than non-SOEs due to political connections or other supports provided by the government in China (Allen, 2005; Cai and Liu 2009; Jin et al., 2015). Thus, we predict that non-SOEs have stronger responses to the 2004 VAT reform due to their poorer availability of external finance compared to SOEs.

We split all domestic firms into state-owned enterprises and non-state-owned enterprises according to their ownership information in 2004. Following Dollar and Wei (2007) and Guariglia et al. (2011), we use the ratio of paid-in capital contributed by different types of investors to identify firms' ownership. A firm is considered as a SOE (non-SOE), if the state (non-state shareholder) owns the largest share of the firm's total paid-in capital. We remove 3,316 observations whose state-owned capital equals to private-owned capital.

[Insert Table 5 Here]

Table 5 shows the results. In Columns (1) and (2), the estimated coefficients of $NE_{prov}\times Eind_{ind}\times Post2004_t$ using the two subsamples are significantly different, with −0.0080 for SOEs and −0.0087 for non-SOEs, suggesting that innovation for private-owned enterprises experience greater decline after the VAT reform than SOEs. The estimated coefficient for non-SOEs is significantly negative, but not for SOEs. In sum, these findings suggest that the impacts of the VAT reform on firm internal innovation is stronger for non-SOEs than SOEs, which can be explained by different levels of financial constraints of firms.

5.2.3 Foreign-owned Firms verses Domestic Firms

In this section, we repeat the above analysis in the context of foreign ownership. We predict that the innovation of foreign-owned firms are less affected by the tax reform than purely-domestically owned firms for the following three reasons. First, foreign firms are more likely to obtain external financing, such as joint ventures with foreign partners, compared to domestic firms (Ayyagari, Demirgüç-Kunt, and Maksimovic, 2011). This argument is also related to our financial constraint hypothesis. Second, multinationals as subsidiaries would receive technology transfer such as new product and process innovation, from their foreign parent companies (Guadalupe, Kuzmina, and Thomas, 2012). Due to foreign acquisition, foreign-owned firms have lower innovation costs, compared with domestic firms. Third, Chinese governments implement several tax subsidies and tax breaks for foreign-owned firms in order to attract more foreign investors during our sample period, which provide more free cash flows to invest for firms. Thus, foreign-owned firms may be less affected by the VAT reform.

In Section 5.2.3, we divide all sample firms into two groups according to their ownerships in 2004. A firm is defined as a foreign owned firm if the foreign sector accounts for the largest share of its total paid-in capital across the state, domestic private sector, and foreign sector. Similar to Section 5.2.2, we remove 3,003 observations in which both foreign sector and domestic sector account for the largest share.

[Insert Table 6 Here]

Table 6 presents the results. The results reported in Column (1) show that there are no significant impacts of the 2004 VAT reform on innovation for foreign-owned firms. However, the results reported in Column (2) show that innovation of domestic firms is affected largely by the reform. Thus, innovation for domestic firms decrease after the 2004 VAT reform while innovation for foreign firms is about unchanged.

5.3 Robustness Checks

5.3.1 Placebo Tests

In this subsection, we conduct three placebo tests to ensure the satisfaction of underlying assumptions for our triple-difference framework. First, we need to ensure the satisfaction of the parallel pre-shock trends assumption, which has been proved to some extent in Figure 1. In this part, we further test whether the difference in firm innovation between affected and unaffected firms is significant in the years prior to the 2004 VAT reform. If so, then we cannot exclude that the difference in firm innovation response to the investment tax credits we find in our baseline results is merely due to a prior downward trends, suggesting existence of the biases in our main results. On the contrary, the insignificance of differential effects in the years prior to the 2004 VAT reform could provide evidence for the parallel pre-shock trends assumption, suggesting that the observed change in firm innovation is due to the treatment, rather than some alternative explanations.

To test this assumption, we replace the prior post-reform indicator that we used with a series of year dummies, (i.e., indicators for the years 2002, 2003, 2004, 2005, 2006 and 2007). Then, we re-estimate Equation (4) using $Ln(1+Pat_t)$ as the dependent variable.

[Insert Table 7 Here]

The estimate results are presented in Column (1) of Table 7. All changes in innovation of eligible firms appear to occur in years 2006 and after, consistent with our assumption that innovation for affected firms appeared the changes from 2006, one year after the first post-reform year. Thus, our results pass this placebo test.

Second, under our assumption, the changes in firm innovation should be different between treatment and control groups had the reform not implemented. We test this assumption by investigating if the innovation for these two groups change differently before the reform. We construct a subsample by keeping the observations from 2001 to 2003 and re-estimate the Equation in Column (1). The result shows that the coefficient estimates of neither *NE*Eind*2002* nor *NE*Eind*2003* is significantly different from zero. Thus, using 2002 and 2003 as two placebo years, we cannot find significant evidence of an effect of a hypothetical reform decreasing innovation for treated firms.

Third, to test if our earlier results appear by chance and prove the degree of the treatment effect on innovation, we conduct three kinds of falsification tests following Chetty, Looney, and Kroft (2009) and La Ferrara, Chong and Duryea (2012).

Specifically, we by constructing placebo interaction variables, *NE*Eind_Random*Post2004*, *NE*Eind*Post_Random*, and *NE*Eind*Post2004_Random*, by generating the random treatment group, the random year of VAT reform, and the random interaction variable, respectively. Our hypothesis for these placebo experiments is that firms that are not within the scope of the 2004 VAT reform should not be affected by the random factor.

[Insert Figure 2 Here]

We first construct a treatment indicator *NE*Eind_Random* by randomly assigning the treatment group. Then we replicate the regressions in Table 3 after replacing the key variable, *NE*Eind*Post2004,* with *NE*Eind_Random*. The procedure of random assignment and regressions is run for 500 times to mitigate the contingency factor and improve the power of the test. We plot the distribution of the 500 estimated coefficients of *NE*Eind_Random*Post2004* in Figure 2. Under our assumptions, the estimated coefficients of *NE*Eind_Random*Post2004* should not be significantly different from zero because the assignment of treatment is totally random. Figure 2-1 shows that the estimated coefficients of *NE*Eind_Random*Post2004* is centered around zero as expected. We present the real coefficient estimates in Table 3 and find it far left end of the probability density functions. Therefore, our baseline results in Table 3 are not spurious.

In the second falsification test, we generate a random year of the VAT reform, *Post_random*, between 2001 and 2007, the sample period in this paper, and it is different from the actual reform year, 2004. We then construct a false the interaction among *NE*, *Eind*, and *Post_random*, reestimate the baseline model in column (1) in Table 3 by replacing the false interaction with the real one, and run 500 replications. The empirical probability density functions and the real estimated coefficient in Table 3 indicated by a vertical line are presented in Figure 2-2. The distribution of the estimated coefficients on the placebo interaction variable is centered on zero and most of the fake coefficients are far larger than the real ones.

In the third simulation, we randomly assign one and zero to the key variable, *NE*Eind*Post2004*, and generate a false one *NE*Eind*Post2004_Random*. Similar to the former two tests, we run the baseline model using *NE*Eind*Post2004_Random* as the independent variable, replicate the procedure for 500 times, and show the results in Figure 2-3. The results are as expected and the estimated coefficient on the placebo interaction is not distinct from zero.

Taken together, the results in Figures 2 enhance our confidence that our findings are not driven by some random factors. Our conclusion passes all the falsification tests.

5.3.2 Propensity Score Matching Analysis

An important assumption of our triple-difference method is that the treatment and control groups should be comparable, meaning it is not related to observable or unobservable characteristics that also affect the outcome variable (innovation). This assumption makes sure the net difference in firm innovation between the two groups can only be attributed to the reform. In our study, however, the scope of sectors and provinces were not randomly selected by the government and were not identical before the reform, but rather coincided with the economic level. The potential selection endogeneity might exist because the development of northeastern regions was backward than many coastal cities regarding technological changes and development. Thus, there is a probability that the eligible industries in northeastern regions were selected because their development lagged behind control firms and were less capital intensive. The pre-reform fundamental differences between the eligible firms and ineligible firms could affect the estimate results of the causal effect of the reform. In other words, the government selected firms which might perform a downtrend in innovation and technology advancing as the pilot of the 2004 VAT reform.

To address this concern, we conduct the propensity score matching approach to reconstruct a new comparable sample and eliminate the potential bias from other observable variables. We adopt a procedure using a nearest-neighbor matching implementation of the propensity score matching approach introduced by Rosenbaum and Rubin (1983). First, we estimate a logit model to ensure that the covariates we use are indeed valid determinants of the VAT reform pilot using the data in 2004. Specifically, our propensity score model includes the dependent variable, *NE×Eind*, which is a dummy variable equal to one if the firm is located in the three northeastern provinces and in eligible industries. According to literature (Cai and Harrison, 2017), the government selected the less developed and market-oriented regions and high capital intensive industries as the pilot of the VAT reform, meaning that the eligible firms might have smaller sizes, worse profitability, older ages, larger state shares and higher level of automation and mechanization. Thus, the matching covariates include firm size (*LnSales*), capital structure (*LongLev*), profitability (*ROA*), the size of internal funds (*CashflowRatio=Cash flow/Net fixed asset stock*), firm age (*LnFirmage*), state ownership (*State Share*), and mechanization and automation (*CapitalLaborRatio* and *LnLabor*). The detailed definitions of covariates are listed in Appendix 2. The goal of the 2004 VAT reform is to encourage firms with less sales income and lower profitability to improve the technological level by purchasing machinery and equipment. Firms in the control group are matched with the treatment group based on the values of these variables in 2004. The logit model is estimated across 145,423 firms containing no-missing data for all the covariates in 2004 to make sure that the covariates capture the determinants of the VAT policy treatment.

The result of the logit model is presented in Appendix 3, showing that the model captures a significant amount of variation in the selection variable, as implied by a very small p-value from the Chi-test of the overall model fitness well below 0.01. In addition, we find that firms in the affected industries in NE regions tend to have smaller size, higher long-term leverage, lower profitability, more state ownership, higher cash flow ratio, and higher capital-labor ratio. This is consistent with the aim of the policy for the less developed regions and high capital intensive industries.

Then, we use the propensity score estimated from the logit regression and implement a one-to-three nearest-neighbor matching with replacement to construct a control group.[26] That is, for each eligible firm, we match it with three control firms with the closest propensity score. Appendix 3 reports the difference between treatment and control groups on various firm characteristics after matching to

[26] Because the number of ineligible firms significantly exceeds the number of eligible firms.

gauge the quality of the matching procedure. The results suggest that there is no significant difference in all firm characteristics between the two groups of firms. In other words, the matching process eliminates major differences between these two groups of firms.

The final paired sample includes 115,723 observations. The innovation output estimation results using the propensity score matched sample are shown in Table 8. The results are robust, suggesting that our results are not driven by the potential bias due to the nonrandom selection of affected firms.

[Insert Table 8 Here]

5.3.3 Alternative Samples

In this section, we use the alternative samples to test the prior results, and show the results in Table 9. First, in order to eliminate the effect of 2004, the year the reform started to implement, we construct an alternative sample by deleting observations in 2004. Second, to eliminate the bias caused by firm entry and exit, we employ the balanced sample, which includes firms operating throughout the whole sample period of 2001 to 2007. The results are robust using these two alternative samples.

[Insert Table 9 Here]

5.3.4 Long-term Effects

In this section, we examine its long-run effect on innovation outcomes in four years. Examining short-term and long-term effects can tell us whether affected firms overreact to the reform in the short term and reverse in the long term. A stable and permanent change in innovation strategies deserves to be studied because innovative investment is a long-term investment and contributes to long-run economic growth (Solow, 1957).

Table 10 reports the results of long-term effects of the 2004 VAT reform. The long-term effect is similar to that of the short-term ones shown in Table 3, but stronger both for the magnitude or the significance level. The coefficient estimates on the interaction term $NE_{prov}*Eind_{ind}*Post2004_t$ are all negative and significant at the 1% level across all columns. These findings suggest that the investment tax credit has a long-term negative effects on reducing firms' internal innovation activities, rather than merely a temporary negative effect. For the long-term innovation measure, the impacts of the VAT reform on firm internal innovation activities between financially constrained firms and financially unconstrained firms are even more contrast in terms of the magnitude and significant level.

[Insert Table 10 Here]

5.3.5 R&D Expenditure

Most of our results in this paper focus on patent-based metrics, a standard measure of innovation, rather than innovation in R&D because we have no access to the R&D expenditures in the ASIF Database. However, R&D expenditure is also an important proxy for the research intensity of the firm and widely used empirically in innovation literature (see, Hall et al., 2010). Since our predictions are on the inputs to innovation and innovation incentives of the firm, R&D investment is also a reasonable dependent variable in our story although it fails to capture the innovation results. In this section, we use investment in R&D as our dependent variable to double-check the definition of firms' innovative activities and to verify that the substitution relationship between internal innovation and acquisition of external technology do not change substantially.

Unfortunately, as we mentioned above, we are not able to acquire the information on R&D investment of firms in ASIF Database. However, firms listed on the A-share market are required to release their R&D expenditure in the notes to financial statements since 2007[27]. In addition, as we mentioned in Section 2, after the first VAT reform pilot in 2004, it was expanded to another 26 cities in six provinces located in central China in 2007, and finally to all industries and provinces of China in early 2009. We try to use the 2009 VAT reform as an alternative exogenous shock to double-check our baseline prediction because the R&D expenditure data covers the years around the 2009 VAT reform from 2007 to 2011. The R&D-related variables and other firm-level accounting variables come from the China Securities Market and Accounting Research database (CSMAR, a leading database on

[27] "Accounting Standard for Business Enterprise: Basic Standard" were released by Chinese Ministry of Finance (http://www.mof.gov.cn/zhengwuxinxi/caizhengwengao/caizhengbuwengao2006/caizhengwengao20061/200805/t20080519_23593.html) on February 15, 2006 and started to take effective on January 1, 2007.

Chinese listed firms), which has been widely used by studies published in top journals (see, e.g., Jiang, Wan and Zhao (2015) and Fang, Lerner and Wu (2017)).

We estimate the DID (difference-in-differences) regression in this section (see Equation (4)) rather than the DDD regression as the baseline results because both the treatment and control groups in 2009 are located in the regions other than the first two pilots and show no variances in the provinces. Thus, the eligibility of industries is the only dimension to distinguish the treatment and control groups and the model is shown as follows:

$$y_{i,t} = \beta Eind_{ind} \times Post2009_t + Controls_{i,t} + \lambda_i + \lambda_t + \varepsilon_{i,t}. \tag{5}$$

We present estimates of Equation (5) with investment in R&D as the dependent variable. The investment in R&D ($y_{i,t}$) is defined as two variables: R&D expenditure scales by total assets and total sales. $Post2009_t$ is an indicator which equals to one for post-reform period, year 2010-2011, and zero otherwise. In addition, λ_i and λ_t represent firm- and year-fixed effects to control for firm-level and yearly unobserved factors, respectively. Control variables are defined as those in Equation (5). In order to make the results comparable to the baseline model, the samples are restricted to manufacturing firms.

[Insert Table 11 Here]

The results on R&D expenditure are shown in Table 11. In Columns (1) and (2), the coefficient estimates on $Eind_{ind} \times Post2009_t$ are -0.0016 and -0.0014, significantly negative, implying that the investment tax credits impede firms' R&D expenditure. This result is consistent with our main results.

5.4 Fixed Investment Response to the 2004 VAT Reform

Our main story is that eligible firms switch investment from internal innovative activities to the acquisition of external technology by purchasing machinery and equipment. However, there is mixed evidence on the impacts of the 2004 VAT reform on firm fixed investment in the literature. Zhang, Chen, and He (2018) and Liu and Lu (2015) show that the 2004 VAT reform increases the capital expenditure in fixed capital for affected firms, while Cai and Harrison (2017) do not find a significant effect. Thus, in this section, we also examine how the 2004 VAT reform affects firm investment in fixed assets. We estimate the same regression as the results in Table 3, except using a measure of investment in fixed assets as the dependent variable. Following Zhang, Chen, and He (2018), we use gross fixed asset investment in year t (GFI_t) normalized by the net fixed asset stock in year t-1 ($NFAS_{t-1}$), as the proxy of firm fixed asset investment ($Rgfinv_t$):

$$Rgfinv_t = \frac{GFI_t \,/\, FIPI_t}{NFAS_{t-1} \,/\, FIPI_{t-1}} \times 100 . \tag{6}$$

In Equation (6), $FIPI_t$ is the price index of fixed asset investment relative to year 1998 from the Statistic Yearbook of China. In this equation, we convert the backed-out *GFI* in current price to a constant price measure using $FIPI_t$. In the ASIF dataset, net asset values are measured at different acquisition prices and are added up, resulting in $NFAS_t$. Due to the low level of inflation since 1990, we divide $NFAS_t$ by $FIPI_t$ to simplify the calculation.

[Insert Table 12 Here]

Table 12 provides evidence on the effect of the 2004 VAT reform on firm-level capital expenditure using the firm's investment in fixed assets in a given year divided by net fixed asset stock as the measure of capital expenditure. The results reported in Column (1) show that the coefficient on the independent variable of interest, the interaction term $NE_{prov} \times Eind_{ind} \times Post2004_t$, is 0.1145 and significant at the 10% level (t-statistics = 1.95). This suggests the VAT reform on average increases 11.45% of the fixed asset investment for affected firms. When controlling for the firm level time variant variables, the results reported in Column (2) show that the VAT reform affected firms increase their fixed asset investment by 13.81%. These results confirm that the firms affected by the VAT reform show a larger increase in capital expenditure following the reform, compared with ineligible firms (the control group). In sum, the 2004 VAT reform may provide incentives for firms to substitute their internal innovation activities by the acquisitions of external technologies after the 2004 VAT reform.

6. Conclusion and Discussion

In this paper, we examine the effect of investment tax credits on firms' internal innovation and their technology adoption strategies, focusing on the introduction of the 2004 VAT reform pilot in the northeastern region of China. This reform switched the type of VAT from production type to consumption type, resulting in the reduction in the price of purchasing machinery and equipment and leaving the cost of innovation projects unchanged.

Our simple neoclassical framework indicates that this change in relative prices should lead to a decline in investment in innovation projects when the elasticity of substitution between ordinary investment and innovative investment is greater than 1. More importantly, the negative impacts of the investment tax credits on innovation are stronger for firms which have more flexibility and incentives to reallocate inputs between ordinary investment and innovative investment, such as financially more constrained firms. These findings suggest a trade-off for the affected firms between two sources of upgrading technology, internal innovation and acquisition of external technology. The 2004 VAT reform changes the technology adaptation strategies that affected firms employ to boost the technology by reducing the relative cost of acquisition of external technologies.

We derive the consistent empirical results with theoretical predictions. Using a triple-difference approach, we present that the 2004 VAT reform has a negative impact on firm innovation, thus there is a substitution effect between acquisition of external technology and firm innovation. We also do some heterogeneous analyses and find that firms facing with different financial constraints are affected by the 2004 VAT reform to different degrees. The impacts of the 2004 VAT reform on firm internal innovation are stronger (weaker) for financially more constrained (unconstrained) firms, non-SOE (SOE) firms, and domestic-owned (foreign-owned) firms. The main results are consistent using several robustness checks. To conclude, our research suggests the real effect of the change in input factor prices on firm innovation and technology adoption strategies and deepen the understanding the drivers of firm innovation.

The results of the paper provide direct, new evidence that investment tax credits will significantly influence firm decisions on investment behavior and technology adoption strategies. Moreover, the magnitude of this effect depends on financial constraints, which can have implications for aggregate productivity and economic growth. These findings, by quantifying the relationship between investment tax credits and firm technology adoption decisions, are relevant for policy makers considering an optimal tax policy to improve the innovation and boost economic growth. Meanwhile, it helps to evaluate the effect of related tax policies and has certain reference significance for policy designers to provide effective policy schemes.

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Table 1 Yearly Sample Distribution

	Total	Northeastern (NE) Region		
		Total	Number of Firms in Eligible Industries	Percentage of Firms in Eligible Industries
Year	(1)	(2)	(3)	(4)
2001	80,261	4,796	3,927	81.88
2002	95,177	5,711	4,693	82.17
2003	102,127	5,959	4,921	82.58
2004	152,645	8,408	7,007	83.34
2005	171,004	10,179	8,469	83.20
2006	195,521	12,831	10,710	83.47
2007	184,538	12,117	10,144	83.72
Total	981,273	60,001	49,871	83.12

Note: This table presents the yearly distribution of my firm-year observations over the 2001-2007 period by regions and industry. Northeastern (NE) region includes Heilongjiang, Jilin, and Liaoning provinces. Eligible industries include six broadly defined manufacturing industries. Sample excludes firms located in the 26 cities of central China to eliminate the effect of VAT reform in 2007. In addition, sample excludes firm-year observations with statistical mistakes, such as zero or negative measures of sales, outputs, so on. Third, sample eliminates firms which change locations or industries during the sample period to avoid the bias that they may cause.

Table 2 Summary Statistics of Innovation and Control Variables

VARIABLE	N	Mean	Min	Median	Max	SD
Pat $_{i,t+1}$	981,273	0.072	0.000	0.000	15.000	0.581
Pat_inv $_{i,t+1}$	981,273	0.011	0.000	0.000	5.000	0.139
Pat_utl $_{i,t+1}$	981,273	0.023	0.000	0.000	7.000	0.218
Pat_des $_{i,t+1}$	981,273	0.011	0.000	0.000	12.000	0.180
Pat $_{i,t+4}$	981,273	0.144	0.000	0.000	21.000	1.003
Pat_inv $_{i,t+4}$	981,273	0.028	0.000	0.000	6.000	0.262
Pat_utl $_{i,t+4}$	981,273	0.067	0.000	0.000	12.000	0.534
Pat_des $_{i,t+4}$	981,273	0.011	0.000	0.000	13.000	0.147
LnAssets $_{i,t}$	981,273	9.723	5.234	9.540	16.048	1.347
Leverage $_{i,t}$	981,273	0.578	0.000	0.590	2.657	0.285
ROA $_{i,t}$	981,273	0.067	-1.187	0.026	7.140	0.153
LnFirmAge $_{i,t}$	981,273	1.952	0.000	1.946	4.394	0.838
State Share $_{i,t}$	981,273	0.061	0.000	0.000	1.000	0.227
Rgfinv$_{i,t}$	700,445	0.432	-14.658	0.056	36.684	1.547

Note: This table presents summary statistics for two parts of variables including number of observation, mean, minimum, median, maximum, and standard deviation. The innovation variables are the number of granted patents in one year ahead and four year ahead implemented in our study. *Pat* is the total number of patent applications filed (and eventually granted) by a firm in a given year. *Pat_inv* is the number of invention patent applications filed (and eventually granted) by a firm in a given year. *Pat_utl* is the number of utility model patent applications filed (and eventually granted) by a firm in a given year. *Pat_des* is the number of design patent applications filed (and eventually granted) by a firm in a given year. *LnAssets* is the natural logarithm of total assets of a firm adjusted by the price index relative to year 1998. *Leverage* is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. *ROA* is the return on assets ratio defined as operating income divided by book value of total assets. *LnFirmAge* is the natural logarithm of one plus firm i's age. *State Share* is the proportion of capital owned by the state in the total paid-in capital. *Rgfinv* is firm's fixed investment in a given year divided by net fixed asset stock measured at the end of previous year adjusted by the price index of fixed assets. To mitigate the effect of outliers, we winsorize all continuous variables at the 1st and 99th percentiles of its distribution for each year-province combination.

Table 3 Innovation Response to 2004 VAT Reform

VARIABLES	(1) Ln(1+Pat$_{t+1}$)	(2) Ln(1+Pat$_{t+1}$)	(3) Ln(1+Pat_inv$_{t+1}$)	(4) Ln(1+Pat_utl$_{t+1}$)	(5) Ln(1+Pat_des$_{t+1}$)
NE*Eind*Post2004	-0.0089***	-0.0087***	-0.0036**	-0.0046**	-0.0009**
	(-2.98)	(-2.91)	(-2.44)	(-2.27)	(-2.23)
LnAssets		0.0125***	0.0041***	0.0056***	0.0022***
		(21.70)	(18.23)	(17.79)	(9.00)
Leverage		0.0001	-0.0002	-0.0004	-0.0002
		(0.05)	(-0.43)	(-0.60)	(-0.48)
ROA		0.0100***	0.0026***	0.0038***	0.0029***
		(6.85)	(4.47)	(4.91)	(4.93)
LnFirmAge		-0.0024***	-0.0013***	-0.0015***	-0.0002
		(-3.59)	(-5.07)	(-4.17)	(-0.95)
State Share		-0.0074***	-0.0025**	-0.0035**	-0.0015*
		(-3.02)	(-2.25)	(-2.27)	(-1.85)
Observations	981,273	981,273	981,273	981,273	981,273
Firm FE	Yes	Yes	Yes	Yes	Yes
Year*Province FE	Yes	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes	Yes
Clusters (firms)	256,350	256,350	256,350	256,350	256,350
Adjusted R-squared	0.386	0.387	0.265	0.320	0.310

Note: This table provides evidence on the effect of VAT reform on firm-level innovation. The dependent variables are the logged value of one plus number of total patents, invention patents, utility model patents and design patents, all of which are successfully granted by CNIPA and defined in year $t + 1$. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 4 Heterogeneity: financial constraint indexes

	Ln(1+Pat_{t+1})	
	Low	High
	(1)	(2)
NE*Eind*Post2004	-0.0033	-0.0109**
	(-1.14)	(-2.18)
LnAssets	0.0052***	0.0227***
	(8.63)	(18.45)
Leverage	0.0013	-0.0016
	(1.06)	(-0.67)
ROA	0.0051***	0.0276***
	(3.65)	(6.30)
LnFirmAge	-0.0005	-0.0052***
	(-0.78)	(-3.95)
State Share	-0.0061**	-0.0090**
	(-2.35)	(-2.15)
Observations	339,436	382,684
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.287	0.424

Note: This table presents the heterogeneous effect of VAT reform on innovation by financial constraint index. We use financial constraint measured in the reform year 2004 to divide our firm sample into two groups according to the sample, where financial constraint is measured as the SA index, relying solely on firm size and firm age according to Hadlock and Pierce (2010). Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. LnAssets is the natural logarithm of total assets of a firm. Leverage is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. ROA is return on assets ratio, defined as operating income divided by book value of total assets. LnFirmAge is the natural logarithm of one plus firm i's age. State Share is the proportion of capital owned by the state in the total paid-in capital. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 5 Heterogeneity: state-owned firms vs domestic private firms

	$Ln(1+Pat_{t+1})$	
	SOE	Domestic private
	(1)	(2)
NE*Eind*Post2004	-0.0080	-0.0087**
	(-0.78)	(-2.50)
LnAssets	0.0185***	0.0136***
	(5.62)	(17.70)
Leverage	0.0041	0.0004
	(0.84)	(0.25)
ROA	0.0268***	0.0110***
	(2.69)	(6.05)
LnFirmAge	-0.0005	-0.0023***
	(-0.15)	(-2.74)
State Share	-0.0086*	-0.0071*
	(-1.85)	(-1.77)
Observations	41,512	549,102
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.481	0.379

Note: This table presents the heterogeneous effect of the 2004 VAT reform on innovation by state ownership. We use the ownership information of firms in 2004, and divide firms into state-owned enterprises and domestic private-owned enterprises. Then, we estimate the model in Table 3 using the two subsamples. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. LnAssets is the natural logarithm of total assets of a firm. Leverage is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. ROA is return on assets ratio, defined as operating income divided by book value of total assets. LnFirmAge is the natural logarithm of one plus firm i's age. State Share is the proportion of capital owned by the state in the total paid-in capital. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 6 Heterogeneity: foreign-owned firms vs domestic firms

	$Ln(1+Pat_{t+1})$	
	Foreign	Domestic
	(1)	(2)
NE*Eind*Post2004	-0.0040	-0.0088***
	(-0.4599)	(-2.6753)
LnAssets	0.0180***	0.0138***
	(9.2323)	(18.5308)
Leverage	-0.0018	0.0006
	(-0.4729)	(0.4484)
ROA	0.0148**	0.0116***
	(2.5639)	(6.5031)
LnFirmAge	-0.0051	-0.0023***
	(-1.5259)	(-2.8137)
State Share	-0.0404**	-0.0071**
	(-2.4502)	(-2.3977)
Observations	128,130	590,958
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.416	0.396

Note: This table presents the heterogeneous effect of VAT reform on innovation by foreign ownership. We use the ownership information of firms in 2004, and divide firms into foreign-owned enterprises and domestic enterprises. Then, we estimate the model in Table 3 using the two subsamples. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. LnAssets is the natural logarithm of total assets of a firm. Leverage is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. ROA is return on assets ratio, defined as operating income divided by book value of total assets. LnFirmAge is the natural logarithm of one plus firm i's age. State Share is the proportion of capital owned by the state in the total paid-in capital. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 7 Robustness check: placebo tests

	Full Sample	2001-2003
VARIABLES	$Ln(1+Pat_t)$	$Ln(1+Pat_{t+1})$
	(1)	(2)
NE*Eind*2002	-0.0049	-0.0004
	(-1.51)	(-0.11)
NE*Eind*2003	0.0000	-0.0029
	(0.01)	(-0.75)
NE*Eind*2004	-0.0061	
	(-1.26)	
NE*Eind*2005	-0.0062	
	(-1.11)	
NE*Eind*2006	-0.0087	
	(-1.61)	
NE*Eind*2007	-0.0163***	
	(-2.75)	
Observations	981,273	254,351
Controls	Yes	Yes
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.383	0.463

Note: We replace the prior post-reform indicator we used with a series of year dummies, i.e., indicators for the years 2002, 2003, 2004, 2005, 2006 and 2007. Standard errors are clustered by firm in all regressions. *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 8 Robustness check: PSM analysis

VARIABLES	$Ln(1+Pat_{t+1})$
NE*Eind*Post2004	-0.0197***
	(-3.48)
LnAssets	0.0114***
	(7.44)
Leverage	0.0007
	(0.26)
ROA	0.0043
	(0.93)
LnFirmAge	0.0005
	(0.29)
State Share	-0.0139**
	(-2.36)
Observations	115,723
Firm Fixed Effects	Yes
Year*Province FE	Yes
Year*Industry FE	Yes
Adjusted R-squared	0.379

Note: This table uses the PSM sample to estimate the model in Table 3. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. *LnAssets* is the natural logarithm of total assets of a firm. *Leverage* is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. *ROA* is return on assets ratio, defined as operating income divided by book value of total assets. *LnFirmAge* is the natural logarithm of one plus firm i's age. *State Share* is the proportion of capital owned by the state in the total paid-in capital. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 9 Robustness check: alternative sample

	Delete Sample in 2004	Balanced Sample
VARIABLES	$Ln(1+Pat_{t+1})$	$Ln(1+Pat_{t+1})$
	(1)	(2)
NE*Eind*Post2004	-0.0126***	-0.0092**
	(-3.83)	(-2.15)
LnAssets	0.0138***	0.0092***
	(6.36)	(7.96)
Leverage	0.0000	-0.0030
	(0.03)	(-1.50)
ROA	0.0107***	0.0061***
	(3.36)	(2.86)
LnFirmAge	-0.0025***	-0.0012
	(-2.76)	(-1.14)
State Share	-0.0099***	-0.0077*
	(-3.65)	(-1.91)
Observations	818,061	213,038
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.379	0.262

Note: This table reports regression results from the baseline specifications presented in Table 3 using alternative samples. The Column "Delete obs in 2004" removes the observations in year 2004; Column "Balanced sheet" use a balanced panel of firms that continuously operated for all 7 years. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. LnAssets is the natural logarithm of total assets of a firm. Leverage is firm i's leverage ratio, defined as book value of debt divided by book value of total assets. ROA is return on assets ratio, defined as operating income divided by book value of total assets. LnFirmAge is the natural logarithm of one plus firm i's age. State Share is the proportion of capital owned by the state in the total paid-in capital. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 10 Long-term effects of the 2004 VAT reform

VARIABLES	Ln(1+Pat$_{t+4}$)	Ln(1+Pat$_{t+4}$)	Ln(1+Pat_inv$_{t+4}$)	Ln(1+Pat_utl$_{t+4}$)	Ln(1+Pat_des$_{t+4}$)
	(1)	(2)	(3)	(4)	(5)
NE*Eind*Post2004	-0.0122**	-0.0120**	-0.0051**	-0.0107***	-0.0023***
	(-2.55)	(-2.51)	(-2.56)	(-2.90)	(-5.07)
LnAssets		0.0178***	0.0066***	0.0125***	0.0022***
		(21.87)	(18.05)	(21.72)	(9.02)
Leverage		0.0010	-0.0002	0.0013	-0.0003
		(0.64)	(-0.32)	(1.17)	(-0.63)
ROA		0.0074***	0.0026***	0.0051***	0.0017***
		(3.72)	(2.94)	(3.59)	(3.05)
LnFirmAge		-0.0023**	-0.0015***	-0.0023***	0.0001
		(-2.51)	(-3.34)	(-3.44)	(0.25)
State Share		-0.0164***	-0.0081***	-0.0099***	-0.0008
		(-5.38)	(-5.39)	(-4.39)	(-1.10)
Observations	981,273	981,273	981,273	981,273	981,273
Firm FE	Yes	Yes	Yes	Yes	Yes
Year*Province FE	Yes	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes	Yes
Clusters (firms)	256,350	256,350	256,350	256,350	256,350
Adjusted R-squared	0.406	0.406	0.331	0.351	0.276

Note: This table provides evidence on the effect of VAT reform on firm-level innovation. The dependent variables are the logged value of one plus number of total patents, invention patents, utility model patents and design patents, all of which are successfully granted by CNIPA and defined in year $t + 4$. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 11 R&D Expenditure

VARIABLES	R&D expenditure / total assets		R&D expenditure / sales	
	(1)	(2)	(3)	(4)
Post2009*Eind	-0.0016**	-0.0014**	-0.0019*	-0.0018**
	(-2.18)	(-2.36)	(-1.79)	(-1.98)
LnAssets		-0.0016**		0.0006
		(-2.52)		(0.67)
Leverage		-0.0033*		-0.0082***
		(-1.85)		(-3.08)
ROA		0.0041		-0.0015
		(1.58)		(-0.52)
LnFirmAge		0.0089***		0.0101***
		(5.25)		(3.56)
state		0.0012*		0.0020*
		(1.86)		(1.76)
Observations	3,609	3,599	3,609	3,599
Firm FE	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
cluster	Firm	Firm	Firm	Firm
Adjusted R-squared	0.634	0.643	0.621	0.624

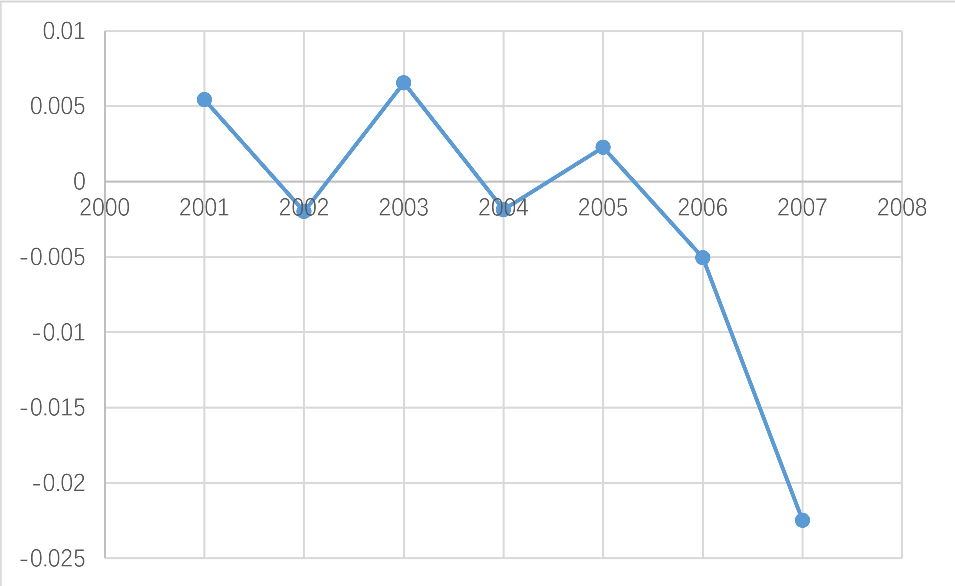
Note: This table provides evidence on the effect of VAT reform on firm-level innovation using R&D expenditure/total assets and R&D expenditure/sales as dependent variables. Standard errors are clustered by firm in all regressions. Post2004, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 12 Fixed investment response to the 2004 VAT reform

VARIABLES	Rgfinv	
	(1)	(2)
NE*Eind*Post2004	0.1145*	0.1381**
	(1.95)	(2.34)
LnAssets		0.9692***
		(84.00)
Leverage		-0.4041***
		(-20.01)
ROA		-0.3795***
		(-12.79)
LnFirmAge		-0.1891***
		(-22.68)
State Share		-0.0572***
		(-3.22)
Observations	700,445	700,445
Controls	No	Yes
Firm FE	Yes	Yes
Year*Province FE	Yes	Yes
Year*Industry FE	Yes	Yes
Adjusted R-squared	0.0528	0.0985

Note: This table provides evidence on the effect of the 2004 VAT reform on firm-level fixed investment. Rgfinv is the firm's fixed investment in a given year divided by capital stock measured at the end of previous year. Standard errors are clustered by firm in all regressions. *Post2004*, a binary variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period; *NE*, a binary variable which equals 1 for firm i located in Northeastern region and 0 otherwise; *Eind* is a binary variable which equals 1 if a firm belongs to one of the six eligible industries and 0 otherwise. Firm, industry-year, and province-year fixed effects are controlled. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Figure 1: Time Trends of the Difference in Number of Patents



Note. This figure plots the difference in the gap of average number of patents of NE relative to the non-NE regions between the eligible and ineligible industries over the period from 2001 through 2007.

Figure 2: Empirical Probability Density Function of the Placebo Estimates

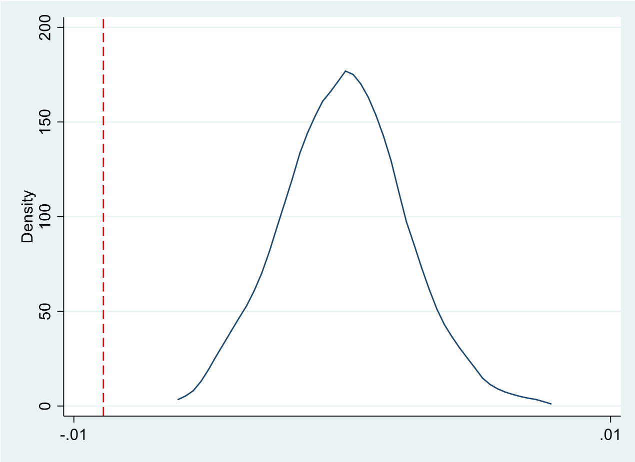


Figure 2-1: NE*Eind_Random*Post2004

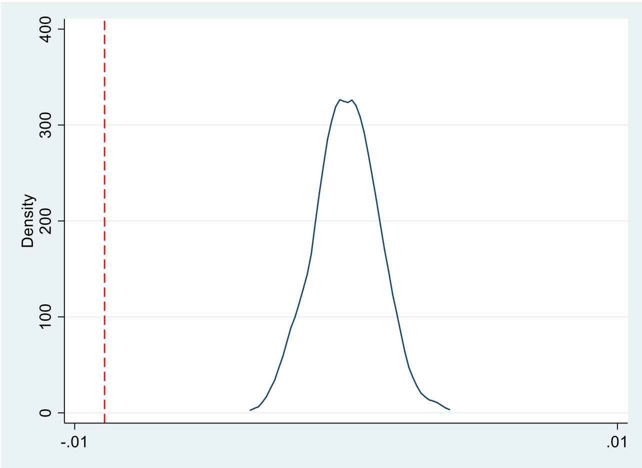


Figure 2-2: NE*Eind*Post_Random

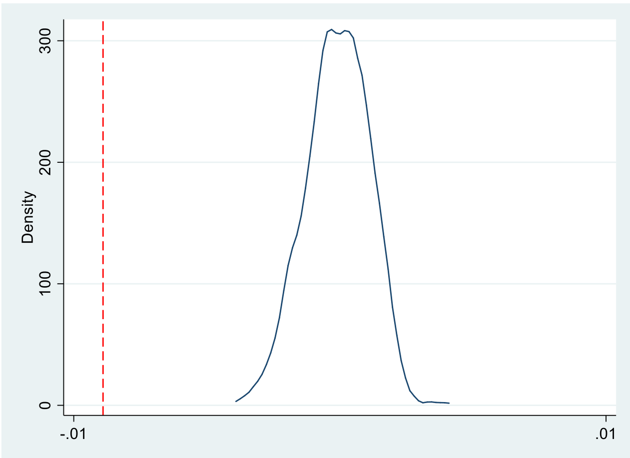


Figure 2-3: NE*Eind*Post2004_Random

Note: This figure plots the empirical distributions of placebo effects for firm innovation. The PDFs are constructed from 500 placebo estimates of *NE*Eind_Random*Post2004, NE*Eind*Post_Random, NE*Eind*Post2004_Random* using the specification in column 1 of Table 3, respectively. *NE*Eind_Random*Post2004*, *NE*Eind*Post_Random*, and *NE*Eind*Post2004_Random* are three placebo interaction variables constructed by generating the random treatment group, the random year of VAT reform, and the random interaction variable, respectively. The vertical lines show the treatment effect estimates reported in Table 3.

Appendix 1: Details of Theoretical Models

Nested constant elasticity of substitution (CES) specification is widely used to model production and examine the relationships between input factors, such as capital-skill complementarity, in economics literature. Thus, the following setup was chosen to investigate the relationship between two factors we focus on in this paper: capital expenditures on fixed assets and innovative inputs.

Following Acemoglu and Autor (2011), we consider a framework where the aim of a firm was to maximize its profits under financial constraints. Suppose a firm's final output comes from two kinds of investment: ordinary, non-innovative investment and innovative investment. Standardize the price of final outputs and the production function of a firm can be written as

$$Q = (\beta N^{\rho} + (1-\beta)R^{\rho})^{\frac{1}{\rho}} \tag{A1}$$

In model (A1), σ governs the elasticity of substitution between ordinary, non-innovative production (*N*) and innovation production (*R*) outputs. If σ is zero, the production is a Leontief type where the output is produced by using non-innovative and innovative inputs; if σ is between 0 and 1, non-innovative and innovative projects are complements; if σ is 1, the case is the Cobb-Douglas production; if σ is larger than 1, then non-innovative and innovative projects are substitutes; and when σ goes infinity, non-innovative and innovative projects are perfect substitutes. Ordinary and non-innovative production is a function of two types of inputs, physical capital (*K*) and labor (*L*). To simplify the math, we define the ordinary and non-innovative production as a simple production function in (A2):

$$N(K,L) = \left(\alpha K^{\psi} + (1-\alpha)L^{\psi}\right)^{\frac{1}{\psi}}. \tag{A2}$$

We assume that firms are price takers in input markets, facing the cost of capital equal to c_K per unit of fixed capital, a wage rate of c_L per unit of labor, and the cost of innovation equal to c_R per unit of innovation input. The total cost of all input factors are no more than the total investment, I ($I >$ 0). Moreover, the profit function of a firm is given as follows:

$$\underset{\{K,L,R\}}{Max}\left[\beta\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}}+(1-\beta)R^{\rho}\right]^{\frac{1}{\rho}}-c_K K-c_L L-c_R R, \tag{A3}$$

subject to the budget constraints,

$$c_K K+c_L L+c_R R=I. \tag{A4}$$

The implications of the switch to consumption-type VAT for factor inputs and project choices can be derived simply by interpreting the profit maximization of a firm and investigating how its decisions change in response to a decline in the relative price of fixed capital, c_K.

Then, we lay out the details in deriving the optimal choices of firms' factor inputs and production strategies. The Lagrangian function of the maximization is

$$L(K,L,R,\lambda)=\left[\beta\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}}+(1-\beta)R^{\rho}\right]^{\frac{1}{\rho}}-(1+\lambda)(c_K K+c_L L+c_R R)+\lambda I$$

Let $M=\beta\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}}+(1-\beta)R^{\rho}$, and then we derive $L(K,L,R,\lambda)=M^{\frac{1}{\rho}}-(1+\lambda)(c_K K+c_L L+c_R R)+\lambda I$. Thus, we could acquire the first order conditions as follows:

$$L_K=\alpha\beta M^{\frac{1}{\rho}-1}\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}-1}K^{\psi-1}-(1+\lambda)c_K=0 \tag{A5}$$

$$L_L=(1-\alpha)\beta M^{\frac{1}{\rho}-1}\left(\alpha K^{\psi}+(1-\alpha)L^{\psi}\right)^{\frac{\rho}{\psi}-1}L^{\psi-1}-(1+\lambda)c_L=0 \tag{A6}$$

$$L_R=(1-\beta)M^{\frac{1}{\rho}-1}R^{\rho-1}-(1+\lambda)c_R=0 \tag{A7}$$

Combining equations (A5) and (A6), we derive

$$\frac{\alpha}{1-\alpha}=\frac{c_K}{c_L}\left(\frac{K}{L}\right)^{1-\psi} \tag{A8}$$

Combining equations (A5), (A7) and (A8), we derive

$$\frac{\left(1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{\rho}{\psi}-1}K^{\rho-1}}{c_K R^{\rho-1}}=\frac{1-\beta}{\beta c_R}\alpha^{-\frac{\rho}{\psi}} \tag{A9}$$

Taking natural logarithm of both sides of equation (A9), we derive

$$\frac{\rho-\psi}{\psi}ln\left(1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)=ln(c_K)+(\rho-1)ln(R)+(1-\rho)ln(K)+\widetilde{N},$$

where $\widetilde{N}=ln\left(\frac{1-\beta}{\beta c_R}\alpha^{-\frac{\rho}{\psi}}\right)$.

Taking the derivatives w.r.t. c_K, we derive

$$\frac{1}{K}\frac{\partial K}{\partial c_K}-\frac{1}{R}\frac{\partial R}{\partial c_K}=\frac{\rho-\psi}{(1-\psi)(1-\rho)c_K}\frac{\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}}{1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}}-\frac{1}{(1-\rho)c_K} \tag{A10}$$

Combining equations (A4) and (A8), we derive

$$\left(c_K+\left(\frac{1-\alpha}{\alpha}c_K\right)^{\frac{1}{1-\psi}}c_L^{\frac{\psi}{1-\psi}}\right)K+c_RR=I \tag{A11}$$

Taking the derivatives of equation (A11) w.r.t. c_K, we derive

$$c_K\left(1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)\frac{\partial K}{\partial c_K}+c_R\frac{\partial R}{\partial c_K}=-\left(1+\frac{1}{1-\psi}\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)K \tag{A12}$$

Let $X=\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}$ and equations (A10) and (A12) can be simplified.

$$\frac{1}{K}\frac{\partial K}{\partial c_K}-\frac{1}{R}\frac{\partial R}{\partial c_K}=\frac{\rho-\psi}{(1-\psi)(1-\rho)c_K}\frac{X}{1+X}-\frac{1}{(1-\rho)c_K} \tag{A13}$$

$$c_K(1+X)\frac{\partial K}{\partial c_K}+c_R\frac{\partial R}{\partial c_K}=-\left(1+\frac{1}{1-\psi}X\right)K \tag{A14}$$

We can derive $\frac{\partial R}{\partial c_K}$ from equations (A13) and (A14):

$$\frac{\partial R}{\partial c_K}=\frac{\rho}{(1-\rho)\left[(1+X)\frac{c_K}{R}+\frac{c_R}{K}\right]}=\frac{\rho}{(1-\rho)\left[\left(1+\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{1-\psi}}\left(\frac{c_K}{c_L}\right)^{\frac{\psi}{1-\psi}}\right)\frac{c_K}{R}+\frac{c_R}{K}\right]}$$

When $\sigma>1$, which means innovative and non-innovative projects work as gross substitutes and the elasticity of substitution is larger than 1, $\frac{\partial R}{\partial c_K}>0$.

Appendix 2: Variable Definition

Variable	Definition
Measures of innovation	
Pat	Total number of patent applications filed (and eventually granted) by a firm in a given year
Pat_inv	The number of invention patent applications filed (and eventually granted) by a firm in a given year
Pat_utl	The number of utility model patent applications filed (and eventually granted) by a firm in a given year
Pat_des	The number of design patent applications filed (and eventually granted) by a firm in a given year
Measures of Firm Fixed Investment	
Rgfinv	Firm's fixed investment in a given year divided by net fixed asset stock measured at the end of previous year adjusted by the price index of fixed assets
Other Variables	
Post2004	A dummy variable which equals 1 for 2005-2007 period and 0 for 2001-2004 period
NE	A dummy variable which equals 1 for a firm located in three northeastern provinces (Heilongjiang, Jilin, and Liaoning) and 0 otherwise
Eind	A dummy variable which equals 1 if a firm belongs to one of the six broadly defined eligible industries and 0 otherwise
LnAssets	Natural logarithm of total assets of a firm adjusted by the price index relative to year 1998
Leverage	Firm i's leverage ratio, defined as book value of debt divided by book value of total assets
ROA	Return on assets ratio defined as operating income divided by book value of total assets
LnFirmAge	Natural logarithm of one plus firm i's age
State Share	The proportion of capital owned by the state in the total paid-in capital
LnSales	Natural logarithm of sales income of a firm adjusted by the price index relative to year 1998
Long_Lev	Firm i's long-term leverage ratio, defined as book value of long-term debt divided by book value of total assets
Cashflow ratio	Cashflow ratio defined as cash flow divided by net fixed asset stock
Capital_labor	Capital-to-labor ratio defined as net fixed asset stock divided by total number of employees
Ln_labor	Natural logarithm of total number of employees of a firm

Appendix 3: Propensity Score Matching Regression

	(1)
VARIABLES	*NE*×*Eind* dummy = 1 if in treatment group
LnSales	-0.103***
	(-6.48)
Long_Lev	-0.485***
	(-4.15)
ROA	-1.668***
	(-10.28)
LnFirmAge	-0.001
	(-0.04)
State Share	0.816***
	(16.09)
Cashflow ratio	0.070***
	(3.52)
Capital_labor	1.677***
	(16.56)
Ln_labor	0.001
	(0.08)
Constant	-2.172***
	(-19.05)
Observations	145,423
Pseudo R-squared	0.015
Prob > chi2	0.000

Note: This table presents the major determinants of the implement of the VAT reform using a logit model. The dependent variable, *NE*×*Eind*, which is a dummy variable equal to one if the firm is located in northeastern of China and is in the eligible industries and zero otherwise. The logit is run at the firm level, and all covariates included in the regression are as reported in 2004. The model is used to generate the propensity scores for matching. The control variables of the logit model include firm sales, profitability, long-term leverage, age, state-owned ownership, cash flow ratio, capital to labor ratio and labor. The detailed definitions of control variables are listed in Appendix 1. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.

Appendix 4: Balanced Tests for Propensity Score Matching

		Pre-match		Post-match	
	Treated	Control	Difference	Control	Difference
VARIABLE	(1)	(2)	(3)	(4)	(5)
LnSales	9.825	9.916	-0.092***	9.815	-0.092
			(-6.30)		(0.46)
Long_Lev	0.045	0.044	0.001	0.045	0.001
			(0.40)		(0.26)
ROA	0.033	0.056	-0.023***	0.031	-0.023
			(-13.86)		(0.81)
LnFirmAge	1.803	1.764	0.039***	1.793	0.039
			(3.49)		(0.62)
State Share	0.097	0.045	0.052***	0.091	0.052
			(20.58)		(1.16)
Cashflow ratio	0.091	0.068	0.023***	0.092	0.023
			(-8.29)		(-0.34)
Capital_labor	0.334	0.428	-0.093***	0.327	-0.093
			(-8.29)		(0.45)
Ln_labor	4.756	4.800	-0.045***	4.746	-0.045
			(-3.59)		(0.54)

Note: This table tests the comparisons of the firm characteristics on which the matching is performed between treatment and control groups both pre-match and post-match. The t -statistics for comparison of means tests are reported in parenthesis. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.