Tax Policy and Lumpy Investment Behavior: Evidence from China's VAT Reform*

Zhao Chen
Fudan University

Xian Jiang
Duke University

Zhikuo Liu
Shanghai University of Finance and Economics

Juan Carlos Suárez Serrato
Duke University & NBER

Daniel Yi Xu
Duke University & NBER

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Abstract

A universal fact of firm-level data is that investment is lumpy: firms either replace a considerable fraction of their existing capital (spike) or do not invest at all (inactive). This paper incorporates the lumpy nature of investment into the study of how tax policy affects investment behavior. We show that tax policy can directly impact the lumpiness of investment and that the effectiveness of tax incentives at stimulating investment depends crucially on interactions with investment frictions. We illuminate these results by studying the effects of one of the largest tax incentives for investment in history: China's 2009 VAT reform. Using administrative tax data and a differences-in-differences design, we document that the reform increased investment by 36% and that the majority of the response was due to additional investment spikes. Given the magnitude of the tax incentive, however, our results imply a relatively small user-cost-elasticity of 2.3. We then estimate a dynamic model of investment that is consistent with the reduced-form effects of the policy and use the model to simulate the fiscal cost of stimulating investment through different tax policies. Policies that directly reduce the likelihood of firm inaction (e.g., investment tax credits) are more effective at stimulating investment than policies that only reduce the tax cost of investment (e.g., corporate income tax cuts).
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Governments around the world want to know how tax policy affects business investment. Empirical research in public finance follows the neo-classical investment framework by documenting investment elasticities to the tax-adjusted cost of capital. This approach abstracts from the central fact that investment is lumpy. Investment is said to be lumpy because in most micro-data firm investment is either negligible or replaces a significant fraction of existing capital. While lumpy investment features prominently in canonical models of firm investment, industry dynamics, and in macroeconomics, existing research has not studied how tax policies interact with the investment frictions that generate lumpy investment. This paper contributes to our understanding of how tax policy affects business investment by taking into account the lumpy nature of investment behavior.

We provide an organizing framework that clarifies how different tax instruments interact with the adjustment frictions that generate lumpy investment. We illustrate theoretically and quantitatively that the impact of tax policies on a firm's decision to invest or remain inactive is a key determinant of its investment response. This extensive margin response is not summarized by investment-to-user-cost elasticities. Importantly, the extensive margin plays an important role in determining the fiscal cost of stimulating investment. It is therefore necessary to understand how taxes impact intensive- and extensive-margins of investment in order to fully grasp how tax policy affects business investment.

Our analysis is grounded in one of the largest tax incentives for investment in history: China's 2009 value-added-tax (VAT) reform. Understanding how tax policy impacts investment in China is of first order importance since investment comprises 45% of China's GDP and since, as shown in Figure 1, investment in China has long surpassed investment levels in the US and the European Union. The reform unexpectedly removed a tax on investment by allowing domestic firms to deduct input VAT on the purchases of new equipment. The reform lowered the user cost of capital by 15% and reduced the partial irreversibility of investment — the gap between the purchase and the resale price of capital — which is a key driver of the lumpiness of investment.[1] We use administrative tax data to shed light on this important stimulus program and to develop important insights into how the administration of VAT systems can impact business investment.

Our paper has two main takeaways. First, we use a difference-in-differences research design to document that China's 2009 VAT reform had a large effect on investment, with affected firms increasing investment by 36% relative to the control group. The majority of this increase is driven by additional investment "spikes" suggesting extensive margin responses were central to stimulating investment. Second, we estimate a dynamic model of investment that incorporates

[1]By way of comparison, the recent tax reform in the United States lowered the user cost of capital by about 4% [Barro and Furman, 2018]. The VAT reform lowered partial irreversibility since, prior to the reform, firms paid VAT on equipment but did not collect VAT on the sale of used equipment.

interactions between different tax policies and investment frictions, and that is consistent with the reduced-form effects of the reform. The model shows that policies that reduce the likelihood of firm inaction are more effective at stimulating investment. In our empirical example, the VAT reform was more effective at stimulating investment than income tax cuts or accelerated depreciation policies since the reduction in partial irreversibility decreased the likelihood of firm inaction. This lesson is relevant for other countries since indirect taxes and investment tax credits used in many countries directly impact partial irreversibility and the lumpiness of investment.

We develop these insights in four steps. First, we incorporate important tax policies in China (VAT, income taxes, depreciation deductions) into a standard model of dynamic investment featuring a rich set of adjustment costs (convex and fixed costs, partial irreversibility). We provide intuition for how different frictions lead to lumpy investment and how different policies affect firm investment at the extensive and intensive margins. In particular, we show that the VAT reform reduced the partial irreversibility of investment by narrowing the price gap between new and used capital. This change reduced the likelihood of firm inaction and increased the fraction of firms investing in equipment. Our model also characterizes how the intensive- and extensive-margin effects of the VAT reform differ from those of other policies and how different policies interact with one another. Specifically, our model shows that the fiscal effectiveness of a corporate income tax cut depends on whether other policies generate partial irreversibility.

The second step of our analysis uses a novel dataset of administrative tax records from the Chinese State Administration of Tax and a difference-in-differences identification strategy to study how firms respond to this policy change. Since foreign firms with preferential treatment were able to deduct input VAT on equipment prior to the reform, our research design uses foreign firms as a control group for domestic firms. We find substantial effects of the reform on firm investment. On the extensive margin, the fraction of firms investing in equipment increased by 5 percentage points, or an 8% increase. On the intensive margin, investment increases by 3.6% of the existing capital stock, for a 36% increase in investment. Relative to the change in the user cost of capital, the intensive margin results imply an investment-to-cost-of-capital elasticity close to 2.3.[2] Finally, we find that the majority of the investment response was due to additional spikes in investment where firms replaced more than 20% of their existing capital.

The validity of this research design rests on the assumption that, absent the reform, domestic firms would have had the same investment patterns as foreign firms. Three sets of auxiliary results suggest that foreign firms are a suitable control for domestic firms. First, we show that both sets of firms had similar investment trends prior to the reform. Second, the results

[2]Recent estimates for the US report investment-to-cost-of-capital elasticities of 7.2 [Zwick and Mahon, 2017]. Our estimates also imply an investment-rate-to-tax-term coefficient of 0.19, which is smaller than the value of 1.6 reported by Zwick and Mahon [2017] or the range of $[0.5, 1]$ used by Hassett and Hubbard [2002] to summarize the previous literature.

are robust to a number of checks including using alternative measures of investment, different sample restrictions, re-weighting the data to match the characteristics of foreign and domestic firms, and to controlling for firm-level characteristics and other changes in tax policy. Finally, to further validate this assumption, we conduct placebo tests using domestic and foreign firms which were included in a pilot program that allowed firms to deduct input VAT from new investments starting in 2004. We find no evidence that the reform had differential effects on firms in the pilot program, suggesting that domestic and foreign firms were not subject to time-varying shocks that would confound our estimates. These results significantly limit the risk that our main results are a spurious feature of the data and are not driven by the tax reform.

We estimate the structural model of investment in the third step of our analysis. Our estimation relies on the Method of Simulated Moments (MSM) to recover fixed and convex adjustment costs of investment, while allowing the VAT reform to influence the partial irreversibility of investment. This approach matches simulated data from our model with observed moments that include both reduced-form estimates of the effects of the reform and pre-reform statistics on investment patterns, such as measures of lumpiness and the autocorrelation of investment. We find that canonical models of investment do a good job of matching the reduced-form effects of the reform. In contrast, we find that investment-to-cost-of-capital elasticities vary considerably across tax policies, which limits the usefulness of reduced-form estimates for forecasting purposes.

In the fourth and final step of our analysis, we use our estimated model to simulate the effects of potential tax policies on investment, tax revenue, and firm value. We first compare the effects of the VAT reform to other potential reforms. We measure the effectiveness of different reforms by comparing the change in investment to the tax revenue cost from a given policy. We find that the VAT reform was more effective at stimulating investment than lowering the corporate income tax rate or accelerating the timing of depreciation deductions. This result is driven by the fact that the VAT reform lowered the degree of partial irreversibility, which decreased the likelihood of firm inaction. In contrast, a corporate income tax cut is less effective since a large fraction of firms are infra-marginal — their investment is unaffected but they benefit from the lower tax rate. Overall, we find that China's 2009 VAT reform was more effective at stimulating investment than policies that mirror the 2017 Tax Cut and Jobs Act in the United States.

This paper is related to a long line of research in public finance dating to Hall and Jorgenson [1967]. Recent work has revolutionized our understanding of how firms respond to taxation by exploiting credible identification strategies with administrative tax data (e.g., Yagan [2015], Maffini, Xing, and Devereux [2016], Rao [2016], Zwick and Mahon [2017], Ohrn [2018a], Ohrn [2018b], and Moon [2019]). Papers that study how Chinese firms respond to tax incentives include Cai and Harrison [2016], Liu and Mao [2018], Chen, He, and Zhang [2016], and Chen, Liu, Suárez Serrato, and Xu [2017]. We contribute to this literature by measuring the effects of a large

natural experiment using administrative tax data. In addition, our framework gives a coherent interpretation to the intensive- and extensive-margin responses to tax incentives documented using quasi-experimental variation.

By investigating real world tax reforms in a lumpy investment model, we also contribute to the empirical investment literature. Thomas [2007] summarizes the origins of adjustment costs in dynamic investment models used by Caballero and Engel [1999], Cooper and Haltiwanger [2006], Gourio and Kashyap [2007], Khan and Thomas [2008], Lanteri [2018], and Winberry [2018].[3] The identification of investment frictions, including convex and fixed adjustment costs, often relies on matching investment patterns in a stationary environment. As argued by Cummins, Hassett, and Hubbard [1994], tax reforms generate large and plausibly exogenous shifts in firms' economic fundamentals and are useful in uncovering the nature of investment frictions. This source of variation also mitigates the role of measurement error in firms' idiosyncratic profitability shocks. By incorporating quasi-experimental estimates of the effects of tax reform in our quantification of adjustment costs, we validate and improve the estimation of dynamic models of investment. Our unified approach is therefore well-suited for simulating the effects of potential tax reforms and to determining which policy instruments are more effective at stimulating investment.[4]

The results of this paper have implications beyond China. First, countries that rely on VAT systems should avoid distorting investment decisions by making VAT credits refundable. Our reduced-form results show that, even after the VAT reform, firms with excess VAT credits respond to the VAT as a tax on investment. This result shows that VAT systems may depress investment when excess VAT payments are non-refundable. Starting in 2019, China started refunding excess input VAT credits [Ministry of Finance, 2019] but excess credits are non-refundable in 24 other countries [EY, 2017]. A second implication of our results is that policies that lower the degree of partial irreversibility will make other stimulus policies more effective. For instance, an investment tax credit can lower the price gap between new and used capital, which would make other policies, such as a corporate income tax cut, more effective stimulus tools.

The paper is organized as follows. Section 1 develops intuition for how tax policies interact with firm frictions and culminates by detailing an empirical model of investment. Section 2 discusses China's 2009 VAT reform. Section 3 describes the administrative tax data and Section 4 documents the reduced-form effects of the reform. Section 5 estimates the model, Section 6 simulates the effects of potential tax reforms, and Section 7 concludes.

[3]Our paper is also related to classic papers that follows a model-centric estimation approach. For instance, Abel [1980], Salinger and Summers [1981], Summers [1981], and Hayashi [1982] relied on a q-theory approach for quantifying the roles of taxes on investment. Dynamic models with adjustment costs have also been considered by Auerbach [1986], Auerbach [1989], and Auerbach and Hines [1988].

[4]Our paper's focus is to study the interaction between tax instruments and producer-level investment behaviors, while recent papers such as Khan and Thomas [2008] and Winberry [2018] have clarified conditions in general equilibrium under which the micro-level investment will have aggregate implications or not.

1 Modeling Tax Policy and Lumpy Investment

Empirical models of investment aim to match two empirical features of investment data. First, the sluggish response of investment to changes in economic fundamentals suggests that investment is subject to convex costs of adjustment. Second, the observed pattern of infrequent and lumpy investment suggests firms face fixed costs and partial irreversibility. We first characterize how these frictions affect the effectiveness of different tax policies in a simple, static model. We then describe a dynamic investment model and show that the intuition from the static model carries over to the dynamic world. Appendix A presents detailed derivations.

1.1 Theoretical Motivation

Consider a firm with pre-existing capital k_0, productivity a, and profit function $a^{1-\theta}k^{\theta}$, where $\theta < 1$ is the curvature of profit function.

Taxes on Corporate Income

We first consider the effects of the corporate income tax (CIT) on firm investment. The firm pays a corporate tax rate τ on profits. We model the *after-tax* price of capital $p = p_k(1 - \tau p_v)$, where p_k is the capital goods price and $p_v \leq 1$ is the discounted present value of depreciation deductions.[5] Absent additional frictions, the firm solves the problem:

$$\max_k \ (1-\tau)a^{1-\theta}k^{\theta} - p(k-k_0) \implies k^* = a\left[\frac{1}{\theta}\underbrace{\frac{p_k(1-\tau p_v)}{(1-\tau)}}_{UCC}\right]^{\frac{-1}{1-\theta}}. \tag{1}$$

Equation 1 implies the firm will change its capital in response to any changes in taxes or productivity — i.e., there is no inaction or extensive-margin response.[6] The user cost of capital (UCC) is given by $\frac{p_k(1-\tau p_v)}{(1-\tau)}$. The symmetric effect of p_k and the tax term $\frac{(1-\tau p_v)}{(1-\tau)}$ is one reason the empirical public finance literature estimates the user-cost-elasticity of investment. In this model this elasticity is governed by the curvature of profit function and equals $\frac{-1}{1-\theta}$.[7]

[5] p_v is determined by the depreciation schedule of capital. When a firm can immediately expense investment (i.e. $p_v = 1$), τ does not enter the user cost of capital. We provide more details of how depreciation schedule maps into p_v in the dynamic model.

[6] By an extensive-margin response, we refer to a firm's decision to invest in a given year relative to a counterfactual of not investing. Our empirical analysis focuses on a balanced panel of existing firms, and we do not study firm entry as part of a broader extensive-margin response.

[7] As an example, when firms face a downward sloping residual demand curve, assuming $\theta = 0.75$ implies a markup excluding capital costs of 25%, and results in $\frac{-1}{1-\theta} = 4$.

Convex Costs

We now introduce convex adjustment costs and show how they help explain the sluggish response of investment to changes in taxes. Convex costs can be interpreted as technological constraints, including work stoppages and short-run capacity limits that firms face when they replace machinery. Following this interpretation, we assume that firms have to pay a non-tax-deductible convex cost, $D(k)$, in order to adjust their capital. The firm's optimal capital level is now:

$$k^* = a\left[\frac{1}{\theta}\left(UCC + \frac{D'(k)}{1-\tau}\right)\right]^{\frac{-1}{1-\theta}},$$

where the total marginal cost of investment is given by $UCC + \frac{D'(k)}{1-\tau}$. Since τ enters separately from UCC in this expression, the UCC is not a sufficient statistic for tax policy.[8]

The capital elasticity with respect to p_k is now:

$$\varepsilon_{k,p_k} = \frac{-s^p}{1-\theta+(1-s^p)\alpha(k)} \leq -\frac{1}{1-\theta},$$

where $s^p = \frac{p}{p+D'(k)} \in [0,1]$ is the share of the price of capital relative to the total marginal cost of investment and $\alpha(k) = \frac{D''(k)k}{D'(k)} \geq 0$ is a measure of the convexity of adjustment costs. If there are no convex adjustment costs ($s^p = 1$), ε_{k,p_k} equals the elasticity in the frictionless case.

Intuitively, convex costs dampen how firms respond to changes in p_k in two ways. First, convex costs decrease the relative importance of p in the total marginal cost of investment ($s^p \leq 1$ in the numerator). Second, firms take into account the fact that larger changes in k impact the marginal cost of investment by moving the firm into more convex regions of the function $D(k)$ ($\alpha(k) \geq 0$ in the denominator).

To consider the capital elasticity with respect to $1-\tau$, we first define $\varepsilon_{UCC,1-\tau} \in [-1,0]$ as the elasticity of the UCC with respect to $1-\tau$, to obtain:

$$\varepsilon_{k,1-\tau} = \frac{-s^p\varepsilon_{UCC,1-\tau} - (1-s^p)}{1-\theta+(1-s^p)\alpha(k)} \leq \frac{1}{1-\theta},$$

This elasticity is also subject to the two dampening effects mentioned above. In addition, because adjustment costs are paid with after-tax funds, a tax cut increases the importance of convex costs, which further dampens the investment response by $(1-s^p)$ (in the numerator).[9]

[8] Note that, while the UCC is a sufficient statistic in the extreme case where $D(k)$ is fully tax-deductible, the case where $D(k)$ is not fully deductible is the more relevant empirical case.

[9] The differences in the expressions for ε_{k,p_k} and $\varepsilon_{k,1-\tau}$ further show that the UCC is not a sufficient statistic for tax policy. A central example in the literature is the case of quadratic costs. Assuming $D(k) = \frac{\gamma}{2}\left(\frac{k-k_0}{k_0}\right)^2 k_0$

Partial Irreversibility

Partial irreversibility occurs when firms face different prices to purchase and sell equipment. This distortion can arise from imperfections in the market for used capital or from tax policies. For instance, sales taxes on equipment purchases have been shown to affect the investment of US firms [e.g., Desai, Foley, and Hines, 2004] and increase partial irreversibility. On the other hand, investment tax credits at the state level in the US [e.g., Chirinko and Wilson, 2008] decrease partial irreversibility. In the case of China, the VAT system pre-2009 increased the purchase price of capital by a factor of $(1+\nu)$, where ν is the VAT rate. Firms selling capital could not charge the VAT rate. The effective after-tax purchase price is then $p^b = p_k(1+\nu-\tau(1+\nu)p_v)$ and the sales price is $p^s = p_k(1-\tau(1+\nu)p_v)$.[10]

Partial irreversibility generates inaction — a range of productivity where firms do not adjust their capital stock in response to small changes in economic fundamentals. While firms usually set the after-tax marginal product of capital (MPK) equal to the price of capital, firms do not adjust their capital when the MPK of their existing capital falls in the range $[p^s, p^b]$. The dashed line in Panel (A) of Figure 2 shows how the MPK increases with productivity. The two horizontal lines denote p^b and p^s. The inaction region is the range of productivity where the MPK falls between these two lines and is given by:

$$a \in [\underline{a}, \bar{a}] \equiv \left[\left(\frac{p^s}{\theta(1-\tau)} \right)^{\frac{1}{1-\theta}} k_0, \left(\frac{p^b}{\theta(1-\tau)} \right)^{\frac{1}{1-\theta}} k_0 \right].$$

Panel (B) of Figure 2 shows how p^b, p^s, and the inaction region affect the firm's policy function — the relation between productivity and capital.

To see how tax policies influence the inaction region, note that:

$$\ln(\bar{a}) - \ln(\underline{a}) = \frac{1}{1-\theta} \left[\ln(1-\tau p_v) - \ln\left(\frac{1}{1+\nu} - \tau p_v \right) \right].$$

China's VAT reform directly reduced the region of inaction by reducing ν. In addition, changes in τ and p_v also affect the inaction region, and these effects depends on interactions with ν.[11] However, while policies that directly influence p_k shift both p^b and p^s, they do not influence the inaction region. For this reason, different policy changes can have the same effect on the UCC but have different effects on the inaction region.

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implies $\varepsilon_{k,p_k} = \frac{-1}{(1-\theta)+(2-\theta)\frac{\gamma}{p}\frac{k}{k_0}}$ and $\varepsilon_{k,(1-\tau)} = \frac{-\varepsilon_{ucc,1-\tau} - \frac{\gamma}{p}\frac{k}{k_0}}{(1-\theta)+(2-\theta)\frac{\gamma}{p}\frac{k}{k_0}}$.

[10] Note that the VAT also increases the book-value of capital as well as depreciation deductions.

[11] Note that sales taxes or an investment tax credit would also influence this region as long as they differentially affect p^b and p^s.

Fixed Costs

In addition to partial irreversibility, fixed costs also generate inaction. Assume now that a firm has to pay a fraction ξ of its desired capital stock (k^*) in order to adjust its level of capital.[12] A firm decides to adjust its capital if profits after adjusting, $(1-\tau)a^{1-\theta}k^{*\theta} - p(k^* - k_0) - \xi k^*$, are greater than the profits from inaction, $(1-\tau)a^{1-\theta}k_0^{\theta}$.

Comparing the relative profit levels from these two alternatives, we have:

$$\overbrace{\underbrace{\left[(1-\theta) - \theta\frac{F}{p}\right]\left[\frac{\theta}{\text{UCC}}\right]^{\theta/(1-\theta)}}_{\text{Slope}} a + \underbrace{\text{UCC}k_0}_{\text{Intercept}}}^{\text{Profit conditional on adjusting to optimal capital } k^*} = \overbrace{k_0^{\theta}a^{1-\theta}}^{\text{Profit using initial capital } k_0}. \tag{2}$$

The inaction region is characterized by this indifference condition. The solid line in Figure 3 Panel (A) plots the after-tax profit in the case of no adjustment costs. Fixed costs have the effect of rotating this line clockwise. The inaction region $[\underline{a}, \bar{a}]$ is defined by the intersection of this rotated line and the curved profit line that holds capital at the initial level. The optimal profit with fixed costs is the red envelope of these two lines. Panel (B) shows how fixed costs generate inaction in capital adjustment.

Equation 2 can be used to illustrate how tax policy affects the inaction region. Consider first the effects of a corporate income tax cut. By increasing p and decreasing the UCC, a cut in τ increases the slope and reduces the intercept of Equation 2. These changes on the optimal profit function shift the inaction region to the left. Now consider the effects of a VAT cut. This change has ambiguous effects on the slope of Equation 2 and the effect on the inaction region is indeterminate. These two examples show that the effects of tax policy on the UCC are not sufficient to characterize effects on the inaction region.

Takeaways

The simple models above yield three concrete insights. First, it is now clear how investment frictions help match empirical investment patterns. Convex costs help match the sluggish response of investment to tax changes. Fixed costs and partial irreversibility generate lumpy investment and give a coherent interpretation to the extensive-margin investment responses to tax changes documented in empirical studies.

Second, these models show that accounting for interactions between tax policies and the frictions that generate lumpy investment are crucial to characterizing the effects of tax policy on investment. In particular, changes in the UCC are not sufficient statistics for tax policy.

[12] The desired capital stock is given by Equation 1.

In addition, the fact that tax policy can directly influence firm inaction should be taken into account when modeling the effects of tax policy changes.

A final insight is that the effects of changing one tax parameter depend on how other policies affect the likelihood of firm inaction. For example, the fraction of firms that respond to a corporate income tax cut is lower when other tax policies generate partial irreversibility. For this reason, a corporate income tax cut would be more effective at stimulating investment if it is accompanied by policies that reduce partial irreversibility.

1.2 A Dynamic Model of Tax Policy and Lumpy Investment

We now incorporate how investment frictions interact with tax policy in a dynamic model that is rich enough to characterize our empirical setting.

Profit Function

Firms have a profit function given by:

$$\Pi(K, A^{\Pi}) = (A^{\Pi})^{1-\theta} K^{\theta}, \tag{3}$$

where K is the pre-determined capital stock and A^{Π} is a profit shock that is realized at the beginning of the period.[13] $a_{it} \equiv \log(A^{\Pi}_{it})$ denotes a firm's log profitability, which has three components:

$$a_{it} = b_t + \omega_i + \varepsilon_{it}, \tag{4}$$

where b_t is an aggregate shock, ω_i is a firm-specific permanent heterogeneity and ε_{it} is an idiosyncratic transitory shock. Firms draw their permanent productivity ω_i from a normal distribution. The aggregate shock b_t and the transitory shock ε_{it} evolve over time following AR(1) processes.

Taxes

As in the static model, firms pay the VAT rate ν on purchases of new equipment. Consistent with the institutional setting, we assume that new capital purchases can not be deducted from output VAT (in contrast to intermediate expenditures). Similarly, firms pay the CIT at rate τ on profits. Finally, firms depreciate a fixed fraction $\hat{\delta}$ of the end-of-year book value of capital

[13] We view this as a reduced-form way to model the profit function but it is easy to micro-found it as the result of a static profit optimization problem. We give an example using a decreasing-return-to-scale (DRTS) production function and competitive final good market in Appendix A.2. An alternative is to assume a monopolistic competitive environment with constant-returns-to-scale (CRTS) technology.

stock each period. We summarize the impact of the depreciation schedule on the effective capital purchase price with the sufficient statistic p_v, which is the present discounted value of depreciation deductions.[14] The depreciation schedule interacts with both the CIT and the VAT since depreciation is deductible from the tax base of the CIT, while the VAT affects the book value of fixed assets.

Adjustment Costs

Firms face three types of adjustment frictions: a convex adjustment cost, a fixed disruption cost, and partial irreversibilty.[15] We assume that the only source of irreversibility is the non-deductible VAT on equipment purchases, so the resale price is set to one.[16]

Firms incur a fixed disruption cost ξK^* when adjusting the capital stock.[17] ξ is assumed to be independent and identically distributed across firms and over time, and is drawn from the distribution $G(\xi)$. In practice, ξ is drawn from a uniform distribution over the interval $[0, \bar{\xi}]$.

Finally, the convex cost follows a quadratic form $\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 K$.

Recursive Formulation and Normalization

We normalize the firm problem relative to a given permanent productivity, which reduces the state space to (k, b, ε, ξ) by defining $k = K/\exp(\omega)$.[18]

In order to state the firm's problem in recursive form, define the *ex-ante* value function (before the fixed cost draw is realized) by:

$$v^0(k, b, \varepsilon) = \int_0^{\bar{\xi}} v(k, b, \varepsilon, \xi) dG(\xi).$$

The firm's problem in recursive form is

$$v(k, b, \varepsilon, \xi) = \max(v^b(k, b, \varepsilon, \xi), v^s(k, b, \varepsilon, \xi), v^i(k, b, \varepsilon, \xi)),$$

[14] The geometric depreciation schedule is similar to accelerated depreciation without specifying a depreciation period. By abstracting from the depreciation, this allows us to study the firm's problem recursively. $p_v = \hat{\delta} + (1 - \hat{\delta})\beta\mathbb{E}[p'_v]$. Assuming a fixed and exogenous real interest rate r, $\beta\mathbb{E}[p'_v] = \frac{p_v}{1+r}$. This formulation is similar to that of Winberry [2018]. We show this result holds in our setting in Appendix A.3.2.

[15] Partial irreversibility arises naturally from the fact that firms need to pay VAT to the sellers when purchasing capital but do not retain VAT payment when selling capital.

[16] In Section 6, we show our results are robust to allow for additional sources of partial irreversibility.

[17] We represent the units of the fixed disruption cost in terms of the "desired capital level" K^* to make it proportional to the firm's profitability.

[18] This follows from the fact that the profit function (Equation (3)) and the costs of investment are homogeneous of degree one in the pair (K, A), and thus on $(K, \exp(\omega))$, the value function is also homogeneous of degree one in the pair $(K, \exp(\omega))$. See Appendix A.3.3 for additional details.

where

$$v^b(k,b,\varepsilon,\xi) = \max_{i>0}\ (1-\tau)\pi(k,b,\varepsilon) - \left[[1+\nu-\tau p_v(1+\nu)]i + \frac{\gamma}{2}\left(\frac{i}{k}\right)^2 k + \xi k^*\right] + \beta\mathbb{E}\left[v^0\left(k',b',\varepsilon'\right)|b,\varepsilon\right],$$

$$v^s(k,b,\varepsilon,\xi) = \max_{i<0}\ (1-\tau)\pi(k,b,\varepsilon) - \left[[1\quad -\tau p_v(1+\nu)]i + \frac{\gamma}{2}\left(\frac{i}{k}\right)^2 k + \xi k^*\right] + \beta\mathbb{E}\left[v^0\left(k',b',\varepsilon'\right)|b,\varepsilon\right],$$

$$v^i(k,b,\varepsilon,\xi) = (1-\tau)\pi(k,b,\varepsilon) + \beta\mathbb{E}\left[v^0\left(k(1-\delta),b',\varepsilon'\right)|b,\varepsilon\right].$$

$v^b(k,b,\varepsilon,\xi)$ is the value function conditional on investing. The costs of investing include the VAT-inclusive price of capital $(1+\nu)$, depreciation deductions $\tau p_v(1+\nu)$, as well as convex and fixed costs. When the firm decides to dis-invest, the value function $v^s(k,b,\varepsilon,\xi)$ differs by not including ν in the resale price, which is the source of partial irreversibility. In the last case, that of inaction, the firm collects profits and transitions to the next period with depreciated capital. Notice that our model embeds a "time-to-build" assumption since investment in this period does not affect current profit.

Implications for Policy Reform

While it is not possible to analytically characterize the effects of tax policy in the dynamic model, we can solve the model numerically. This allows us to characterize how different policies affect the investment policy function and to confirm that many of the lessons from the static model also hold in the dynamic setting.[19]

Figure 4 plots the policy function against the firm's transitory productivity shock to illustrate how various policy reforms affect the firm's investment decisions. Panel A plots the pre-reform baseline. The dotted line is the firm's optimal capital choice in a frictionless environment without adjustment costs.[20] In this case, the optimal capital choice is log-linear in the firm's transitory productivity shock. The slope is determined by the return-to-capital parameter θ and the persistence of the idiosyncratic shock ε.

The red line in Figure 4 plots the optimal policy in the presence of all investment frictions. Both the partial irreversibility generated from the VAT and the fixed investment cost generate an inaction region where firms do not respond to small productivity shocks. When the productivity shocks are large enough, firms adjust their capital. However, the convex adjustment cost prevents them from adjusting directly to the optimal capital level, which gives the policy function a flatter slope with respect to productivity shocks.

[19] These simulations are based on model estimates that match the empirical setting. We discuss model parameters in detail in Section 5. The qualitative features of the model are robust to alternative parametrizations.

[20] We maintain the one period time-to-build assumption to make it more comparable with the frictional model.

The yellow solid line in Panel B of Figure 4 shows how the VAT reform impacts the policy function.[21] The VAT reform eliminates the large asymmetry between the purchase and sales price of capital. This change substantially shrinks the inaction region and allows firms to adjust their capital under more modest productivity shocks. The reform generates extensive-margin responses from firms with productivity shocks that fall outside of the yellow inaction region but that would otherwise be inside the red inaction region. In addition to changing which firms respond to productivity shows, the VAT reform directly reduces the purchase price of new investment by $(1+\nu)$. The joint effects of reducing the purchase price and narrowing the inaction region are key building blocks for understanding the effectiveness of the VAT reform on aggregate investment.

In Panel C, we report the policy function following a CIT cut. A CIT cut increases the after-tax marginal benefit of new capital but decreases the value of depreciation deductions. In our simulation, these countervailing forces almost perfectly cancel out for firms with low productivity shocks. In contrast, the rise in the after-tax value of new capital leads firms with large productivity shocks to increase their investment. We also see a small narrowing of the inaction region. Note, however, that a large fraction of firms are infra-marginal to a CIT cut since they are likely to receive a productivity shock in the inaction region.

Finally, in Panel (D) we report the effects of bonus depreciation — which accelerates the timing of depreciation deductions and increases the value of p_v — on the policy function. By shifting the yellow line to the left, this reform increases investment for firms with low and high productivity shocks. However, the inaction region does not narrow considerably and a significant fraction of firms are also inframarginal to this incentive.

Figure 4 shows that different tax reforms have distinct interactions with adjustment costs. These interactions are the source of the different intensive- and extensive-margin responses documented in empirical studies.[22]

2 Policy Background: China's 2009 VAT Reform

China's 2009 reform was one of the largest tax incentives for investment in history. This section describes the reform and how it generated quasi-experimental variation in the after-tax cost of investment.

The VAT is the largest source of tax revenue in China. In 2016, VAT revenues comprised 39% of overall tax revenue. By comparison, corporate and personal income taxes accounted for

[21] For simplicity, we assume that, after the reform, firms use the post-reform VAT rate when calculating the present-value of their depreciation deductions.

[22] In Appendix F.1, we show numerically that VAT and CIT changes with the same effect on the UCC have different effects on intensive and extensive margins of investment.

22% and 8% of tax revenue, respectively. Note that China's reliance on the VAT for tax revenues mirrors much of the developed and developing world. China has a standard VAT rate of 17%, which applies to the majority of sales.[23]

The Reform as a Natural Experiment

One of the purported benefits of the VAT is that it does not distort the choice of production inputs — that is, it preserves "production efficiency." In practice, however, VATs can distort input choices depending on how they are implemented. Before 2004, China's "production-based" VAT allowed firms to offset output VAT on sales with VAT paid on inputs such as materials and factory expenses. In contrast, firms were not allowed to deduct the VAT on fixed investment from their VAT base. The lack of deductibility discouraged investment and broke the production efficiency of the VAT. To correct this distortion, China launched a reform to transition to a "consumption-based" VAT that allows for the deductibility of investment.

The Chinese government experimented with this transition starting in 2004. The reform was first piloted on firms in selected industries in Northeastern China.[24] As with most other reforms in China, the reform was designed to follow a slow roll-out to allow for trial and error. However, the reform was unexpectedly extended *nationwide* in 2009 as a response to the global financial crisis. Starting on January 1, 2009, all firms were able to deduct the input VAT on equipment from the VAT on sales.[25]

The reform can be best understood as an unexpected and permanent change to firms' after-tax cost of investment. Because the reform was unexpected, it is unlikely that firms re-timed their investment plans. In addition, because the reform eliminated an undesirable aspect of the VAT system, firms did not expect a reversal of the policy.

The reform generated a natural experiment since it had no effect on the after-tax cost of investment of a group of foreign firms. In particular, foreign firms in industries categorized by the government as "encouraged" had previously been allowed to deduct equipment purchases from VAT on sales.[26] Our research strategy uses foreign firms in encouraged industries as a

[23]The VAT is calculated using a credit-invoice method. Exports are zero-rated and some selected goods face a lower rate of 13%. Most of the goods that are affected by the reform face a 17% rate.

[24]The initial provinces include Heilongjiang, Jilin, Liaoning, and the city of Dalian. From 2004-2008, the pilot was extended to Inner Mongolia and to areas affected by earthquakes in the province of Wenchuan. Appendix B documents the legislative background and timeline for the reform from 2004 through 2009. Cai and Harrison [2016] and Chen et al. [2016] study the effects of the pilot reform.

[25]Equipment includes machinery, mechanical apparatus, means of transportation, and other equipment, tools, and fixtures related to production and business operations that are used for over 12 months. Purchased and self-made housing, buildings, and other real estate were not included in the reform.

[26]Qualified foreign firms were able to deduct input VAT on purchases of equipment starting in 1999. Since April 1, 2002, the government classified foreign investment projects as encouraged, allowed, restricted or prohibited. The *Catalogue for the Guidance of Foreign Investment Industries* lists the Encouraged, Restricted and Prohibited

control group for domestic firms. The identifying assumption behind this strategy is that treated and control firms are not subject to differential shocks in this time period. To bolster this assumption, we conduct a "placebo" test using domestic firms that were part of the 2004 pilot. We find that the 2009 reform did not have differential effects on the investment of foreign and domestic pilot firms. We provide more details behind this identifying variation in Section 4, where we also discuss different strategies that support the assumption that investment in foreign firms can be a suitable counterfactual for the investment of domestic firms.[27]

The VAT and the After-Tax Cost of Investment

To see how the reform affected firms' after-tax cost of investment, consider a domestic firm purchasing equipment at a price of 1,000 RMB. Table 1 shows that, prior to the reform, the VAT-included cost would be 1,170 RMB since the firm would pay a 17% VAT on the purchase. The asset generates depreciation deductions according to Chinese accounting standards, which have a discounted present value of 984 RMB.[28] At a corporate income tax rate of 25%, these deductions reduce the firm's corporate income tax obligations by 237 RMB. The after-tax cost of the equipment purchase is therefore 932 RMB.

The reform modifies this calculation in two ways. First, the firm's direct cost of investment decreases by 170 RMB since the VAT paid on the equipment is deducted from the VAT on sales. Second, depreciation deductions only lower corporate income tax obligations by 202.7 RMB since the book-value no longer includes the VAT payment. Because the direct effect is larger than the effect on depreciation deductions, the after-tax cost of investment drops to 797.2 RMB. In total, the reform lowered the after-tax cost of investment by close to 15%.[29]

The result of Table 1 can also be expressed by extending the UCC of Hall and Jorgenson [1967] to include the effect of the VAT:

$$\text{UCC} = (1+\nu)\frac{1-\tau p_v}{1-\tau}, \tag{5}$$

projects. If a foreign project is not included in the previous three categories in *Catalogue*, it is considered as Allowed. Additionally, firms participating in the Midwest Advantageous Project list also qualified for preferential treatment. As a robustness check, we also use all foreign firms as controls and we find similar results. This suggests that selection into the encouraged category is not central for our results.

[27] An alternative research strategy would be to use small-scale taxpayers as controls since the reform only targeted general taxpayers [Liu and Mao, 2018]. We focus on large firms since they conduct over 99% of overall investment in China. In general, we avoid issues related to selection into VAT by excluding small-scale taxpayers from the analysis. Since small-scale taxpayers only constitute 0.58% of the data, we do not expect to find significantly different results by including these observations.

[28] This calculation assumes a discount rate of 5%. According to Chinese accounting standards, the book value of the asset would be depreciated over 10 years using the straight line depreciation method. Appendix B documents rules governing depreciation in China.

[29] Equivalently, the non-deductibility of investment purchases (prior to the reform) raised the after-tax cost of investment by 17%, relative to the post-reform value.

where ν is the VAT rate, τ is the CIT rate, and p_v is the present value of depreciation deductions. As in Table 1, the VAT has a direct effect on the purchase price of equipment, $(1+\nu)$, and an indirect effect on the value of depreciation deductions, $(1+\nu)\tau p_v$.

While Equation 5 is not a sufficient statistic for tax policy, we can use it to compare the VAT reform to potential policies and recent reforms. One approach to lowering the UCC is to accelerate the depreciation schedule with the goal of increasing p_v. However, setting $p_v = 1$ through a policy of expensing (or 100% bonus depreciation) only lowers the UCC by 6%. Recent bonus depreciation policies in the US only decreased the UCC by 2.4-3.8% [Zwick and Mahon, 2017]. Alternatively, consider the effects of changing the corporate income tax cut. In order to increase the UCC by 15% one would need to increase τ from 25% to 54%, and eliminating the income tax ($\tau = 0$) would only lower the UCC by 6%. By way of comparison, Barro and Furman [2018] calibrate that the recent US tax reform only reduced the average UCC by 4%. Finally, consider that undoing the effect of the VAT distortion on the UCC would require an investment tax credit (ITC) of 13.6%. This rate is greater than that of the federal ITC in the US when it was eliminated in 1986 [8%, Cummins et al., 1994] and is also greater than current state-level ITCs [4% Chirinko and Wilson, 2008]. These calculations give context to the claim that the VAT reform comprised one of the largest incentives for investment in history. They also show the importance of studying the effects of indirect taxes on investment [e.g., Desai et al., 2004].

One potential concern with our identification strategy is that other reforms may also affect the after-tax cost of investment of foreign and domestic firms. In particular, the VAT reform occurred shortly after a reform of the corporate income tax system in 2008. While this reform harmonized the statutory income tax for foreign and domestic corporations, there was little change in the effective tax rates of foreign and domestic firms and, consequently, on their UCCs. For foreign firms, we find that the UCC is mostly constant during our sample period at 15.5%. For domestic firms, the reform reduces the UCC by 15% from 18.4% in 2008 to 15.6% in 2009.[30] The fact that the UCC is not affected by the CIT reform is reassuring for our analysis that focuses on the VAT reform. In addition, we report robustness checks that control for firms' CIT rates in our empirical analysis.

Finally, we note that these calculations ignore a practical and important aspect of how the VAT is administered. Specifically, countries differ in how they process excess VAT credits. Ideally, tax authorities would automatically refund excess credits to firms. In China, as in many other countries [EY, 2017], firms can carry-over credits to future tax periods. The degree to which firms are able to claim these credits varies in practice, however, and firms may view excess credits

[30] Table F.2 shows these calculations by year and by ownership. We implement Equation 5 using firms' effective tax rate, τ. We also assume that $r = 5\%$, which implies $p_v = 81\%$, and that the rate of economic depreciation $\delta = 10\%$. The UCC for foreign firms increases from 15.3% in 2007 to 15.5% in 2009, a change of only 1%.

as completely foregone. The non-refundability of excess VAT credits can have real effects on the activities of cash-constrained firms. In our empirical analysis in Section 4, we test whether the lack of refundability of excess VAT payments hampers the effects of the reform.

3 Administrative Data From Corporate Tax Returns

The main dataset we use is the administrative tax records from the Chinese State Administration of Tax (SAT) from 2007 to 2011. This dataset contains detailed information on VAT payments and investment in fixed assets. Importantly, these data directly measure investment and separate investments in buildings and structures, which are not part of the reform, from other types of investment. Finally, the dataset includes a flag that identifies firms that were part of the pilot program as of 2007.[31]

We complement these data with two additional datasets. First, we use data on foreign direct investment records from the Ministry of Commerce (MOC). This dataset contains information on the type of foreign firms, namely encouraged, restricted, or whether the project is considered advantageous under the midwest program. We merge this dataset with our main dataset from SAT to identify the foreign firms that had preferential VAT treatment on equipment purchases.[32] In addition, we extend our tax return data by merging the tax records with survey responses from the Chinese Annual Survey of Manufacturing (ASM) from 2005 to 2007. This merge allows us to extend our sample period to 2005, which provides an extended period of analysis prior to the reform.

We restrict our analysis to firms with non-negative values of fixed assets for production and to firms that do not change ownership type in our sample. Our analysis relies on a balanced panel of firms that stay in the data for all five years. Our baseline specifications also require that the dependent variable is non-missing for all years in our sample. However, we also report robustness checks on an unbalanced versions of our data.

Table 2 reports summary statistics of firms in our sample. Our sample include data on close to 315,000 firm-year observations. The sampling of this dataset is such that it includes large firms in every year and it includes smaller firms on a rotating basis. Since our baseline sample restricts firms to have investment data in all years, the number of observations used in our estimations is lower. However, we show that our estimates are similar when we rely on an unbalanced sample.

In our data, average total investment is 4.7 million RMB. The policy we study only affected the after-tax cost of equipment investment, which constitutes 67% of total investment. Table 2 shows that, while foreign firms invest more on average, the average investment rate (equipment

[31] See Appendix C.2 for more details on pilot versus non-pilot firms.
[32] See Appendix C.3 for more details on merging results.

investment relative to the stock of equipment) is 10% for both domestic and foreign firms.

Investment data in China is lumpy. Panel A of Figure 5 shows the distribution of investment rates and shows that 49% of firms do not invest in any given year. In addition, 17% of firms replace more than 20% of their capital stock in any given year. These lumpy data patterns make it clear that investment decisions are subject to fixed costs and motivate our study of how taxes affect lumpy investment decisions. By way of comparison, Zwick and Mahon [2017] report that 24% of firms in the US replace less than 1% of their capital and that 14% of firms replace more than 20%.[33] Panel B shows that, despite the large number of years where firms do not invest, the investment rate is serially correlated with a serial correlation of 0.20. The comparable number for the US is 0.40 [Zwick and Mahon, 2017].

Table 2 also reports data on firm sales, fixed assets, cash flow, and debt for both domestic and foreign firms. We uses these variables as controls in some specifications. Since these variables show that foreign firms are larger than domestic firms, we follow Yagan [2015] in reweighting our data to match the distribution of firm characteristics between domestic and foreign firms. Specifically, we first estimate a propensity score model that controls for firm industry, region, exporting status, sales, and interaction terms between these variables. We then generate estimation weights following DiNardo, Fortin, and Lemieux [1996]. As we show in Figure F.4, this inverse probability weighting (IPW) method ensures that our treatment and control groups are comparable.[34]

Finally, we discuss the role of state-owned-enterprises (SOEs) in the Chinese economy. SOEs make up 8.4% of all firms, account for 4% of large manufacturing firms (those sales above 5 million RMB), and have an investment rate of 11%, which is similar to other firms. In our estimation sample, SOEs account for 3% of observations and 5.2% of total investment in equipment. Our empirical results are robust to excluding SOEs.

4 Reduced-Form Effects of China's VAT Reform

We estimate the effects of the reform on investment using two sets of analysis. First, we rely on a difference-in-differences research strategy that exploits the different policy treatments of domestic and foreign firms prior to the reform. Second, we use this variation in the after-tax cost of investment to estimate how changes in the user-cost-of-capital (UCC) affect investment, and how this effect varies across firm characteristics.

[33] Similarly, Levinsohn and Petrin [2003] report than, depending on the industry, about 60% of Chilean firms replace less than 1% of their capital. Additional data for the US can be found in Cooper and Haltiwanger [2006]. Since we use firm-level data, as opposed to plant-level data, statistics from Zwick and Mahon [2017] are more comparable to our setting.

[34] We describe this procedure in more detail in Appendix D.1.

4.1 Difference-in-Differences Estimates

As detailed in Section 2, aside from firms in the pilot reform, domestic firms were not able to deduct input VAT on equipment before 2009. In contrast, foreign firms in encouraged sectors enjoyed a preferential treatment that allowed them to deduct equipment from VAT. Therefore, the reform did not affect foreign firms with preferential treatment while it significantly reduced investment cost for domestic firms. We study this natural experiment using a difference-in-differences strategy to estimate the effects of the reform on firm investment.

Our main difference-in-differences specification takes the following form:

$$Y_{ijt} = G_i\gamma_t + \mu_i + \delta_{jt} + X'_{it}\beta + \varepsilon_{ijt}, \tag{6}$$

where Y_{ijt} is a firm-level measure of investment for firm i in industry j in year t. For instance, we measure extensive-margin responses with the fraction of firms with positive investment and we measure intensive-margin responses with the investment rate. G_i is an indicator for treatment, which we set to 1 for domestic firms and to 0 for foreign firms.[35] The parameter of interest – γ_t – is the average effect on domestic firms. Firms fixed effect μ_i control for firm-specific time unobservables. Industry-year fixed effects δ_{jt} control for industry-specific trends. For instance, these fixed effects rule out the possibility that our results are driven by differential growth rates across industries. In some specifications we also include province-year fixed effects, which rule out the concern that differential growth rates across provinces impact our results. Finally, we also show that our results are robust to including firm-level controls, $X'_{it}\beta$, which include lagged cash-flow measures, corporate income tax rates, as well as quartic expansions of sales, firm age, and profit margin.

The key identifying assumption is that no other unobserved ownership-year-specific shocks coincide with the reform. We first show graphical evidence that prior to the reform domestic and foreign firms had similar trends. Figure 6 plots investment trends from 2005 to 2011. Panel A plots the fraction of firms investing in any given year and shows that domestic and foreign firms had similar trends prior to the reform. Panel B plots the same figure for the investment rate.[36] Panels C and D report the coefficients γ_t in Equation 6 and show that, indeed, the parallel trends observed in Panel A result in statistically insignificant estimates before 2009. These parallel trends are consistent with our assumption that domestic and foreign firms would

[35] Our main specification only includes foreign firms with preferential treatment and excludes domestic firms in the pilot program.

[36] To create this figure, we use tax data which has information on equipment investment for years 2007 to 2011 as well as total investment data in the ASM from 2005 to 2008. Since the ASM only reports total investment, this figures assumes that firms invest in equipment and other assets proportionately. Finally, we normalize investment outcomes to domestic levels in 2007.

have had the same investment patterns absent the reform. After the reform, however, we see that domestic firms are more likely to report any investment (Panels A and C) and that their overall investment rate is also higher (Panels B and D).[37]

In order to quantify the effects of the reform, Table 3 provides estimates of the following difference-in-difference regression:

$$Y_{ijt} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + X'_{it}\beta + \varepsilon_{ijt} \tag{7}$$

The first three columns in Panel A show that, on average, the reform increased the fraction of domestic firms by close to 5 percentage points. This result lines up very well with the visual evidence in Figure 6. Relative to a base participation of 60%, this increase represents an 8% increase in the fraction of firms investing. These columns also show that this result is robust to including industry-by-year and province-by-year fixed effects.

The last three columns of Panel A report average effects of the reform on the investment rate. These columns show that, relative to foreign firms with preferential treatment, domestic firms increased investment by about 3.6% of the capital stock. Relative to an average investment rate of 10%, this effect represents a 36% increase in investment.

Panel B of Table 3 shows that these results are robust to the set of firms used in our estimation. First, we show that our results are robust to weighting observations to ensure that foreign and domestic firms have similar observable characteristics.[38] Columns (1) and (4) show that we obtain very similar estimates after this adjustment. The remaining columns of Panel B show that our results are robust to including firms with missing values of the outcome variable or to using all foreign firms (and not just those in preferential industries) as controls.

Panel C of Table F.11 shows that our estimates are also robust to controlling for firm-level characteristics. Columns (1) and (4) include a measure of lagged cash-flow and columns (2) and (5) control for quartics in sales, firm age, and profit margin. Finally, columns (3) and (6) show that our results are robust to controlling for changes in the corporate income tax rate. As we discuss in Section 2, while a 2008 reform changed the statutory CIT for foreign and domestic firms, the reform had very small effects on firms' effective tax rates. These columns show that controlling for this policy change does not affect our main estimate.[39] This panel shows that firm-level characteristics and other observable policies are not driving our results. By including these controls we also limit the number of potential unobservable shocks that can challenge our identifying assumption.

[37] We report the coefficients in Figure 6 in Table F.7. Table F.8 shows these results are robust to the same robustness checks performed in our difference-in-differences analysis.

[38] We describe this IPW weighting strategy in Section 3. See Appendix D.1 for more details.

[39] This result is also visible in Figure 6 since there is no change in investment patterns in 2008.

In order to further explore the identifying assumption that foreign and domestic firms did not face differential shocks at the time of the reform, we now conduct a placebo test that compares foreign firms to domestic firms that were part of the pilot reform in 2004. Since these firms were already able to deduct equipment purchases from the VAT, the reform should not affect their investment decisions. Panel D in Table 3 reports the results of this placebo test. These results show that foreign and domestic firms in the pilot had statistically indistinguishable investment patterns. Moreover, these null effects are estimated relatively precisely and can rule out the estimates from Panel A. These results therefore support our identifying assumption that foreign and domestic firms did not face differential shocks that would affect investment during this time period.

The last panel in Table 3 shows that our results are robust to how we measure investment outcomes. Columns (1)-(3) now report the effects of the reform on the logarithm of investment. Precisely because lumpy investment patterns imply that firms will have zero investment in many years, using the logarithm of investment limits the number of observations in our regressions. Nonetheless, we find similar estimates in this selected sample. Specifically, we find that investment increases by 40-45% in contrast to the 36-38% implied by columns (4)-(6) in Panel A. Finally, columns (4)-(6) of Panel E report effects on the inverse hyperbolic sine (IHS) of investment, i.e. $\log(I + \sqrt{1 + I^2})$. The IHS has the advantage that it can deal with zero values of investment and it also approximates the logarithm for large values of investment. These estimates imply larger effects than the log specification and imply increases of 63-72%. However, because the derivative of the IHS is greater near zero, this value places considerable weight on extensive-margin responses. These results show that the conclusion that the reform led to significant increases in investment by domestic firms does not rely on how we measure investment outcomes.

As a final robustness check, we consider whether firms could avoid or evade the VAT tax on equipment. It is unlikely that firms could evade this tax since China's VAT system with third-party reporting would make it likely that firms would get caught misreporting, especially when it comes to a large purchase, such as production equipment. In addition, if firms wanted to avoid paying this tax, there is a much simpler and legal strategy they could employ: to lease equipment from a foreign company. That is, a domestic company could lease production equipment and deduct leasing payments from VAT, while a foreign company could deduct the purchase price of its equipment from its VAT. In order to test this hypothesis, we estimate the effects of the reform on a measure of capital utilization that includes changes in leased equipment and investment. Table F.10 reports the results of these estimates and finds similar estimates to those of Panel A of Table 3. This result suggests that evasion or avoidance is not an important concern when interpreting our reduced-form results.

Investment Spikes

To further investigate the effect of VAT reform on the large investment, we conduct similar analysis on investment spikes. We follow the literature (e.g. Cooper and Haltiwanger [2006]) for easier comparison, and define investment spikes to be investment rates larger than 0.2. We replace the outcome variable in our difference-in-difference specification (7) with three measures regarding investment spikes. First, we define a dummy variable set to be 1 if the investment rate is larger than 0.2 to capture the extensive margin response of spikes, i.e. $D_{it}^{spike} = \mathbb{1}\{IK_{it} \geq 0.2\}$ where IK_{it} is the investment rate of firm i at time t. Second, we consider the spike investment rate which is the product of investment rate and the investment spike dummy, i.e. $IK_{it}^{spike} = IK_{it} \times \mathbb{1}\{IK_{it} \geq 0.2\}$. Lastly, we also consider the non-spike investment rate to complement results of spikes, i.e. $IK_{it}^{non-spike} = IK_{it} \times \mathbb{1}\{IK_{it} < 0.2\}$

Table 4 reports the difference-in-difference results. Column (1) to (3) shows that the fraction of firms undergoing investment spikes increased by 7.3 percentage points, which is larger than the magnitude concerning all investment including spikes and non-spikes (4.6 percentage points). Column (4) to (6) and column (7) to (9) show the results for investment rate of spikes and non-spikes, respectively. Combining the two sets of estimates, we can see the investment response is driven by surges in investment spikes.

VAT Deductibility

We define a firm to be at positive tax position if a firm has positive *potential* VAT credit, defined by an excessive VAT credit even without input credit from investment. In particular, potential VAT credit $= \text{InputVAT}_{it} - \text{OutputVAT}_{it} + \text{Credit}_{i,t-1}$ for domestic firms prior the reform; $= \text{InputVAT}_{it} - \text{OutputVAT}_{it} + \text{Credit}_{i,t-1} - 17\% \times I_{it}$ otherwise (i.e., foreign firms prior the reform or all firms after the reform). Then, we define a dummy variable TP_{it} set to 1 if a firm has positive VAT credit. [40]

Table 5 reports the heterogeneity effects on investment due to tax position. We conduct diff-in-diff analysis separately for firms with and without positive VAT credit. Column(1) and (4) shows the results for all firms;[41] column (2) and (5) for firms without positive VAT credit; column(3) and (6) for firms with positive VAT credit. We can see that investment responses, especially at the extensive margin, are driven by firms without any tax credit. Those firms are able to fully enjoy the benefits from deducting input VAT credit of equipment purchase. On the other hand, firms with positive VAT credit are not allowed to have full deduction, leading to a

[40] After the reform, around 13.38% domestic firms are at positive tax position.

[41] The number of observations for column(1) and (4) is different from baseline results because we keep a balanced panel of firms with non-missing tax position.

smaller responses.

5 Estimating a Dynamic Investment Model

Our baseline reduced-form results are broadly consistent with our model's intuition, which is reassuring for the theoretical mechanisms of how the VAT affects firm-level investment dynamics. In order to further investigate the impact of alternative fiscal instruments such as the CIT or Bonus Depreciation, we need to uncover the fundamental investment frictions that slow down and dampen the impact of different tax instruments. We can then rely on our structural model to compare the fiscal efficiency of these various policies.

We now estimate the model outlined in Section 1. We set the preference discount factor β to 0.95. We set the CIT rate to the average effective rate in the data: 15.4%. The VAT rate is 17%, which is the statutory rate before the reform. We choose the accounting depreciation rate $\hat{\delta}$ to match the present value of capital depreciated over 10 years by straight-line method.[42] With an interest rate $r = 5.26\%(= 1/\beta - 1)$ and a 10 year depreciation period, the present value of depreciation deductions p_v is 0.803. We estimate the rest of the parameters in two steps.

The first group of parameters governs the firms' static profit functions and productivity processes. Recall that we model profit in a reduced-form way that implies:

$$\pi_{it} = \theta k_{it} + (1-\theta)a_{it} = \theta k_{it} + (1-\theta)(b_t + \omega_i + \varepsilon_{it}), \tag{8}$$

where π_{it} and k_{it} are log profit and log capital stock. Here, the profit shock a_{it} is decomposed into an aggregate shock b_t, a firm-specific permanent shock ω_i, and an idiosyncratic transitory shock ε_{it}, i.e. $a_{it} = b_t + \omega_i + \varepsilon_{it}$. We assume that the transitory shock ε_{it} follows an AR(1) process with persistence and standard deviation $(\rho_\varepsilon, \sigma_\varepsilon)$. The aggregate shock b_t also follows an AR(1) process with parameters (ρ_b, σ_b). The firm permanent shock ω_i is assumed to be normally distributed with mean zero and standard deviation σ_ω. We first estimate the curvature of the profit function θ in Equation (8) as well as the parameters governing productivity, $(\rho_\varepsilon, \sigma_\varepsilon, \rho_b, \sigma_b, \sigma_\omega)$, using a system GMM approach developed by Blundell and Bond [2000].

We then estimate the second group of parameters including the convex adjustment cost and the random fixed cost distribution. We estimate these costs using the method of simulated moments (MSM). We combine two sets of moments. One set includes pre-reform *cross-sectional* moments in a stationary environment that are widely used in structural investment literature.

[42] The minimum depreciation period for production equipment is 10 years, including aircrafts, railway rolling stock, ships, machinery, mechanical apparatus and others. Tax practitioners in China told us that most firms use straight-line depreciation method rather than the accelerated one because of simplicity.

They include serial correlation of investment rate, a measure of the lumpiness of investment, the "spike" rate, and the standard deviation of the invest rate. The second, more novel set of moments, is from our reduced-form estimates. We quantify our structural model by also requiring our model to reproduce the *overtime sensitivity* of firm's investment to user cost changes induced by the Chinese VAT reform. As we discuss below, this second set of moments is useful for over-identification and validation purposes.

5.1 Estimating the Profit Function and Decomposing Productivity

Estimating the profit function in Equation (8) directly raises a few challenges. First, economic profit is typically hard to measure using firm-level accounting data. We mitigate this problem by making the standard assumption in the investment literature such that firm profits are proportional to revenue. When we logarithmize, the profit and revenue shocks differ by a constant. This implies that the evolution properties including persistence and variance are the same for the two shocks.[43] Second, Equation (8) is subject to endogeneity concerns since capital k_{it} is likely correlated with productivity. Additionally, capital is usually believed to be measured with error. In order to deal with these concerns, we employ the system GMM approach proposed by Blundell and Bond [2000] to estimate Equation (8).

Denoting m_{it} as classical measurement error (or any other unexpected optimization error), the revenue equation becomes

$$r_{it} = \theta k_{it} + (1-\theta)b_t + (1-\theta)\omega_i + (1-\theta)\varepsilon_{it} + m_{it}. \tag{9}$$

Here, the transitory shock ε_{it} follows an AR(1) process, i.e. $\varepsilon_{it} = \rho_\varepsilon \varepsilon_{i,t-1} + e_{it}$ where e_{it} is an innovation term independently and identically distributed across firms and over time. We exploit the AR(1) property of ε_{it} to difference out the persistent component in ε_{it}. In this way, we obtain the differenced revenue equation

$$r_{it} = \rho_\varepsilon r_{i,t-1} + \theta k_{it} - \rho_\varepsilon \theta k_{i,t-1} + b_t^* + \omega_i^* + m_{i,t} - \rho_\varepsilon m_{i,t-1} + (1-\theta)e_{it}, \tag{10}$$

where $b_t^* = (1-\theta)b_t - \rho_\varepsilon(1-\theta)b_{t-1}$ is the year fixed effect and $\omega_i^* = (1-\theta)(1-\rho_\varepsilon)\omega_i$ is the firm fixed effect. To avoid problems arising from endogenous capital, we use lagged capital and revenue from up to two periods as instruments. We then estimate the curvature of the profit function θ and the persistence of idiosyncratic transitory shocks ρ_ε using the system GMM model

[43] Appendix A.2 gives examples where this assumption holds either with a DRTS production function and perfect competition, or with CES demand and monopolistic competition; two cases that are commonly analyzed in the macro investment literature. In addition, without loss of generality, we can also decompose revenue shocks as $a_{it}^R = b_t + \omega_i + \varepsilon_{it}$.

of Blundell and Bond [2000].[44]

The estimate of ρ_ε is 0.860 with standard error 0.012. The estimate of θ is 0.734 with standard error 0.030. To better understand the magnitude of the profit function curvature θ, we map θ into the markup in a simple monopolistic competitive model with constant markup. Appendix A.2 illustrates that, under conventional assumptions regarding the factor shares of manufacturing firms in China, the markup implied by θ is 1.224, which is comparable to values in the literature.[45]

Having the estimated $\hat{\theta}$ in hand, we can compute productivity as $\hat{a}_{it} = r_{it} - \hat{\theta} k_{it}$. We further decompose $\hat{a}_{it}$ using Equation (8) to recover the distributions of b_t, ω_i and ε_{it}. The standard deviation of aggregate shocks σ_b is estimated to be 0.010 and its persistence ρ_b is 0.009. Due to the short panel nature, aggregate shocks play a relatively small role in our data, once persistent idiosyncratic uncertainties are accounted for. The standard deviation of transitory shock σ_ε is estimated to be 0.529; that of permanent heterogeneity σ_ω is 0.854. As a result, a large fraction of productivity dispersion comes from permanent heterogeneity across firms. Despite the fact that firm size and capital stock level are highly dependent on the permanent heterogeneity, as we show in our model, the investment dynamics are mostly determined by the transitory shocks.

Table 6 summarizes the calibrated and estimated parameters which we use for the structural estimation of adjustment costs.

5.2 Estimating Adjustment Costs

We next estimate the adjustment costs using the method of simulated moments (MSM). We estimate two empirical models that differ in terms of the distributional assumption of fixed cost ξ. The first, based on Cooper and Haltiwanger [2006], assumes a degenerate distribution $G(\xi)$ with mass at a single point. The second type of model follows recent approaches in the literature by assuming that ξ is drawn from a uniform distribution between 0 and $\bar{\xi}$ [e.g., Caballero and Engel, 1999, Khan and Thomas, 2008, Winberry, 2018]. The three parameters we estimate are then economic depreciation rate δ, convex adjustment cost parameter γ, and fixed adjustment cost parameter $\bar{\xi}$.

To estimate these parameters, we form the following two sets of moments:

1) The first set of moments (m^A) are based on pre-reform stationary moments:

[44] Particularly, we use changes in lagged revenue Δr_{it-s} and capital Δk_{it-s}, $s \geq 2$, to instrument the revenue Equation (43). We also use lagged revenue r_{it-s} and capital k_{it-s}, $s \geq 3$, to instrument the first-differenced revenue equation: $\Delta r_{it} = \rho_\varepsilon \Delta r_{i,t-1} + \theta \Delta k_{it} - \rho_\varepsilon \theta \Delta k_{i,t-1} + \Delta b_t^* + \Delta m_{i,t} - \rho_\varepsilon \Delta m_{i,t-1} + (1-\theta)\Delta e_{it}$.

[45] More specifically, Appendix A.2 gives an example where a firm has a constant-return-to-scale (CTRS) production function and faces a demand with constant elasticity of substitution (CES). In that case, the markup is constant and equals to $\frac{1}{\theta}\frac{\alpha(1-\sigma)}{(1-\alpha)(1-\sigma)+\sigma} + 1$, where α is the share of capital out of value added and σ is the share of materials. Assuming $\alpha = 0.5$ [Bai, Hsieh, Qian, et al., 2006] and $\sigma = 0.7$ [Jones, 2011], the markup is 1.224.

(a) the mean and standard deviation of investment rate i/k, μ_i and σ_i;

(b) the empirical distribution of investment rate, defined by the fraction of firms with i/k less than 0.1, 0.2, and 0.3 respectively (notice that the spike rate λ_{sp}, i.e. fraction of firms with $i/k > 0.2$, is implicitly included in these moments); and

(c) the 1-year autocorrelation of investment rate $\rho_{i,i_{-1}}$.

These moments are widely used as targets to identify adjustment costs, particularly in macroeconomics and the productivity literature.[46] For example, among other moments, Cooper and Haltiwanger [2006] use the spike rate λ_{sp} and autocorrelation $\rho_{i,i_{-1}}$; Winberry [2018] uses the standard deviation of investment rate σ_i and the spike rate λ_{sp}; and Clementi and Palazzo [2016] also use the standard deviation σ_i and autocorrelation $\rho_{i,i_{-1}}$.[47].

2) The second set of moments (m^B) are based on our dif-in-dif reduced-form estimates reported in Table 3:

(a) the DID estimate of investment rate post-VAT-reform ε_i; and

(b) the DID estimate of the fraction of investing firms post-VAT-reform ε_{ia}.

These elasticity moments are seldom used to calibrate or estimate parameters in macro or the productivity literatures. We use them to validate our estimates based only on m^A and to provide over-identifying restrictions.

Identification

We briefly discuss the identification of our model parameters since the argument is standard in the investment literature. In principle, the first set of stationary moments (m^A) is already sufficient to identify all three structural parameters. The economic depreciation rate δ is closely tied to the average investment rate μ_i. The identification of γ and $\bar{\xi}$ are intertwined. Consider the convex adjustment cost γ. A higher convex adjustment cost motivates firms to smooth overtime and decreases the lumpiness of the investment. In other words, the fraction of firms in the inaction region and the fraction of firms with spikes both go down. On the other hand, a higher $\bar{\xi}$ increases the fraction of firms with lumpy investment and the standard deviation of investment rate σ_i as a result. Meanwhile, higher $\bar{\xi}$ also reduces the serial correlation $\rho_{i,i_{-1}}$. How the convex adjustment cost affects serial correlation is more ambiguous in our model specification though. Since the total fixed cost of adjustment is proportional to firm's capital level, convex

[46] We follow the definitions of the spike rate in Cooper and Haltiwanger [2006]. Since we do not observe negative investment, i.e. retirement of equipment, we only use the positive spike rate as a moment.

[47] Most of these studies also target the average investment rate. We are also able to match this moment well despite not directly targeting it.

adjustment cost increases $\rho_{i,i_{-1}}$ by the direct channel of "smoothing" but could also reduces $\rho_{i,i_{-1}}$ by suppressing average capital level and indirectly raising effective fixed cost of adjustment.

We then use the quasi-random elasticity moments m^B as validation and potentially over-identifying moments. As showed in Section 1, γ and $\bar{\xi}$ have effects of the same direction on the elasticity ε_{ia}: higher γ and $\bar{\xi}$ lead to lower ε_{ia}. Similarly, the elasticity of investment rate with respect to the price of capital ε_i decreases in the convex cost γ.

Finally, We conduct more systematic sensitivity analysis of these moments in E.3. To evaluate the sensitivity of our estimates to potential misspecification, we calculate the sensitivity measure proposed by Andrews, Gentzkow, and Shapiro [2017].

Method of Simulated Moments Estimator

We now form the criterion function for the MSM estimator. Denote $\phi = \{\delta, \gamma, \bar{\xi}\}$, $\hat{m}$ as the data moments, and $m(\phi)$ as the moments simulated under the model. The estimate $\hat{\phi}$ minimizes the following criterion function:

$$\hat{g}(\phi) = [\hat{m} - m(\phi)]' \hat{W} [\hat{m} - m(\phi)],$$

We use identity weighting matrix in our baseline estimation, which gives equal weights to all moments. We also conduct robustness checks with the bootstrapped variance-covariance matrix of the moments. For each ϕ, we simulate investment statistics under the initial VAT rate $\nu = 17\%$, as well as the transitional path following the simulated VAT reform. We calculate the simulated reduced-form elasticities using investment responses during the three years following the elimination of VAT to mirror the actual reform.

Table 7 reports estimates of adjustment costs, γ and $\bar{\xi}$, and the depreciation rate δ. We compare data moments with the simulated moments. The first row reports estimates from a model where ξ is fixed at a single value, as in Cooper and Haltiwanger [2006], and that only uses the pre-reform stationary statistics m^A as target moments. While this model does a relatively good job of matching the spike rate and the standard deviation of investment, it results in a very high value of the serial correlation of investment. Looking at semi-elasticities in m^B, this model predict a response to the reform that would be two to three times as big as the reduced-form results in Section 4 suggest.

The second row of Table 7 reports estimates of a model that allows ξ to be distributed i.i.d. with a uniform distribution. In this case where we only target m^A and we allow for a random fixed cost, our estimates are able to generate elasticities that are more comparable to the reduced-form estimates of investment responses at both the extensive and the intensive margin. Our model quantitatively generates around two thirds of the observed reduced-form elasticities in the data.

The third row of Table 7 reports estimates of a model where we use both m^A and m^B, such that the reduced-form elasticity estimates can serve as over-identifying restrictions. As expected, this model does a better job of fitting the reduced-form moments. However, the decrease in the loss function is quite small. This is driven by the fact that the macro moments are relatively more precisely estimated. Matching the reduced-form elasticity results in a slightly lower estimate of convex adjustment cost γ and worse fit for serial correlation $\rho_{i,i_{-1}}$.

Additionally, we compare the simulated diff-in-diff estimates on investment spikes, which are not targeted, to the reduced-form estimates. The first row of Table F.13 are the diff-in-diff coefficients from column (3) and (6) in Table 4; the second row reports the model simulated counterparts. The model is able generate comparable investment spike results to the reduced-form estimates, confirming that our model quantitatively captures key investment patterns in data.

We now consider the economic magnitude of the estimated adjustment costs. The estimate of the convex cost parameter γ is 1.432. Given the sample average of investment rate to be about 10 percentage points, i.e. $i/k \approx 0.10$, the convex adjustment cost is $0.7\%(= 1.432/2 \times (0.10)^2)$ of the capital stock, at the average value of i/k. Similarly, the estimated upper bound of fixed cost $\bar{\xi}$ is 0.119. Since the fixed cost is uniformly distributed in the interval $[0, \bar{\xi}]$, the average fixed cost is 5.95% of the desired capital stock.

6 Simulating Potential Tax Reforms

In this section, we simulate alternative tax reforms and compare their impact on the aggregate investment rate and the average firm value. We consider the following scenarios:

1. the VAT reform with 17% tax rate reduction (Our Baseline);
2. a CIT cut from the current effective tax rate 15.4% to 10%;
3. Bonus depreciation, which allows firms to deduct a fraction $b \in [0, 1]$ of capital expenditures immediately; and
4. a version of the Tax Cuts and Jobs Act (TCJA) that combines full bonus depreciation (expensing) with the CIT cut.

To evaluate the cost (loss in tax revenue) versus benefit (increase in investment rate and firm value) of those policies, we compare the percentage changes in the investment rate and on firm value to the percentage change in tax revenue. We consider a policy with a larger ratio to be more effective at stimulating investment or enhancing firm value.

Table 8 shows the simulated effects of these policies on investment, firm value, and tax revenues through a 10-year window. We first report the reduction in the UCC for each reform. The VAT reform leads to a significant decrease in UCC – 15% associated with the full 17% rate reduction. The CIT reform, on the other hand, has a limited effect on the UCC. Reducing the effective CIT rate from 15.4% to 10%, i.e 5.4% reduction, decreases the UCC by only 1%.

Consider first the effects of this reform in a world without fixed or adjustment costs. Panel B reports changes in investment and firm value in this "frictionless" case, where the presence of the investment VAT still generates partial irreversibility. The investment rate increases the most in the VAT reform, followed by TCJA and bonus depreciation. The CIT cut has the smallest effect in stimulating investment. The ranking of the magnitude of these changes mirrors the extent of reduction in the user cost of capital. For firm value, although the VAT reform still tops the ranking, the CIT becomes more effective. This is because a permanent CIT cut directly raises all of firms future discounted after-tax profits.

However, UCC changes are not sufficient to explain the *quantitative* changes in the investment rate. This can be best illustrated when we compare the investment rate to tax revenue loss ratio. Compare, for instance, our baseline VAT reform with Bonus Depreciation. While both scenarios reduce the effective price of new investment, a one percent of tax revenue loss increases aggregate investment rate by 5.07% in the VAT reform but only by 3.63% with Bonus Depreciation. This difference is due to the fact that the VAT reform also eliminates the source of partial irreversibility and generates a larger extensive margin response compared with Bonus Depreciation. It now follows from this comparison why the CIT reduction is the least "fiscally effective" policy in generating new investment. In contrast to the other reforms, which target the effective capital purchase price, the CIT reduction benefits all the firms, including those in the inaction region. However, only those with large enough productivity shocks will invest more due to the change.

Panel A reports the investment and firm value changes with our baseline estimates of investment frictions $\gamma = 0.8$ and $\bar{\xi} = 0.31$. In the presence of adjustment frictions, tax instruments that directly target at investment such as VAT reform and Bonus Depreciation become less effective. The response of the investment rate is around one fifth (0.38 vs.1.72 for VAT and 0.07 vs. 0.31 for Bonus Depreciation) of that in frictionless case. The presence of capital adjustment frictions substantially slows down the speed with which capital approaches its desired level. This slow-down, in turn, raises the effective cost of investment and offsets the reduction in the investment price from the VAT reform and Bonus Depreciation. Overall, policies that directly target investment are still more effective than the CIT reduction, although the gap is smaller in the case with investment frictions.

To summarize the quantitative pattern more systematically, we report a whole menu of tax policy changes in Figure 7. In Panel A, we report the elasticity of investment rate to tax revenue

ratio for each percentage points of VAT rate, CIT rate, and investment tax credit rate reduction, and a given fraction of Bonus Depreciation write-off. The slope of the curve for each policy instruments maps into their respective "fiscal effectiveness" in stimulating new investment. We find that the VAT tax and Investment Tax Credit are the most effective (steepest slope), which confirms our intuition that tax policies help to reduce the gap between purchase and sales price of capital and partial irreversibility generate the largest investment rate response. In Panel B, we report the elasticity of firm value to tax revenue ratio. A similar slope ranking applies, although the CIT rate is more effective at raising firm value than Bonus Depreciation in this case.

In Appendix F.2, we show that our baseline simulation results are robust to the following extensions. First, we explore the general equilibrium effect of increasing capital price by allowing the capital supply curve to be upward-sloping. In our baseline model, we assume that capital price – net of taxes – is constant. One concern is that capital price is endogenous and thus it increases as the demand goes up. We relax the assumption of constant capital price by incorporating an upward-sloping capital supply. Another concern is that the capital market for used capital is imperfect so the resale price is smaller than the purchase price even without taxes. To explore this possibility, we reduce the resale price from one (as in the baseline model) to 0.95. Third, since VAT reform took place in 2009 as one of the measures to deal with the financial crisis, investment might be reflected by aggregate productivity drop. To explore the role of aggregate productivity in our model and simulation results, we feed in a one standard-deviation drop of aggregate productivity (pernament) at the same time of the tax reform. Fourth, we extend the constant interest rate r to weighted average cost of capital (WACC) which is affected by CIT rate. In this case, CIT cut affects both the interest rate and the discount factor. We find our results robust to those extensions.

Investment Tax Credit

In this appendix section, we present simulation results of the investment tax credit (ITC), along with those of VAT cut and CIT cut. Particularly, ITC affects the purchase price of capital $UCC = \frac{(1+\nu)(1-\tau p_v)-ITC}{1-\tau}$. On the other hand, ITC does not affect capital's book value nor its resale price. ITC stimulates investment similar to VAT cut. First, ITC decreases the capital purchase price. Second, it reduces the gap between purchase and resale price of capital.

Figure 7 shows the percentage changes in investment rate (Panel A) and firm value (Panel B) at different ITC rates. The graphs further confirm that ITC and VAT work similarly. ITC, however, is slightly more "effective" in stimulating investment rate and firm value conditional on the same tax expenditure. This is because ITC does not affect the resale price of capital while the VAT cut reduces the resale price by reducing the book value (due to less depreciation

deduction).

7 Conclusion

The empirical observation that firms make lumpy investment decisions has important implications for tax policy. This paper develops this point in several ways.

First, the paper shows that models of investment with partial irreversibility or fixed costs of investment are required in order to generate extensive-margin responses to tax policy changes and that, in these models, changes to the user cost of capital are not sufficient statistics that capture how firms will respond to taxes.

Second, we analyze an important tax policy change in China that reduced the after-tax cost of investment by close to 15%. We show that this reform also directly affected firms' inaction regions by reducing the degree to which partial irreversibility leads firms to delay adjusting their capital stock. We use administrative tax data and a difference-in-differences approach to document that, as a result of the reform, domestic Chinese firms increased investment by 36%, relative to foreign firms. We also show that firms view the VAT as a tax on investment when VAT credits are non-refundable.

Finally, we estimate an empirical dynamic model of investment that embeds adjustment frictions and relevant tax parameters. The model shows that policies that limit partial irreversibility, such as eliminating a tax on investment or subsidizing it through an investment tax credit, are more effective at stimulating investment than other policy tools, such as a corporate income tax cut or an accelerated depreciation schedule.

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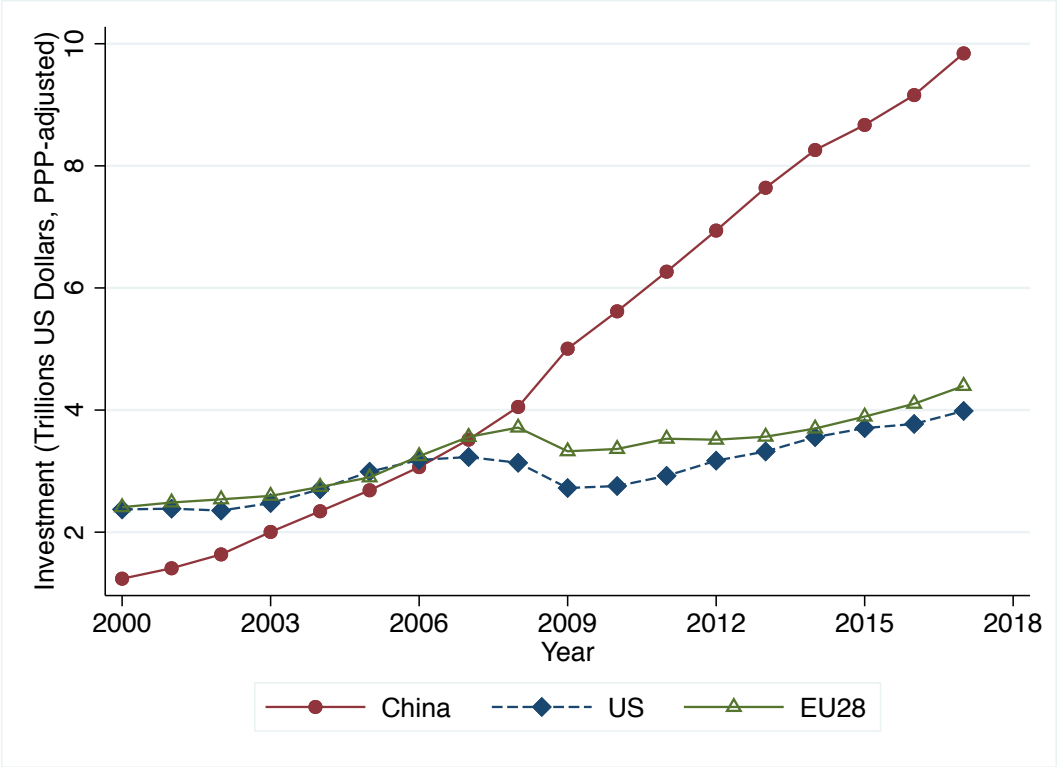
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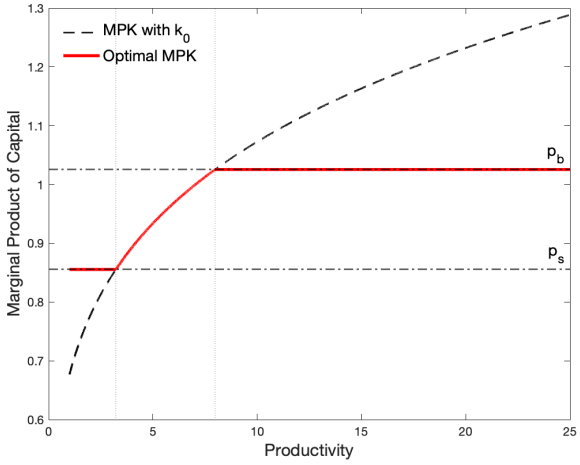
Figure 1: **Cross-Country Comparison of Investment**



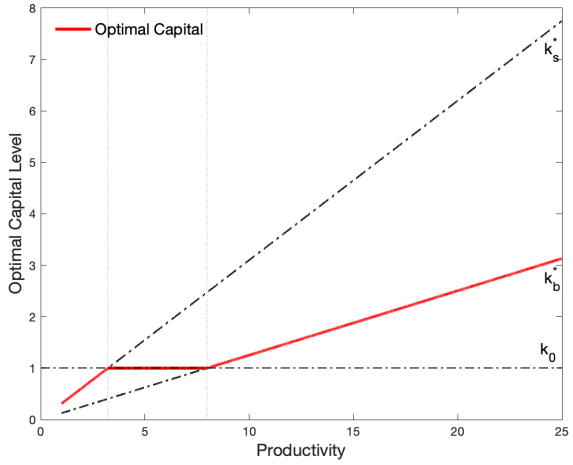
Notes: This figure displays OECD investment (gross fixed capital formation) of the US, the European Union countries and China from 2000 to 2016. It shows that investment in China has long surpassed investment levels in the US and the European Union, and been increasing drastically.

Figure 2: **Partial Irreversibility**

(A) Marginal Product of Capital



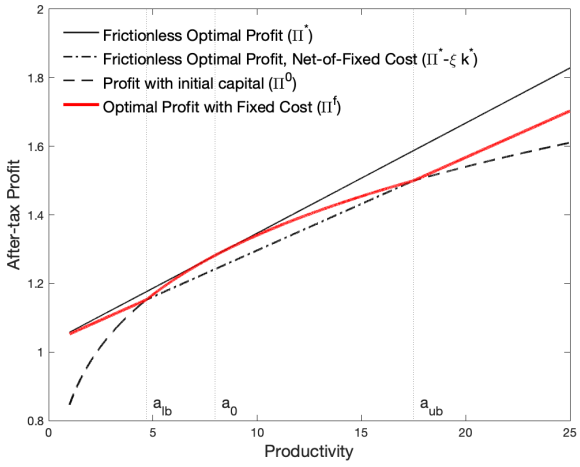
(B) Optimal Capital: Partial Irreversibility



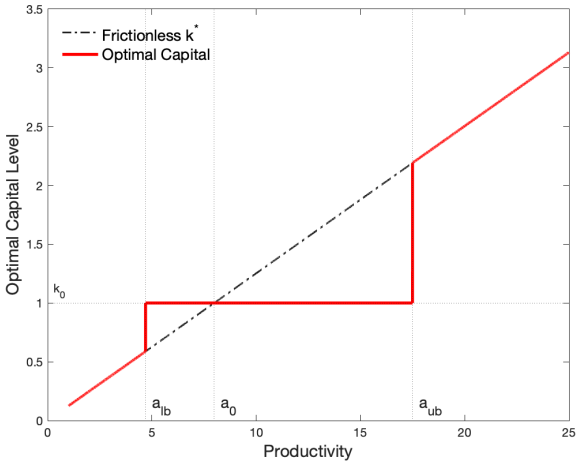
Notes: This figure plots the optimal capital against productivity in a simple static model with only partial irreversibility, i.e. the resale price (p^s) is smaller than the purchase price (p^b). Panel (A) plots the marginal product of capital (MPK) against productivity. The blue line corresponds to the MPK at initial capital stock k_0; The upper horizontal line indicates the purchase price p^b; The lower horizontal line indicates the resale price p^s. The red line indicates the MPK at associated optimal capital levels. In Panel (B) the red line plots the optimal capital level agains productivity.

Figure 3: **Fixed Cost**

(A) Optimal Profit

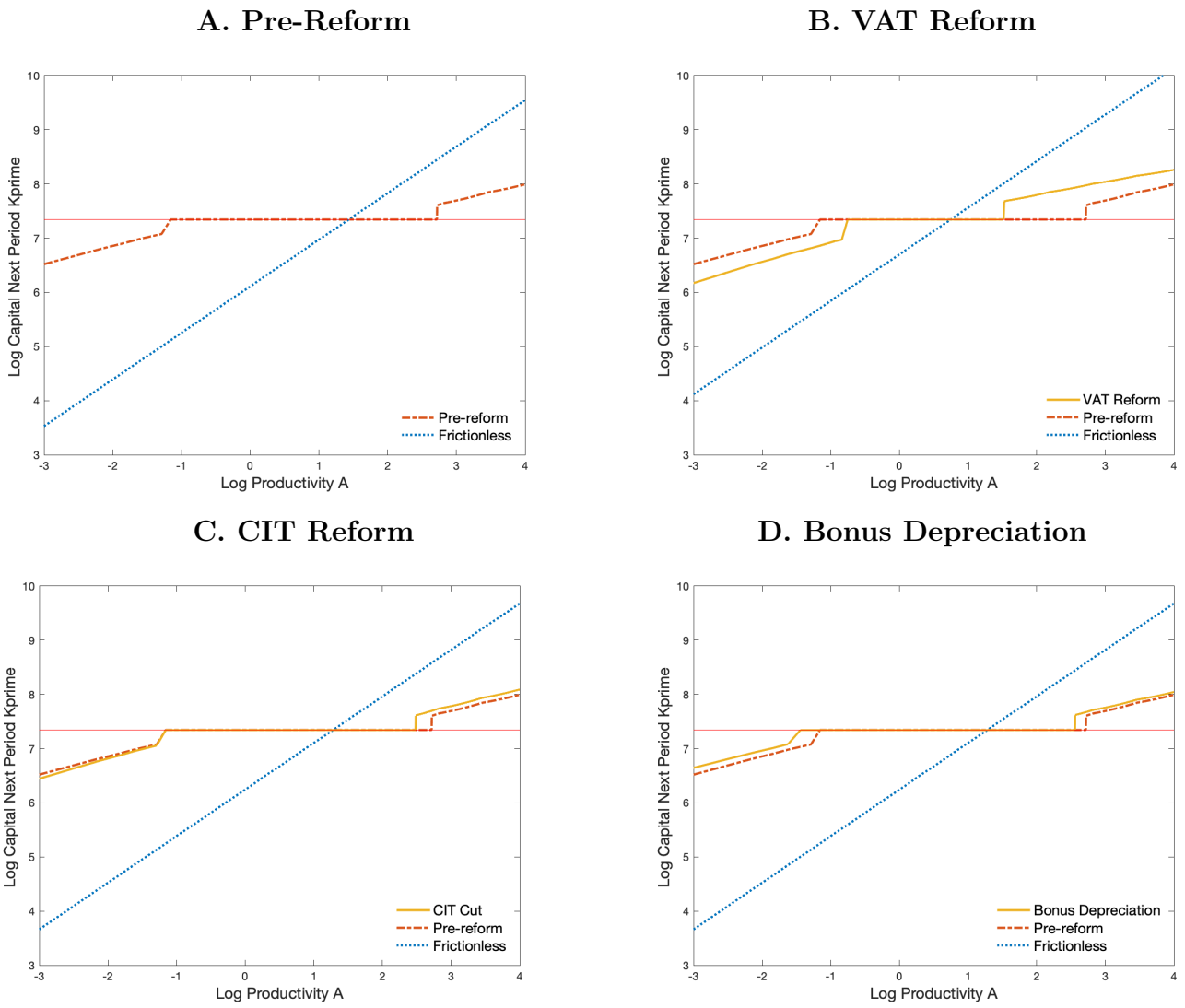


(B) Optimal Capital



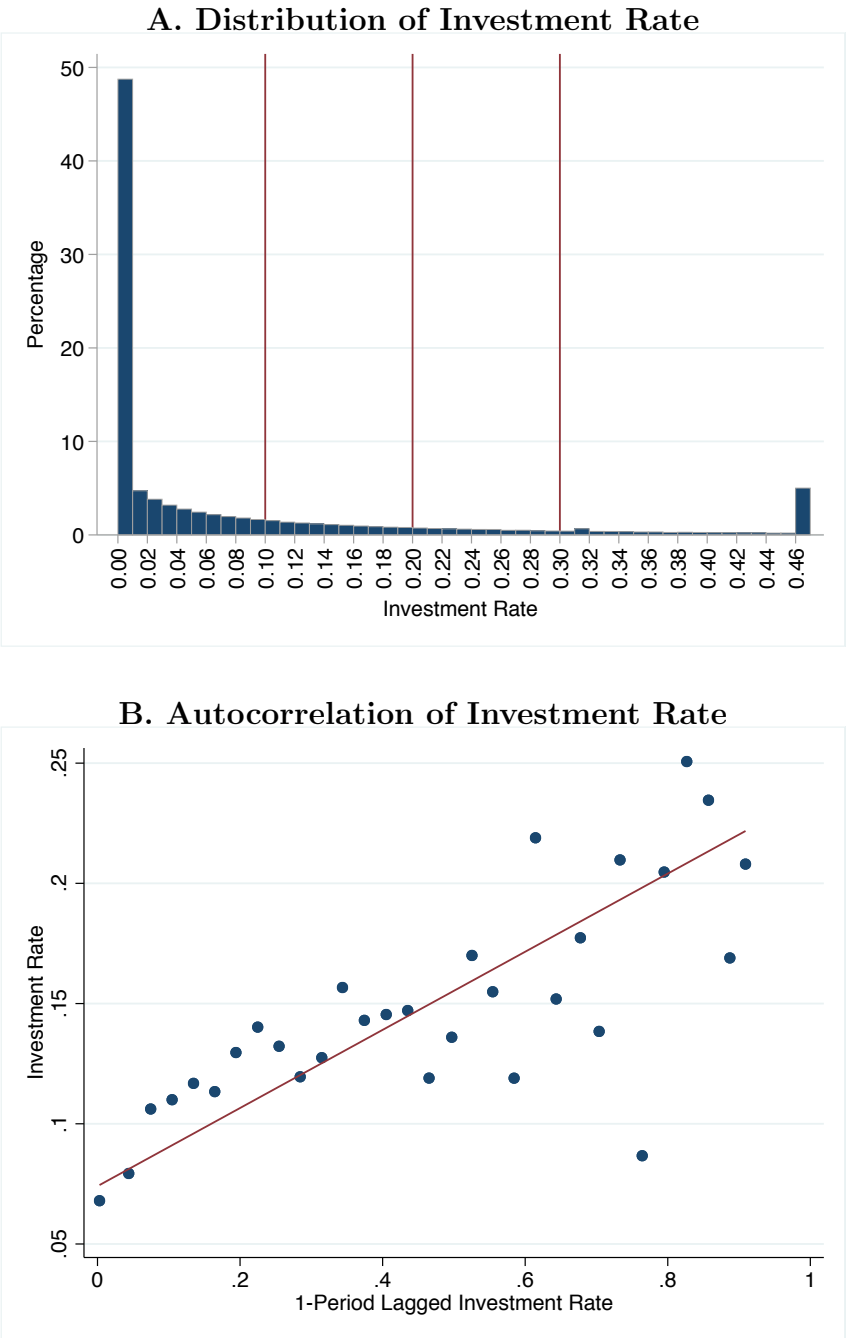
Notes: This figure plots the optimal profit and capital against productivity in a simple static model with only fixed cost. In Panel (A) the solid line indicates the optimal profit without any frictions (Π^*); The dashed line indicates the profit evaluated at initial capital level (Π^0). Panel (B) adds another solid gray line which indicates the optimal profit net of fixed cost ($\Pi^f = \Pi^* - \xi k^*$). The red line indicates the upper envelope of Π^f and Π^0, which is the optimal profit in the present of fixed cost. Similarly, Panel (C) plots the frictionless optimal capital level (k^*) against productivity. In Panel (D) the red line indicates the optimal capital level taking into account the fixed cost.

Figure 4: **Effects of Tax Policy and Investment Frictions on Policy Functions**



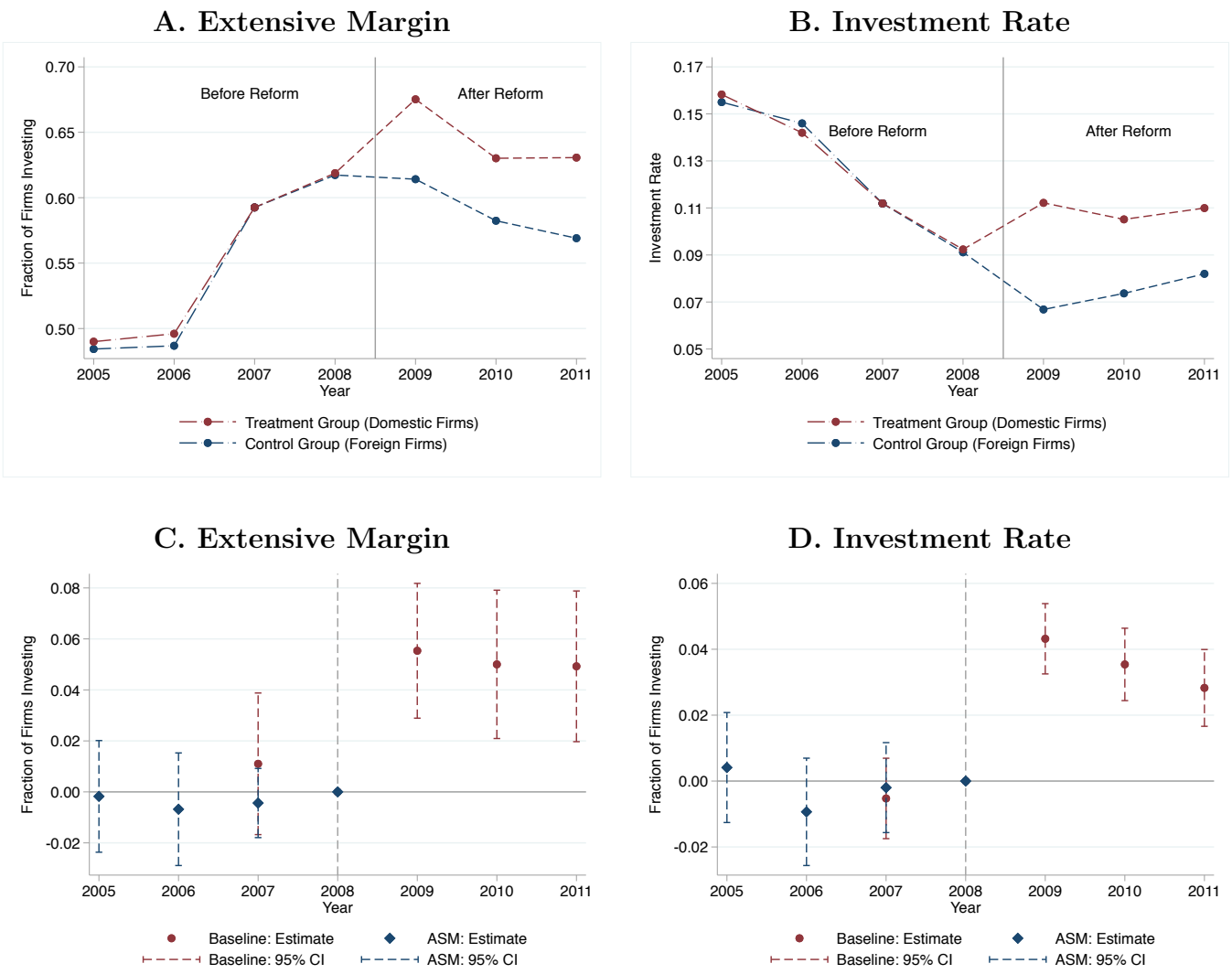
Notes: This figure displays the policy functions against productivity before the reform, after VAT reform, CIT reform and Bonus Depreciation, respectively. Panel A shows that in the frictionless case, the logarithm of optimal capital is linear in log productivity (blue line). Before the reform, fixed cost and partial irreversibility due to VAT create an inaction region (red line) – the productivity region where firms do not adjust their capital stock to productivity shocks and simply let capital depreciate. In addition, the convex cost reduces the slope of policy function to productivity shocks. That is, firms are less responsive to productivity shocks due to convex cost. Panel B shows that VAT reform – removing the gap between purchase and resale price of capital – substantially shrinks the inaction region (yellow line). Firms with low productivity starts downsize while high productivity firms increase investment. Panel C shows that CIT cut shrinks the inaction region but the effect is limited. Panel D shows that Bonus Depreciation – allowing firms to write off depreciation immediately – shifts the inaction region to the left. That is, while Bonus Depreciation stimulate more productive firms to invest, it also keep less productive firms to hold more capital.

Figure 5: **Distribution of Investment Rate and Moments**



Notes: This figure displays the static moments used in the estimation. Panel A plots the distribution of investment winsorized at top 5 percent for domestic firms before the reform. Panel B plots the investment rate against one-period lagged investment rate. Particularly, lagged investment rate is group into 34 equalized bins from 0 to 1, and then we calculate the average investment rate for each bin. The red line is OLS linear fit line.

Figure 6: **Reduced-Form Effects of China's 2009 VAT Reform**

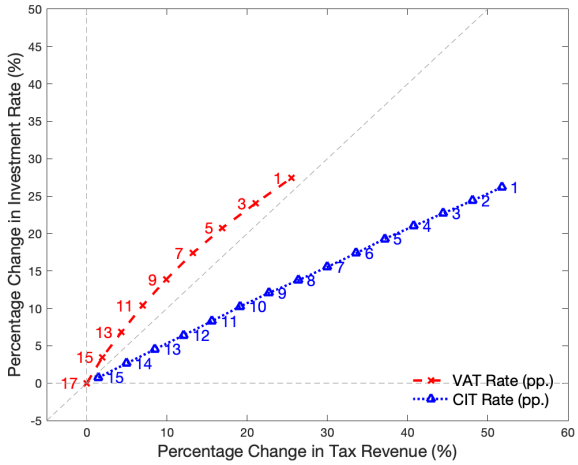


Notes: We first use Tax data to calculate the average investment rate of equipment for each year from 2007 to 2011 for domestic firms (the treatment group) and foreign firms (the control group). For easier comparison, we set 2008 as the base year, and align the investment rate of equipment for domestic and foreign firms to the pooled average rate in 2008. In addition, we complement Tax data with ASM data. That is, we use ASM data to calculate the average rate of total investment for each year from 2005 to 2008 for domestic and foreign firms. Similarly, we align the rates of total investment of the two groups to the pooled average rate of equipment in 2008. To do so, we subtract the average rate of total investment in 2008 from each average rate and add the pooled average investment rate of equipment that we got from Tax data. The assumption we make is that firms invest in equipment and buildings proportionately.

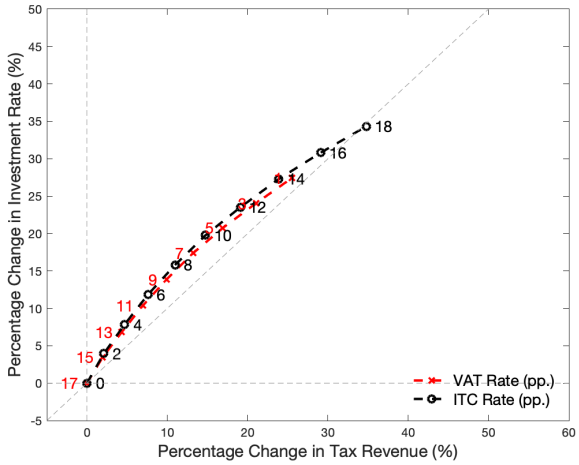
Figure 7: **Simulating Alternative Tax Reforms**

A. Elasticity of Investment Rate to Tax Revenue

VAT Cuts Vs. CIT Cuts

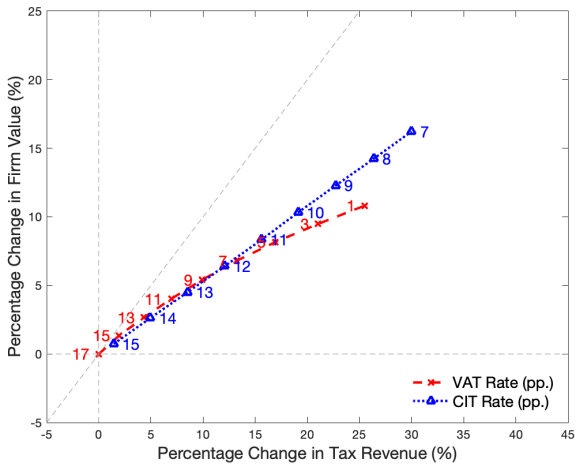


VAT Cuts Vs. ITC

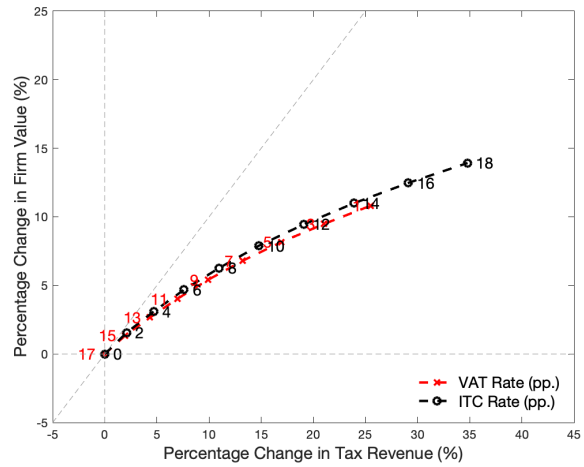


B. Elasticity of Firm Value to Tax Revenue

VAT Cuts Vs. CIT Cuts



VAT Cuts Vs. ITC



Notes: These figures plots the simulated percentage change of aggregate investment rate, and firm value to the percentage loss in tax revenue at different rate of VAT, CIT and Investment Tax Credit (ITC). For each tax rate, we solve the model and simulate investment, tax revenue and firm value, and calculate corresponding changes in each outcome. Panel A plots the percentage change in aggregate investment rate against the percentage change in tax revenue. The left graph compares VAT cuts with CIT cuts at different rates; The right graph compares VAT cuts with ITC. Panel B plots the percentage change in average firm value.

Table 1: **VAT Reform and Investment Costs: Example of a 1,000 RMB Equipment Purchase**

	Pre-Reform	Post-Reform	Change
VAT-Included Cost	1170	1170	
Deductible from VAT	**0**	**170**	**+ 170**
Book Value	1170	1000	-170
PV of Total Depreciation	948.6	810.8	-137.8
Deductible from CIT	237.2	202.7	-34.5
After-Tax Cost of Investment	**932.8**	**797.3**	**-135.5**

Notes: This calculation assumes a discount rate of 5% and a marginal corporate income tax rate of 25%. According to Chinese accounting standards, the book value of the asset would be depreciated over 10 years using a straight line depreciation method. This calculation assumes a zero salvage value. Section A.2 documents depreciation rules in China.

Table 2: **Summary Statistics**

	All Firms			Domestic Firms			Foreign Firms		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Equipment Investment (million RMB)									
Investment	3.15	12.37	221,069	2.61	11.02	202,155	9.01	21.27	18,914
Investment Rate	0.10	0.19	215,813	0.10	0.19	197,050	0.10	0.16	18,763
Log Investment	6.50	2.31	118,913	6.36	2.27	104,929	7.54	2.36	13,984
Other Characteristics (million RMB)									
Total Investment	4.70	17.27	258,736	4.00	15.71	234,475	11.40	27.33	24,261
Fixed Assets	33.77	100.32	310,003	28.85	91.57	282,582	84.48	156.65	27,421
Sales	133.80	390.83	314,595	114.79	351.52	287,033	331.77	643.16	27,562
Cash Inflow	126.74	384.06	283,694	106.45	344.23	257,280	324.38	622.06	26,414
Debt	85.13	241.28	313,074	77.58	228.86	285,570	163.49	334.81	27,504

Notes: This table presents summary statistics of equipment investment measures and variables used in the analysis. Investment is reported in millions RMB and deflated by national price index of equipment investment. Investment rate is defined as the ratio of investment to capital stock measured in book value of net fixed assets. Total investment include investments in equipment, buildings and structures, and other productive capital. Fixed assets are measured in book value, deflated by national price index of fixed-assets investment. Sales is the total sales including domestic and export sales. Cash flow is the business cash inflow from cash flow statement. Debt is the total debt at the end of year. Variables are winsorized at the one percent level.

Table 3: **Estimates of Difference-in-Difference Regressions**

	Extensive Margin: % Firms			Intensive Margin: Investment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Main Results						
Domestic × Post	0.058***	0.044***	0.046***	0.036***	0.037***	0.038***
	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)	(0.004)
N	86870	86870	86870	81270	81270	81270
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y
Panel B. Robustness Checks						
	IPW	Unbalanced	All Foreign	IPW	Unbalanced	All Foreign
Domestic × Post	0.075***	0.059***	0.055***	0.030***	0.041***	0.034***
	(0.024)	(0.007)	(0.006)	(0.008)	(0.003)	(0.002)
N	82785	221069	107255	79195	215813	100980
Industry × Year FE	Y	Y	Y	Y	Y	Y
Panel C. Additional Firm-Level Controls						
	CF	Firm Controls	CIT	CF	Firm Controls	CIT
Domestic × Post	0.055***	0.060***	0.061***	0.036***	0.037***	0.036***
	(0.010)	(0.010)	(0.011)	(0.004)	(0.004)	(0.005)
N	83418	86284	86870	79547	80823	81270
Industry × Year FE	Y	Y	Y	Y	Y	Y
Firm Controls		Y			Y	
Panel D. Placebo Test						
Domestic × Post	-0.011	-0.018	-0.010	0.016	0.012	0.017
	(0.030)	(0.031)	(0.032)	(0.013)	(0.013)	(0.013)
N	13940	13940	13940	12350	12350	12350
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y
Panel E. Alternative Investment Measures						
	Log Investment			IHS Investment		
Domestic × Post	0.449***	0.404***	0.414***	0.716***	0.633***	0.653***
	(0.052)	(0.054)	(0.054)	(0.083)	(0.086)	(0.087)
N	20720	20720	20720	86870	86870	86870
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y

Notes: This table estimates difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + X'_{it}\beta + \varepsilon_{ijt},$$

where Y_{it} is equipment investment, G_i is the treatment indicator, and $Post_t$ is the post-reform indicator. Panel A reports the baseline results. Dependent variables are the fraction of firms investing and investment rate. Column (1) and (4) control for industry-year fixed effects. Column (2) and (5) control for province-year fixed effects. Column (3) and (6) include both fixed effects. Panel B reports robustness checks: Column (1) weights observations by inverse probability weighting (IPW) method; Column (2) uses unbalanced panel; Column (3) uses all foreign firms as control group. Panel C augments the regression with additional controls. Column (1) controls for firm's net cash flow scaled by capital stock. Column (2) adds quadratics in sales, profit margin and age. Panel D reports the placebo test with the same specification as Panel A but using domestic and foreign firms in the pilot project. Panel E runs the baseline specification with log and inverse hyperbolic sine of investment as dependent variables. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table 4: **Estimates of Difference-in-Difference Regressions: Investment Spikes**

	Extensive Margin:			Intensive Margin:					
	% Firms Investing with $IK > 0.2$			Spike Investment Rate			Non-Spike Investment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Domestic × Post	0.070***	0.071***	0.073***	0.031***	0.034***	0.035***	0.005***	0.003**	0.003**
	(0.009)	(0.009)	(0.010)	(0.004)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)
N	81270	81270	81270	81270	81270	81270	81270	81270	81270
Industry × Year FE	Y		Y	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y		Y	Y

Notes: This table estimates difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + X_{it}'\beta + \varepsilon_{ijt},$$

where Y_{it} is a measure regarding investment spike, G_i is the treatment indicator, and $Post_t$ is the post-reform indicator. The dependent variable for column (1) to (3) is a dummy variable set to 1 if the investment rate is larger than 0.2, i.e., $D_{it}^{spike} = \mathbb{1}\{IK_{it} \geq 0.2\}$ where IK_{it} is the investment rate of firm i at time t. The dependent variable for column (4) to (6) is the spike investment rate defined by $IK_{it}^{spike} = IK_{it} \times \mathbb{1}\{IK_{it} \geq 0.2\}$; that for column (7) to (9) is the non-spike investment rate defined by $IK_{it}^{non-spike} = IK_{it} \times \mathbb{1}\{IK_{it} < 0.2\}$. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table 5: **Estimates of Difference-in-Difference Regressions: VAT-Deductibility**

	Extensive Margin: % Firms Investing			Intensive Margin: Investment Rate		
	All Firms	No VAT Credit	Positive VAT Credit	All Firms	No VAT Credit	Positive VAT Credit
	(1)	(2)	(3)	(4)	(5)	(6)
Domestic × Post	0.041***	0.051***	-0.007	0.040***	0.046***	0.016***
	(0.012)	(0.012)	(0.014)	(0.005)	(0.005)	(0.006)
N	72815	61183	11632	67765	56712	11053
P-val of difference			0.00			0.00
Industry × Year FE	Y	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y	Y

Notes: This table estimates difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + X'_{it}\beta + \varepsilon_{ijt},$$

where Y_{it} is equipment investment, G_i is the treatment indicator, and $Post_t$ is the post-reform indicator. We conduct analysis separately for three sets of firms depending on their tax position. A firm is said to be at positive tax position if it has positive potential VAT credit. Particularly, VAT credit of firm i at time $t = \text{InputVAT}_{it} - \text{OutputVAT}_{it} + \text{Credit}_{i,t-1}$ for domestic firms prior the reform; $= \text{InputVAT}_{it} - \text{OutputVAT}_{it} + \text{Credit}_{i,t-1} - 17\% \times I_{it}$ otherwise (i.e., foreign firms prior the reform or all firms after the reform). We report in column (1) and (4) the results using all firms; in column (2) and (5) using firms with no VAT credit; and in column (3) and (6) using firms with positive VAT credits. The dependent variable for column (1) to (3) is a dummy variable set to 1 if a firm makes positive investment, i.e. $D_{it} = \mathbb{1}\{IK_{it} > 0\}$ where IK_{it} is investment rate of firm i at time t. The dependent variable for column (4) to (6) is the investment rate IK_{it}. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table 6: **Summary of Assigned and Estimated Parameters**

Description		Value (S.E)
Panel A. Calibrated Parameters		
Preference discount factor	β	0.950
VAT rate	ν	0.170
CIT rate	τ	0.154
PV depreciation schedule	p_v	0.803
Panel B. Parameters Estimated Independently		
Profit curvature	θ	0.734 (0.030)
Persistence firm transitory shocks	ρ_ε	0.860 (0.012)
SD firm transitory shocks	σ_ε	0.529 (0.005)
SD firm permanent shocks	σ_ω	0.854 (0.007)
Persistence aggregate shocks	ρ_b	0.009 (0.152)
SD aggregate shocks	σ_b	0.010 (0.001)
Panel C. Parameters Estimated by MSM		
Convex cost	γ	1.432 (0.061)
Upper bound of fixed cost	$\bar{\xi}$	0.119 (0.004)
Economic depreciation rate	δ	0.071 (0.001)

Notes: This table summarizes parameters in Section 5. Panel A displays the parameters we set (i.e. not estimated) to simulate the model. Specifically, we set tax parameters to the empirical counterparts. Panel B summarizes the estimated parameters from the first-stage production function estimation and productivity decomposition. In particular, we estimate profit curvature (θ) and the persistence of firm transitory shocks (ρ_ε) using the system GMM. Standard errors are reported in the parenthesis. The rest of parameters in Panel B are results of productivity decomposition (see Section 5.1). Standard errors of those parameters, i.e., σ_ε, σ_ω, ρ_b, and σ_b, are calculated from 100 bootstrap samples. Panel C displays the estimated adjustment frictions and depreciation rate using MSM (see Section 5.2). Standard errors of those parameters, i.e., γ, $\bar{\xi}$, and δ, are calculated from 100 bootstrap samples.

Table 7: **Structural Estimation and Moments**

Model	Parameters			Moments							
	γ	$\bar{\xi}$	δ	Avg i	Share $i < 0.1$	Share $i < 0.2$	Share $i < 0.3$	$Corr(i, i_{-1})$	SD i	DID. Ext	DID. Int
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Data				0.102	0.720	0.834	0.892	0.200	0.186	0.046	0.038
				(0.001)	(0.003)	(0.002)	(0.002)	(0.013)	(0.002)	(0.010)	(0.004)
Fixed	0.427	0.074	0.087	0.092	0.861	0.861	0.863	0.271	0.228	0.149	0.151
(A)	(0.141)	(0.012)	(0.001)								
Uniform	1.594	0.118	0.071	0.080	0.742	0.793	0.879	0.198	0.137	0.030	0.028
(A)	(0.090)	(0.003)	(0.001)								
Uniform	1.432	0.119	0.071	0.081	0.748	0.795	0.875	0.208	0.140	0.042	0.033
(A+B)	(0.061)	(0.004)	(0.001)								
Average Fixed Cost (conditional on investing): 0.024											

Notes: This table displays estimates of convex adjustment cost γ, upper bound of fixed cost $\bar{\xi}$, and economic depreciation rate δ using Method of Simulated Moments. Column (4) to (11) show the simulated moments: 1) set A includes pre-reform static moments – the average investment rate, the fraction of firms with investment rate smaller than 0.1, 0.2 and 0.3, one-period serial correlation of investment rate, standard deviation of investment rate; 2) set B includes difference-in-difference estimates at the extensive and intensive margins. In particular, we simulate 10,000 firms over 200 periods with the reform taking place at the 100th period. We use the last 20 periods before the reform to calculate pre-reform static moments. Meanwhile, we simulate another counterfactual economy where the reform does not take place. The difference-in-difference moments are calculated by taking the difference between the two simulated economies. The first row reports the data moments with standard errors in parenthesis which are calculated using 100 bootstrap. The second row assumes the fixed cost is non-random, and uses pre-reform static moments for estimation. The third and the fourth rows (i.e., Uniform (A) and Uniform (A+B)) assumes that the fixed cost is independently and identically distributed across firms and over time, following a uniform distribution over $[0, \bar{\xi}]$. The third row uses pre-reform static moments for estimation. The fourth row uses both pre-reform static moments and the difference-in-difference moments for estimation. In the last row, using model Uniform (A+B) we report the average fixed cost for firms making positive investment. Standard errors of estimates are reported in the parenthesis below point estimates.

Table 8: **Simulating Tax Reforms: 10 Year Window**

Percentage Change in	Baseline 17%	CIT Cut 15.4% to 10%	Bonus Depreciation	TCJA: BD+CIT	ITC 17%
	(1)	(2)	(3)	(4)	(5)
Panel A. Simulation with Baseline Frictions $\gamma = 1.43$, $\bar{\xi} = 0.12$					
Average Investment Rate	0.29	0.09	0.07	0.14	0.33
Aggregate Investment Rate	0.29	0.10	0.07	0.15	0.33
Fraction of Firms Investing	0.10	0.06	0.03	0.08	0.10
Tax Revenue	-0.28	-0.19	-0.13	-0.29	-0.32
Firm Value	0.11	0.10	0.02	0.12	0.13
Ratio of Investment to Tax Revenue	1.04	0.54	0.53	0.52	1.03
Ratio of Firm Value to Tax Revenue	0.41	0.54	0.13	0.41	0.41
Panel B. Simulation without Frictions					
Average Investment Rate	1.72	0.11	0.30	0.30	2.09
Tax Revenue	-0.37	-0.16	-0.10	-0.23	-0.52
Firm Value	0.54	0.10	0.10	0.17	0.65
Ratio of Investment to Tax Revenue	4.64	0.70	2.96	1.33	4.03
Ratio of Firm Value to Tax Revenue	1.46	0.65	1.00	0.76	1.25

Notes: This table displays the simulated responses to five scenarios: column (1) considers reducing VAT rate from 17% to zero, i.e. our baseline reform; column (2) considers reducing effective CIT rate from 15.4% to 10%; column (3) allows firms to fully depreciate capital expenses immediately, i.e. Bonus Depreciation; column (4) combines CIT cut and Bonus Depreciation, i.e. a version of the Tax Cuts and Jobs Act (TCJA); column (5) grants 17% investment tax credit (ITC). We report percentage (%) changes in the outcomes of interest. For instance, it shows that our baseline 17% VAT cut reduces UCC by 15%, and increases average investment rate by 29% over a 10-year window. Panel A shows the simulated responses using our baseline estimates. For comparison, Panel B shows the responses absent frictions.

tablesection figuresection equationsection

Online Appendix: Not For Publication

This appendix includes supplemental information and additional analyses. Appendix A proves the propositions of the model. Appendix B describes additional policy details. Appendix C describes the data sources. Additional results of reduced-form analysis, structural estimation and simulations are reported in Appendix D, E and F, respectively.

A Model Appendix

A.1 Static Model

In this section, we document derivations of the static models for theoretical motivation.

A.1.1 Partical Irreversibility

At the beginning of the period, the firm is endowed with capital stock k_0. Then, it draws productivity from distribution $F(a)$, and then chooses optimal capital stock for production. The profit function is $\Pi(k,a) = a^{1-\theta}k^{\theta}$ with corporate income tax rate τ. The purchase price of capital is p^b while the resale price is $p^s < p^b$.

Firm's problem is

$$\max\left\{\underbrace{\max_{k>k_0}(1-\tau)a^{1-\theta}k^{\theta}-p^b(k-k_0)}_{\text{Invest}},\underbrace{\max_{k<k_0}(1-\tau)a^{1-\theta}k^{\theta}-p^s(k-k_0)}_{\text{Disinvest}},\underbrace{(1-\tau)a^{1-\theta}k_0^{\theta}}_{\text{Inaction}},\right\}$$

The optimal capital level k is characterized as follows.

- There exists an upper threshold $\bar{a}$ such that firms invest if their productivity is sufficiently high $a > \bar{a}$. In particular, optimal capital $k^b = a\left[\frac{(1-\tau)\theta}{p^b}\right]^{1/(1-\theta)}$; the threshold is

$$\bar{a} = \left[\frac{p^b}{(1-\tau)\theta}\right]^{\frac{1}{1-\theta}} k_0 \tag{11}$$

- There exists a lower threshold $\underline{a}$ such that firms disinvest if their productivity is sufficiently low $a < \underline{a}$. In particular, optimal capital $k^s = a\left[\frac{(1-\tau)\theta}{p^s}\right]^{1/(1-\theta)}$; the threshold is

$$\underline{a} = \left[\frac{p^s}{(1-\tau)\theta}\right]^{\frac{1}{1-\theta}} k_0 \tag{12}$$

- Firms with productivity $a \in [\underline{a}, \bar{a}]$ stay inaction with k_0.

A.1.2 Fixed Cost

The setting is similar except that firms are able to purchase and resale the capital at price p. When firms adjust their capital stock, they need to pay a fixed cost Fk^* where k^* is the optimal capital stock absent of fixed cost.[48] At the beginning of the period, the firm is endowed with capital stock k_0, draws productivity from distribution $F(a)$, and chooses optimal capital stock for production.

Firms's problem is

$$\max \left\{ \underbrace{\max_{k \neq k_0} (1-\tau) a^{1-\theta} k^\theta - p(k - k_0) - Fk^*}_{\text{Adjust}}, \underbrace{(1-\tau) a^{1-\theta} k_0^\theta}_{\text{Inaction}}, \right\}$$

Frictionless Case Absent fixed cost, firms always adjust to the optimal capital according to the productivity draw a. Specifically, the optimal capital is

$$k^* = a \left[\frac{(1-\tau)\theta}{p} \right]^{1/(1-\theta)} \tag{13}$$

The frictionless optimal after-tax profit is

$$\Pi^*(a) = (1-\tau)(1-\theta) \left[\frac{(1-\tau)\theta}{p} \right]^{\theta/(1-\theta)} a + pk_0 \tag{14}$$

If firms produce with initial capital stock, the after-tax profit is

$$\Pi^0 = (1-\tau) a^{1-\theta} k_0^\theta \tag{15}$$

The frictionless profit is always larger than that with initial capital stock except a_0 – the productivity level where the initial capital stock is optimal. That is, $\Pi^*(a) > \Pi^0, \forall a \neq a_0$; $\Pi^*(a_0) = \Pi^0$, where productivity a_0 is $a_0 = \left[\frac{p}{(1-\tau)\theta} \right]^{\frac{1}{1-\theta}} k_0$. In particular, a_0 satisfies the following equality

$$\theta(1-\tau) k_0^\theta a_0^{1-\theta} = pk_0 \tag{16}$$

Fixed Cost Fixed cost lowers the optimal profit if firms adjust to the optimal capital. Specifically,

[48] Here, we assume that fixed cost is fixed while the intuition holds to the case where fixed cost is random.

the optimal profit conditional on adjusting is:

$$(1-\tau)\left[(1-\theta)-\theta\frac{F}{p}\right]\left[\frac{(1-\tau)\theta}{p}\right]^{\theta/(1-\theta)}a+pk_0 \tag{17}$$

Thus, fixe cost generates a region of productivity at which firms would rather produce with initial capital stock k_0. In particular, the optimal capital level k is characterized as follows.

- There exits an upper threshold $\bar{a}$ such that firms invest to the optimal capital if their productivity is sufficiently high $a > \bar{a}$. There exits a lower threshold $\underline{a}$ such that firms disinvest to the optimal capital if their productivity is sufficiently low $a < \underline{a}$. In particular, the optimal capital is defined by equation (13).
- Firms with productivity $a \in [\underline{a}, \bar{a}]$ stay inaction with k_0.

At the thresholds ($\bar{a}$ and $\underline{a}$), firms are indifferent between (dis)investing or staying inaction. By equation (17) and (15), we have, at $a = \underline{a}$ and $a = \bar{a}$:

$$\underbrace{(1-\tau)\left[(1-\theta)-\theta\frac{F}{p}\right]\left[\frac{(1-\tau)\theta}{p}\right]^{\theta/(1-\theta)}a+pk_0}_{\text{Profit conditional on adjusting to optimal capital } k^*} = \underbrace{(1-\tau)k_0^{\theta}a^{1-\theta}}_{\text{Profit using initial capital } k_0}$$

To see how tax reforms interact with the fixed cost, scale both sides by a factor of $\frac{1}{1-\tau}$ and denote $\text{UCC} = \frac{p}{1-\tau}$:

$$\underbrace{\left[(1-\theta)-\theta\frac{F}{p}\right]\left[\frac{\theta}{\text{UCC}}\right]^{\theta/(1-\theta)}}_{\text{Slope}}a+\underbrace{\text{UCC}k_0}_{\text{Intercept}}=k_0^{\theta}a^{1-\theta} \tag{18}$$

It is clear that through interacting with the intercept and slope, CIT and VAT cuts affect the inaction region differently.

A.1.3 Convex Adjustment Cost

In the presence of convex adjustment cost, The firm's objective function is:

$$\max_k (1-\tau)a^{1-\theta}k^{\theta}-p(k-k_0)-D(k),$$

where $p = p_k(1-\tau p_v)$ and where we assume that $D'(k) \geq 0$ and $D''(k) \geq 0$. The firm's FOC is:

$$\theta(1-\tau)a^{1-\theta}k^{\theta-1} = p + D'(k) \tag{19}$$

Taking logarithms and differentiating FOC (19) w.r.t. p_k, and we have

$$\begin{aligned}
(\theta-1)\frac{1}{k}\frac{\partial k}{\partial p_k} &= \frac{1}{p+D'(k)}\left(\frac{\partial p}{\partial p_k}+D''(k)\frac{\partial k}{\partial p_k}\right)\\
(\theta-1)\varepsilon_{k,p_k} &= \underbrace{\frac{p}{p+D'(k)}}_{s^p}\varepsilon_{p,p_k}+\frac{D'(k)}{p+D'(k)}\varepsilon_{k,p_k}\underbrace{\left(\frac{D''(k)k}{D'(k)}\right)}_{\alpha(k)}\\
(\theta-1)\varepsilon_{k,p_k} &= s^p\varepsilon_{p,p_k}+(1-s^p)\varepsilon_{k,p_k}\alpha(k)\\
\varepsilon_{k,p_k} &= \frac{-s^p}{1-\theta+(1-s^p)\alpha(k)},
\end{aligned} \tag{20}$$

where the second line multiplies by p_k and arranges terms into elasticities, the third line introduces $s^p = \frac{p}{p+D'(k)}$ and $\alpha(k) = \frac{D''(k)k}{D'(k)}$, and the last line solves for ε_{k,p_k} and uses the fact that $\varepsilon_{p,p_k} = 1$.

Similarly, taking logarithms and differentiating FOC (19) w.r.t $(1-\tau)$, we have

$$\begin{aligned}
\frac{1}{(1-\tau)}+(\theta-1)\frac{1}{k}\frac{\partial k}{\partial(1-\tau)} &= \frac{1}{p+D'(k)}\left(\frac{\partial p}{\partial(1-\tau)}+D''(k)\frac{\partial k}{\partial(1-\tau)}\right)\\
1+(\theta-1)\varepsilon_{k,1-\tau} &= \frac{p}{p+D'(k)}\varepsilon_{p,1-\tau}+\frac{D'(k)}{p+D'(k)}\varepsilon_{k,1-\tau}\left(\frac{D''(k)k}{D'(k)}\right)\\
1+(\theta-1)\varepsilon_{k,1-\tau} &= s^p\varepsilon_{p,1-\tau}+(1-s^p)\varepsilon_{k,1-\tau}\alpha(k)\\
\varepsilon_{k,1-\tau} &= \frac{1-s^p\varepsilon_{p,1-\tau}}{1-\theta+(1-s^p)\alpha(k)}.
\end{aligned} \tag{21}$$

To interpret Equations 20-21, note that s^p is the share of the price of capital in the total marginal cost of investment $(p+D'(k))$.[49] By increasing the marginal cost of investment, convex costs dampen the numerator of these elasticities. In addition, note that $\alpha(k)$ is a measure of the curvature of the adjustment cost function $D'(k)$.[50] Larger increases in k also increase the marginal cost of investment. This indirect effect of the convex costs also dampens the elasticities by increasing the value of the denominator.

Comparing Equations 20 and 21, we note that changes in $1-\tau$ and p_k now have different effects on investment.[51] To see the nature of this difference, note that changes in $1-\tau$ change the after-tax cost of $D(k)$. These adjustment cost are thought to include halts in production. Because these costs are not tax-deductible, we model $D(k)$ as being an after-tax expense. Adjustment costs could also include tax-deductible expenses, such as labor.[52]

[49] Note $s^p \in [0,1]$ as long as $D'(k) \geq 0$.

[50] In the context of expected utility theory, $\alpha(k)$ is the Arrow-Prat measure of risk aversion, or the coefficient of relative risk aversion. Note $\alpha(k) \geq 0$ as long as $D(k)$ is convex.

[51] To make this comparison, we require a change in $1-\tau$ that has a similar effect on p as a change in p_k. Multiplying Equation 20 by $\varepsilon_{p,1-\tau}$ shows these effects are indeed different.

[52] Equations 20 and 21 are symmetric in the extreme case where all adjustment costs are tax deductible.

A particular example of $D(k)$ is the case of quadratic costs. These costs feature prominently in the literature and we use them in our dynamic model. Assuming $D(k) = \frac{\gamma}{2}\left(\frac{k}{k_0}\right)^2 k_0$ implies $\alpha(k) = 1$ and $s^p = \frac{p}{p+\gamma\frac{k}{k_0}}$. These facts imply the following elasticities:

$$\varepsilon_{k,p_k} = \frac{-1}{(1-\theta)+(2-\theta)\frac{\gamma}{p}\frac{k}{k_0}} \quad \text{and} \quad \varepsilon_{k,(1-\tau)} = \frac{1+\frac{\gamma}{p}\frac{k}{k_0}-\varepsilon_{p,1-\tau}}{(1-\theta)+(2-\theta)\frac{\gamma}{p}\frac{k}{k_0}}.$$

A.2 Profit Function

In this section, we micro-found the profit function of the form $\Pi = (A^\Pi)^{1-\theta}K^\theta$ by a simple firm optimization problem. Assume that firms have DRTS production function and the final good market is perfectly competitive. Production function is:

$$Y = A^{1-\eta}[(K^\alpha L^{1-\alpha})^{1-\sigma}M^\sigma]^\eta,$$

where capital K is pre-determined while labor L and intermediate goods M are chosen contemporaneously after productivity A is realized.

Given the price of final goods p_c which is normalized to one, wage w, the price of intermediate goods p^M and corporate income tax rate τ, firms' profit maximization problem is

$$\max_{L,M}(1-\tau)\{A^{1-\eta}\left[(K^\alpha L^{1-\alpha})^{1-\sigma}M^\sigma\right]^\eta - wL - p^M M\}.$$

Solving FOC's, we can get that:

$$L^* = \left\{\eta\left[\frac{(1-\alpha)(1-\sigma)}{w}\right]^{1-\sigma\eta}\left[\frac{\sigma}{p^M}\right]^{\sigma\eta}A^{1-\eta}\right\}^{\frac{1}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}}K^{\frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}},$$
$$M^* = \frac{w}{(1-\alpha)(1-\sigma)}\frac{\sigma}{p^M}L^*.$$

Thus, the optimal revenue and profit are:

$$R^* = \left\{\underbrace{\left[\frac{(1-\alpha)(1-\sigma)}{w}\right]^{\frac{1-\sigma\eta}{1-\eta}}\left[\frac{\sigma}{p^M}\right]^{\frac{\sigma\eta}{1-\eta}}A}_{A^R}\right\}^{1-\frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}} K^{\frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}} = (A^R)^{1-\theta}K^\theta,$$
$$\Pi^* = \{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\}R^*$$
$$= \left\{\underbrace{(1-\tau)^{\frac{1}{1-\theta}}\{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\}^{\frac{1}{1-\theta}}A^R}_{A^\Pi}\right\}^{1-\theta} K^\theta = (A^\Pi)^{1-\theta}K^\theta, \tag{22}$$

where parameter θ, and profit shocks A^{Π} are defined by:

$$\theta = \frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]},$$
$$A^{\Pi} = (1-\tau)^{\frac{1}{1-\theta}} \{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\}^{\frac{1}{1-\theta}} \left[\frac{(1-\alpha)(1-\sigma)}{w}\right]^{\frac{1-\sigma\eta}{1-\eta}} \left[\frac{\sigma}{p^M}\right]^{\frac{\sigma\eta}{1-\eta}} A.$$

A.3 Value Function and Normalization

A.3.1 Original Value Function

Let D be the depreciation allowances accumulating over time. Since the accounting depreciation rate $\hat{\delta}$ differs from the economic depreciation rate δ, firms track the depreciation allowance D besides capital stock K. Thus, state variable is (K, D, A^{Π}, ξ) where K is pre-determined capital stock, D is depreciation allowance, A^{Π} is profit shock and ξ is random draw of fixed cost. Define *ex ante* value function

$$V^0(K, D, A^{\Pi}) = \int_0^{\bar{\xi}} V(K, D, A^{\Pi}, \xi) dG(\xi) \tag{23}$$

Then, firm's problem in recursive formulation is

$$V(K, D, A^{\Pi}, \xi) = \max\{V^b(K, D, A^{\Pi}, \xi), V^s(K, D, A^{\Pi}, \xi), V^i(K, D, A^{\Pi}, \xi)\},$$

where

$$\begin{aligned}
V^b(K, D, A^{\Pi}, \xi) &= \Pi(K, A^{\Pi}) + \tau\hat{\delta}D \\
&+ \max_{I>0} \left\{ -[1+\nu-\tau\hat{\delta}(1+\nu)]I - \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K + \beta\mathbb{E}[V^0(K', D', A^{\Pi'})|A^{\Pi}] \right\} \\
V^s(K, D, A^{\Pi}, \xi) &= \Pi(K, A^{\Pi}) + \tau\hat{\delta}D \\
&+ \max_{I>0} \left\{ -[1+\quad -\tau\hat{\delta}(1+\nu)]I - \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K + \beta\mathbb{E}[V^0(K', D', A^{\Pi'})|A^{\Pi}] \right\} \\
V^i(K, D, A^{\Pi}, \xi) &= \Pi(K, A^{\Pi}) + \tau\hat{\delta}D + \beta\mathbb{E}[V^0(K(1-\delta), D(1-\hat{\delta}), A^{\Pi'})|A^{\Pi}]
\end{aligned}$$

Capital stock K and depreciation allowance D evolves according to the following law of motions

$$K' = (1-\delta)K + I \tag{24}$$
$$D' = (1-\hat{\delta})[D + (1+\nu)I] \tag{25}$$

A.3.2 Simplification

Winberry [2018] shows that depreciation schedule $\hat{\delta}$ can be summarized by a sufficient statistics of its present discounted value p_v defined by

$$p_v = \hat{\delta} + (1 - \hat{\delta})\beta\mathbb{E}[p_v'] \tag{26}$$

Furthermore, $V(K, D, A^\Pi, \xi)$ has the same solution as the following value function

$$\tilde{V}(K, A^\Pi, \xi) = \max\{\tilde{V}^b(K, A^\Pi, \xi), \tilde{V}^s(K, A^\Pi, \xi), \tilde{V}^i(K, A^\Pi, \xi)\},$$

where

$$\begin{aligned}
\tilde{V}^o(K, A^\Pi) &= \int_0^{\bar{\xi}} \tilde{V}(K, A^\Pi, \xi) dG(\xi) \\
\tilde{V}^b(K, A^\Pi, \xi) &= \max_{I>0} \ \Pi(K, A^\Pi) - \left[[1 + \nu - \tau p_v(1 + \nu)]I + \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 K + \xi K\right] + \beta\mathbb{E}[\tilde{V}^0(K', A^{\Pi'})|A^\Pi] \\
\tilde{V}^s(K, A^\Pi, \xi) &= \max_{I<0} \ \Pi(K, A^\Pi) - \left[[1 \quad - \tau p_v(1 + \nu)]I + \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 K + \xi K\right] + \beta\mathbb{E}[\tilde{V}^0(K', A^{\Pi'})|A^\Pi] \\
\tilde{V}^i(K, A^\Pi, \xi) &= \Pi(K, A^\Pi) + \beta\mathbb{E}[\tilde{V}^0(K(1 - \delta), A^{\Pi'})|A^\Pi]
\end{aligned}$$

Since interest rate r is exogenous, $\mathbb{E}[p_v']$ is thus exogenously determined and equals to $\frac{p_v}{1+r}$. Thus, we can solve the present value of depreciation schedule for any given $\hat{\delta}$.

We sketch the proof here. Rewrite the value function as

$$\begin{aligned}
V(K, D, A, \xi) = \Pi(K, A) + \tau\hat{\delta}D + \max_I - \Big\{[1 + \nu - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I>0} + [1 - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I\leq 0}\Big\} I \\
- \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[V(K', D', A', \xi')|A]
\end{aligned} \tag{27}$$

Consider the set of functions of the form $f(K, A, D, \xi) = g(K, A, \xi) + \tau p_v D$, where $p_v = \hat{\delta} + (1 - \hat{\delta})\mathbb{E}[p_v']$, and the operator T defined by the right hand side of Bellman equation (27).

Claim: Operator T maps function of the form $f(K, A, D, \xi) = g(K, A, \xi) + \tau p_v D$ to itself.

Proof: Apply operator T to $f(K, A, D, \xi)$, and we can get that

$$Tf(K, A, D, \xi) = \Pi(K, A) + \tau\hat{\delta}D + \max_I - \left\{[1 + \nu - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I>0} + [1 - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I\leq 0}\right\} I$$
$$-\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[g(K', A', \xi') + \tau p'_v D'|A]$$

By law of motion for depreciation allowance $D' = (1 - \hat{\delta})[D + (1 + \nu)I]$, we have that

$$Tf(K, A, D, \xi) = \Pi(K, A) + \tau\hat{\delta}D + \max_I - \left\{[1 + \nu - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I>0} + [1 - \tau\hat{\delta}(1 + \nu)]\mathbb{1}_{I\leq 0}\right\} I$$
$$-\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[g(K', A', \xi')|A] + \tau(1 - \hat{\delta})\beta\mathbb{E}[p'_v]D + \tau(1 - \hat{\delta})\beta\mathbb{E}[p'_v](1 + \nu)I$$
$$= \Pi(K, A) + \tau[\hat{\delta} + (1 - \hat{\delta})\beta\mathbb{E}[p'_v]]D$$
$$+\max_I - \left\{[1 + \nu - \tau(1 + \nu)(\hat{\delta} + (1 - \hat{\delta})\beta\mathbb{E}[p'_v])]\mathbb{1}_{I>0}I + [1 - \tau(1 + \nu)(\hat{\delta} + (1 - \hat{\delta})\beta\mathbb{E}[p'_v])]\mathbb{1}_{I\leq 0}\right\} I$$
$$-\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[g(K', A', \xi')|A]$$
$$= \Pi(K, A) + \tau p_v D + \max_I - \{[1 + \nu - \tau(1 + \nu)p_v]\mathbb{1}_{I>0}I + [1 - \tau(1 + \nu)p_v]\mathbb{1}_{I\leq 0}\} I$$
$$-\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[g(K', A', \xi')|A] \tag{28}$$

, where the last equation follows the definition of $p_v = \hat{\delta} + (1 - \hat{\delta})\mathbb{E}[p'_v]$. Note that the right-hand-side of (28) is also a function of the form $h(K, A, \xi) + \tau p_v D$. That is, operator T maps function $f(K, A, D, \xi) = g(K, A, \xi) + \tau p_v D$ to itself. Since the set of functions $f(K, A, D, \xi)$ is a closed set, there exists a unique fixed point and the fixed point lies in the set. By definition of value function which is the fixed point, we can get $V(K, A, D, \xi)$ is of the form that

$$V(K, A, D, \xi) = \tilde{V}(K, A, \xi) + \tau p_v D \tag{29}$$

Substitute equation (29) back to the original value function (27), cancel out common terms on both sides, and we have

$$\tilde{V}(K, A, \xi) = \Pi(K, A) + \max_I - \{[1 + \nu - \tau p_v(1 + \nu)]\mathbb{1}_{I>0} + [1 - \tau p_v(1 + \nu)]\mathbb{1}_{I\leq 0}\} I$$
$$-\frac{\gamma}{2}\left(\frac{I}{K}\right)^2 - \xi K\mathbb{1}_{I\neq 0} + \beta\mathbb{E}[\tilde{V}(K', A', \xi')|A] \tag{30}$$

A.3.3 Further Normalization

Recall that we decompose profit shocks into three components $A_t^{\Pi} = \exp(b_t + \omega_i + \varepsilon_{it})$. Then, the state variable is actually $(K, b, \omega, \varepsilon, \xi)$. Since both profit function (3) and cost function (**??**) are homogeneous of degree one in the pair (K, A^{Π}), and thus $(K, \exp(\omega))$, the value function $V(K, b, \omega, \varepsilon, \xi)$ is homogeneous of degree one in the pair $(K, \exp(\omega))$. Defining $k = K/\exp(\omega)$. Then, we can further normalize the value function to $v(k, b, \varepsilon, \xi)$ and work on this normalized value function

$$v(k, b, \varepsilon, \xi) = \max(v^b(k, b, \varepsilon, \xi), v^s(k, b, \varepsilon, \xi), v^i(k, b, \varepsilon, \xi)), \tag{31}$$

where

$$\begin{aligned}
v^0(k, b, \varepsilon) &= \int_0^{\bar{\xi}} v(k, b, \varepsilon, \xi) dG(\xi) \\
v^b(k, b, \varepsilon, \xi) &= \max_{i>0} \ \pi(k, b, \varepsilon) - \left[[1 + \nu - \tau p_v(1 + \nu)]i + \frac{\gamma}{2}\left(\frac{i}{k}\right)^2 k + \xi k \right] + \beta \mathbb{E}\left[v^0\left(k', b', \varepsilon'\right) | b, \varepsilon \right], \\
v^s(k, b, \varepsilon, \xi) &= \max_{i<0} \ \pi(k, b, \varepsilon) - \left[[1 - \tau p_v(1 + \nu)]i + \frac{\gamma}{2}\left(\frac{i}{k}\right)^2 k + \xi k \right] + \beta \mathbb{E}\left[v^0\left(k', b', \varepsilon'\right) | b, \varepsilon \right], \\
v^i(k, b, \varepsilon, \xi) &= \pi(k, b, \varepsilon) + \beta \mathbb{E}\left[v^0\left(k'(1 - \delta), b', \varepsilon'\right) | b, \varepsilon \right].
\end{aligned}$$

The law of motion for capital k is

$$k' = (1 - \delta)k + i. \tag{32}$$

In this case, investment is also normalized by $i = k' - (1 - \delta)k = I/exp(\omega)$.

B Policy Background

We document more details of three major tax components in this appendix section: 1) the VAT reform in Section B.1, 2) the CIT reform in Section B.2 and 3) the depreciation rules in Section B.3. Put together, Table F.2 summarizes the impact of VAT and CIT reforms on the user cost of capital (UCC).

B.1 Legislative Background of VAT Reform

The VAT reform was carried out through four stages. Effective on July 1, 2004, stage I started from eight industries in four provinces and cities in Northeast China (Heilongjiang, Jilin, Liaon-

ing, and Dalian city). The eight industries include equipment manufacturing, petrochemical, metallurgical, automotive manufacturing, shipbuilding, agricultural product processing, military manufacturing, and new- and high-tech industries.

On July 1, 2007, the reform was extended to twenty-six cities in another six provinces (Henan, Hubei, Shanxi, Anhui, and Jiangxi) with eight qualified industries including equipment manufacturing, petrochemical, metallurgical, automotive manufacturing, agricultural product processing, electricity, mining and new- and high-tech industries.

One year later, July 1, 2008, as stage III the reform was further extended to five cities and leagues in eastern Inner Mongolia with the same eight industries as those in Northeast China. At the same time, due to the Wenchuan earthquake, the government allowed firms in the "key earthquake devastated areas of Wenchuan" to deduct input VAT on equipment. Except for several regulated industries, all other industries were covered.[53]

Since January 1, 2009, the reform was unexpectedly extended to all industries across the country. Together with the national expansion of VAT reform, the deduction method of input VAT on equipment changed as well. At the early stages of the reform, the government first collected input VAT and then returned to firms. To alleviate tax losses, at the beginning of each year the government usually set a limit on tax return – the increase in VAT payable from that in last year. At the end of the year, if revenue permitted, the full amount of input VAT on fixed assets would be returned. Since 2009, however, the government switched to the tax credit method so that firms deduct input VAT on equipment from total output VAT directly.

B.2 CIT Reform

In 2008 Chinese government implemented a Corporate Income Tax (CIT) reform that unifies the CIT rate for domestic and foreign firms. Particularly, this reform reduced CIT rate for domestic firms from 33% to 25% while it raised CIT rate for foreign firms from lower rates to 25% (e.g. see Chen et al. [2017]). Table F.1 reports distribution statistics of CIT rate for domestic and foreign firms from 2007 to 2011.[54] For domestic firms, the average CIT rate was stable around 25%. Foreign firms experienced increasing CIT rate from 15% to 20%, on average from 2007 to 2008. Before another rise in 2011, CIT rate of foreign firms during 2008 and 2010 was stable at 20%.

In spite of changes in CIT rate, its on the user cost of capital (UCC) is limited, because CIT distorts capita price only through partial depreciation of capital cost. If firms can immediately write off capital cost, CIT does not affect capital price. Table F.2 summarizes the VAT rate,

[53]The regulated industries include coke processing, electrolytic aluminum production, small-scale steel production, and small thermal power generation.

[54]CIT rate is calculated by τ = actual CIT payable/net profit, which is closer to the "effective" CIT rate. Here we report the summary statistics for firms with positive CIT rate.

CIT rate and UCC for domestic and foreign firms from 2007 to 2011. Particularly, we report two UCC's – theoretical one and the sample average. The theoretical UCC is calculated by statutory VAT rate as well as CIT rate ($= (1+\nu_{\text{statutory}})(1-\tau_{\text{statutory}}p_v)/(1-\tau_{\text{statutory}})(r+\delta)$); the sample average UCC is calculated by statutory VAT rate and empirical CIT rate ($= (1+\nu_{\text{statutory}})(1-\tau_{\text{empirical}}p_v)/(1-\tau_{\text{empirical}})(r+\delta)$).[55] We can see that 2008 CIT reform reduced the theoretical UCC for domestic firms by 0.5 percentage point; 2009 VAT reform reduced it by 2.8 percentage point, almost 6 times larger than that of CIT reform. On the other hand, the theoretical UCC for foreign firms barely changed. The empirical UCC – the sample average – mirrors the theoretical one over time, confirming that VAT reform is the major force driving the user cost of capital.

B.3 Depreciation Rule

Before 2008, there were no explicit restrictions on the depreciation method or depreciation periods for domestic firms. On the other hand, foreign firms were required to use the straight-line method of depreciation with the following minimum depreciation periods:

- 20 years for buildings and structures;
- 10 years for aircrafts, railway rolling stock, ships, machinery, mechanical apparatus and other production equipment;
- 5 years for fixtures, tools and furnishings related to production and business operations; transportation means other than aircrafts, railway rolling stock and ships; and electronic equipment.

The 2008 CIT Law changed the minimum depreciation period for two types of fixed assets: 1) transportation means other than aircraft, railway rolling stock and ships; 2) electronic equipment. The depreciation periods were shortened from five years to four and three years, respectively, for the two types of fixed assets. Additionally, the new CIT law excluded several types of fixed assets – such as fixed assets rented in by commercial lease – from depreciation.

C Data

C.1 More Details of China Tax Data

Comparison to ASM

To examine the data quality, we compare our main data set, the administrative tax records from the Chinese State Administration of Tax – Tax data henceforth – to Annual Survey of Manufactures (ASM) which is widely used in research regarding Chinese firms. Since we only

[55] We do not observe the separate VAT paid for equipment so we use statutory VAT rate for both measures.

have ASM data from 1998 to 2007 and the Tax data from 2007 to 2011, our comparison is based on a merged sample in year 2007. In particular, we compare the following three groups of firms: 1) unmatched Tax firms, i.e firms existing only in the Tax data; 2) unmatched ASM firms, i.e. firms existing only in ASM; 3) matched firms, i.e. firms existing in both the Tax data and ASM. For matched firms, we further investigate whether major measures – sales and fixed assets – from the two data sets match well or not. Figure F.1 shows the inverse hyperbolic sine (IHS) measures for sales (Panel A) and fixed assets (Panel B) for the three groups.

There are two patterns worth noting. First, the Tax data covers a wider range of firms compared to ASM. ASM only covers those firms with annual sales over 5 million RMB, which yields a sharp cutoff in the sales distribution. The sales distribution of firms existing only in the Tax data, however, is right to that of other firms, indicating the Tax data covers many smaller firms. Second, the sales measures from the two data sets overlap well for matched firms. The measure of fixed assets show the same data patterns as the one of sales.

Investment Measure

We construct the equipment investment by subtracting the increase in buildings from total increase in fixed assets for production. We do so because the direct measure of equipment investment only exists in 2007 but missing from 2008 to 2011 in the Tax data. To test the validity of this measure, we compare the 2007 indirect measure the 2007 direct measure and find that the indirect measure is equal to the direct measure for 84.68% of observations, which is reassuring. For coherence, we thus use the indirect measure for all the five years.

CIC Industry Code Change

There was a modification in industry classification code in 2011. So the industry code data in 2011 is coded with the 2011 version. Table 2 shows the changes at the 2-digit code level (comparable to 3-digit NAICS level). We convert all industry code to the 2002 version for analysis.

C.2 Pilot Firms Versus Non-Pilot Firms

In our main analysis we only include firms *not* in the pilot program launched earlier since 2004. Here we provide more details in comparing pilot versus non-pilot firms. Table F.4 reports descriptive statistics of covariates across pilot and non-pilot firms. Pilot firms have a larger fraction of domestic, state-owned, and listed firms. Among foreign pilot firms, the fraction that have VAT preferential treatment is around 10 percent higher than that among non-pilot firms. Pilot firms also have larger sales on average. On the other hand, non-pilot firms have larger

fraction of firms with general and export VAT preferential treatment.[56]

Figure F.2 shows the industry distribution across the two groups. The industry distribution for pilot and non-pilot firms are similar while there are more general equipment (35), special equipment (36) and transportation equipment (37) manufacturing firms among pilot firms.

C.3 Foreign Firms with Preferential Treatment

We report results of merging the Tax data with the foreign direct investment data. First, we successfully match 81.83% foreign firms in the Tax data. Around 26.18% of matched foreign firms have preferential treatment on equipment investment before the VAT reform. Table F.5 shows more details of the merging results. Each cell corresponds to the fraction of variable accounted by the following three groups: 1) firms not matched, 2) matched firms with preferential treatment on equipment investment, and 3) matched firms with no preferential treatment. For example, the three groups account for 18.52%, 31.43% and 50.11% of total sales, respectively. The fraction of sales and investment generated by each group of firms are generally consistent with their fraction of number of firms. Foreign firms with preferential treatment have slightly larger fraction of sales and investment. Domestic firms that are matched, both with and without preferential treatment, have a larger fraction of sales of investment relative to their fraction of number of firms, while the discrepancy is small. There is a small fraction of domestic firms, 0.44%, show up in the data set of foreign direct investment and are identified to have preferential treatment in equipment investment. One of the reason is that some of them were once foreign firms. We exclude those domestic firms from our analysis.

D Additional Reduced-Form Results

In this section we present additional reduced-form results for empirical findings.

D.1 Inverse Probability Weighting (IPW)

This appendix section documents details of the inverse probability weighting (IPW) method that we use in robustness checks. One concern of our empirical strategy is that domestic and foreign firms might not have similar observable characteristics. To address this concern, we reweigh our data to match the distribution of firm characteristics between domestic and foreign firms.

In particular, we first generate propensity scores of being treated by estimating a probit

[56] General VAT preferential treatment includes those for selling used equipment, simplified VAT calculating method, agriculture production and so forth.

model. The model takes the following form:

$$G_i = \mathbb{1}\{\alpha_i + X_i\beta + \Delta Y_i\gamma + u_i > 0\}, \tag{33}$$

where G_i is the treatment variable, X_i is a vector of firm-specific variables including whether a firm had VAT preferential treatment (and for export), whether it is an exporter, its sales and number of workers. ΔY_i includes investment growth measured by whether a firm invests or not, investment rate and IHS investment.[57] Error term u_i is independently and identically drawn from normal distribution. We use information in the pre-reform years to conduct the analysis. That is, we use data in 2007 for all firm-specific terms and use data in 2007 and 2008 for investment growth terms. Table F.6 reports the estimates of the probit model.

We use the specification in column (6) to generate propensity scores for reweighting. Figure F.3 plots the distribution of propensity scores for domestic and foreign firms, respectively. Panel (B) of Figure F.4 shows that after reweighting, domestic and foreign firms are balanced in observable characteristics including investment, sales, fixed assets, and the number of workers.

D.2 Estimates in the Event Study

Table F.7 reports the coefficients in Figure 6 from 2007 to 2011. Particularly, we run the following regression:

$$Y_{ijt} = G_i\gamma_t + \mu_i + \varepsilon_{ijt}, \tag{34}$$

where G_i is an indicator that equals one for domestic firms, and μ_i is firm fixed effects. Dependent variable Y_{ijt} is the investment measure for firm i in industry j at time t: Column (1) to (3) reports the results at the extensive margin – i.e. the fraction of firms investing; Column (4) to (6) reports the results at the intensive margin – i.e investment rate. In column (1) and (3) we control for industry-year fixed effects to account for industry-specific trends; in column (2) and (5) we control for province-year fixed effects; in column (3) and (6) we add both industry- and province-year fixed effects. Coefficients γ_t are the parameters of interest.

As an alternative presentation of parallel trend evidence, the coefficients on 2007 are economically small and statistically insignificant at both the extensive and intensive margin. At the extensive margin, column (1) shows that the reform increased the fraction of domestic firms that invest in equipment by 6.9 percentage point in 2009, which equals to 14.1% of the pre-reform average fraction of domestic firms investing. Despite of slight decrease, the effects are stable in the following years. The estimates are robust when we add province-year fixed effects. Similar results hold for the investment rate.

[57] Growth in log investment is not included because of collinearity with the indicator of firm's investing.

Table F.8 conducts the same robustness checks performed in our difference-in-difference analysis, and shows that those event study coefficients are robust across specifications. Particularly, in column (2) and (5) we adjust the regressions by inverse probability weighting (IPW); in column (3) and (6) we use the sample unbalanced at the variable level for the analysis. Despite slight variation in magnitude, we find our baseline estimates robust to those checks.

D.3 Leased Equipment

Here we consider if firms engage in tax avoidance by leasing capital from a foreign company. That is, a domestic company could lease production equipment and deduct leasing payments from VAT, while a foreign company could deduct the purchase price of its equipment from its VAT. In order to test this hypothesis, we conduct the same difference-in-difference analysis but replace the investment measure by including leased equipment. Table F.10 reports the results and finds similar estimates to our baseline estimates. This result suggests that evasion or avoidance is not an important concern.

D.4 User-Cost-of-Capital Investment Elasticities

As a complement to the difference-in-difference analysis, in this appendix section we quantify how changes in the user-cost-of-capital (UCC) driven by the reform affected investment outcomes. In particular, we estimate the following regression

$$Y_{ijt} = \beta \log(\text{UCC}_{ijt}) + \mu_i + \delta_{jt} + X'_{it}\gamma + \varepsilon_{ijt}, \tag{35}$$

where UCC is the user cost of capital from Equation 5. As in Equation 7, we control for firm fixed effects, industry-by-year fixed effects, and we show robustness of our results to controlling for industry-by-year fixed effects and firm-level characteristics.

Two challenges prevent OLS from delivering unbiased estimates of β in Equation 35. First, both investment and the CIT rate, and thus the UCC, might be correlated with unobserved firm characteristics. For instance, if politically connected firms have lower productivity and enjoy a lower corporate tax rate, an OLS estimation of β would bias β toward zero. Second, measurement error in investment and the UCC would also bias the estimate toward zero.

In order to solve these problems, we use a synthetic UCC as an instrument for the actual UCC. In the synthetic UCC, we allow for ν to change with the reform but we hold all other aspects of the UCC constant. This instrument is a powerful predictor of the actual UCC since, as we discuss in Section 2, the VAT reform had a large effect on the cost of capital. In addition, the exclusion restriction that the synthetic tax change identifies changes in the UCC and is not correlated with differential shocks between foreign and domestic firms is consistent with the

difference-in-differences results in the previous section.

Table F.11 reports estimates of semi-elasticities of investment with respect to the UCC. The coefficients on UCC are all negative, indicating investment increases as the UCC declines. While OLS estimates are biased toward zero, we find that IV estimates are much larger in magnitude. Columns (2)-(8) in the first panel shows that cutting the UCC by 10% leads to an increase in the fraction of firms investing by 2.4-3.1 percentage points.[58] Similarly, cutting the UCC by 10% would increase the investment rate by about 2%. Relative to the average investment rate of 10%, the second row of results implies an investment elasticity of -2 with respect to the user cost of capital. Indeed, the third column shows UCC elasticities between -2.4 and -2.1 for the sample of firms with positive investment. Finally, the last row of Table F.11 shows larger estimates for the IHS, which arise from the larger weight the IHS places on extensive-margin responses.

Table F.11 shows that regardless of how we measure outcomes, the estimates of β are very stable across specification that control for different levels of fixed effects or for firm-level controls. In particular, the last column controls for corporate income tax rates, which ensures that our identifying variation only comes from changes driven by the VAT reform. In our structural estimation in Section 5, we use the elasticity estimates for the fraction of firms investing and the investment rate in column (5) in order to validate and estimate the dynamic model of investment.

We now explore whether these elasticities vary across firm characteristics. Table F.12 reports estimates of Equation 35 where we interact the effect of the UCC with observable characteristics including sales, capital intensity, and the debt-to-capital ratio. We first normalize these variables to have mean zero an unit standard deviation so that β can still be interpreted as the average effect in the population.

Columns (1)-(4) of Panel A of Table F.12 report these heterogeneous effects of the UCC on the fraction of firms that investment. We find that increasing the standard deviation of firm size by one standard deviation from the mean increased the estimated semielasticity from -0.28 to -0.20. More capital intensive firms are also less responsive while firm with a higher debt-to-capital ratio are less responsive. Column (4) includes an interaction with an indicator for whether the firm is in a tax position of having a VAT credit. Since firms in this position will not receive a refund for the VAT on equipment it is likely they will respond less to the reform. Indeed, column (5) shows that firms in this tax position do not respond to the reform (their semielasticity is $0.09 = -0.31 + 0.40$) while restricting the semielasticity to firms that can benefit from the reform results in a smaller estimate of $\beta = -0.31$.

Panel B of Table F.12 reports these heterogeneous effects of the UCC on the investment rate. In this case, we do not find that larger firms, measured in sales, are less responsive but we do find that evidence that more capital intensive firms have smaller responses to the reform. As in the case of the extensive margin, we find that firm with a higher debt-to-capital ratio and firms

[58] Since the reform lowered the UCC by an average of 15%, these estimates are in line with those of Table 3.

that are not in a VAT credit position are more responsive to the reform.

E Additional Structural Estimation Results

E.1 Productivity Estimation

Recall that we decompose productivity a_{it} into $a_{it} = b_t + \varepsilon_{it} + \omega_i$, where b_t is aggregate shock, ω_i is firm-specific permanent shock and ε_{it} firm transitory shock. We further assume that b_t and ε_{it} follow AR(1) processes. As a result, we have five productivity parameters to estimate – the persistence and standard deviation of idiosyncratic shocks $(\rho_\varepsilon, \sigma_\varepsilon)$, the persistence and standard deviation of aggregate shocks (ρ_b, σ_b), and the standard deviation of firm-specific permanent shocks σ_ω.

In this appendix section we describe how we estimate productivity. Particularly, our estimation strategy is consistent with the profit function laid out in Appendix A.2.

E.1.1 Revenue Regression

To justify using revenue measures, instead of profit measures, to estimate the parameters governing firm's profit functions and productivity processes, we first use the same settings as Appendix A.2 to derive optimal revenue and profit functions. Recall that we assume firms have DRTS production function, $Y = A^{1-\eta}[(K^\alpha L^{1-\alpha})^{1-\sigma} M^\sigma]^\eta$, and the final good market is perfectly competitive. By solving firm's optimization problem, we show that the optimal revenue (R^*) and profit (Π^*) are as follows.

$$R^* = \left\{ \underbrace{\left[\frac{(1-\alpha)(1-\sigma)}{w}\right]^{\frac{1-\sigma\eta}{1-\eta}} \left[\frac{\sigma}{p^M}\right]^{\frac{\sigma\eta}{1-\eta}} A}_{A^R} \right\}^{1-\frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}} K^{\frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}} = (A^R)^{1-\theta} K^\theta, \tag{36}$$

$$\begin{aligned} \Pi^* &= \{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\} R^* \\ &= \left\{ \underbrace{(1-\tau)^{\frac{1}{1-\theta}} \{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\}^{\frac{1}{1-\theta}} A^R}_{A^\Pi} \right\}^{1-\theta} K^\theta = (A^\Pi)^{1-\theta} K^\theta, \end{aligned} \tag{37}$$

where parameter θ, revenue shocks A^R and profit shocks A^Π are defined by:

$$\theta = \frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}, \tag{38}$$

$$A^R = \left[\frac{(1-\alpha)(1-\sigma)}{w}\right]^{\frac{1-\sigma\eta}{1-\eta}} \left[\frac{\sigma}{p^M}\right]^{\frac{\sigma\eta}{1-\eta}} A, \tag{39}$$

$$A^\Pi = (1-\tau)^{\frac{1}{1-\theta}} \{1-\eta[(1-\alpha)(1-\sigma)+\sigma]\}^{\frac{1}{1-\theta}} A^R \tag{40}$$

By equations (36) and (37), we can see that profit is proportional to revenue. Then, similar to Cooper and Haltiwanger [2006], we can estimate θ by estimating a revenue regression instead of profit regression. Take logarithm of both sides of equation (36), and we have

$$r_{it} = (1-\theta)a^R_{it} + \theta k_{it}, \tag{41}$$

where the variables are in logarithms. Since we observe sales r_{it} and capital stocks k_{it}, we can thus back out log revenue shocks a^R_{it} by $a^R_{it} = \frac{1}{1-\theta}(r_{it} - \theta k_{it})$. Once having revenue shocks in hand, we can convert to profit shocks by equation (40); that is,

$$a^\Pi = \frac{1}{1-\theta}\log(1-(1-\eta)[(1-\alpha)(1-\sigma)+\sigma]) + a^R. \tag{42}$$

In addition, note that both profit and revenue shocks are proportional to productivity A so the log shocks differ by a constant. Thus, the evolution properties including persistence and variance are the same for the A, A^R, and A^Π.

E.1.2 System GMM

Here we document details in estimating the curvature parameter of profit function (θ) and the persistence of idiosyncratic shocks (ρ_ε), using the system GMM estimator proposed by Blundell and Bond [2000]. Recall that we decompose the log profit shocks as $a^\Pi_{it} = b_t + \omega_i + \varepsilon_{it}$. By equation (42), log revenue shocks and log profit shocks differ by a constant. Thus, without loss of generality, we write $a^R_{it} = b_t + \omega_i + \varepsilon_{it}$, where b_t, ω_i, ε_{it} are aggregate shock, firm permanent component and firm transitory shock, respectively.

Additionally, denote m_{it} as classical measure error or any other unexpected optimization errors. Then, combined with equation (41), we have

$$r_{it} = \theta k_{it} + (1-\theta)b_t + (1-\theta)\omega_i + (1-\theta)\varepsilon_{it} + m_{it}$$

We further assume firm transitory shock ε_{it} follows an AR(1) process i.e. $\varepsilon_{it} = \rho_\varepsilon \varepsilon_{i,t-1} + e_{it}$, where e_{it} is an innovation term independently and identically distributed across firms and over

time. We explot the AR(1) property of ε_{it} to difference out the persistent component in ε_{it}. Then, we can get the following revenue equation

$$r_{it} = \rho_\varepsilon r_{i,t-1} + \theta k_{it} - \rho_\varepsilon \theta k_{i,t-1} + b_t^* + \omega_i^* + m_{i,t} - \rho_\varepsilon m_{i,t-1} + (1-\theta)e_{it}, \tag{43}$$

where $b_t^* = (1-\theta)b_t - \rho_\varepsilon(1-\theta)b_{t-1}$ is year fixed effect and $\omega_i^* = (1-\theta)(1-\rho_\varepsilon)\omega_i$ is the firm fixed effect. In estimating θ and ρ_ε, we further compliment equation (43) with its first-differenced (FD) equation

$$\Delta r_{it} = \rho_\varepsilon \Delta r_{i,t-1} + \theta \Delta k_{it} - \rho_\varepsilon \theta \Delta k_{i,t-1} + \Delta b_t^* + \Delta m_{i,t} - \rho_\varepsilon \Delta m_{i,t-1} + (1-\theta)\Delta e_{it}. \tag{44}$$

Based on both the level equation (43) and FD equation (44), we construct a GMM estimator using two sets of moments. The first set is $\mathbb{E}[z_{i,t-s}^D(\Delta m_{i,t} - \rho_\varepsilon \Delta m_{i,t-1} + (1-\theta)\Delta e_{it})] = 0$, where $z_{i,t-s}^D = [r_{i,t-s}, k_{i,t-s}]$, $s \geq 3$. The idea is to use lagged revenue and capital in levels (r and k) to instrument for the FD equation. The second set of moments is $\mathbb{E}[z_{i,t-s}^L((1-\theta)(1-\rho_\varepsilon)\omega_i + m_{i,t} - \rho_\varepsilon m_{i,t-1} + (1-\theta)e_{it})] = 0$, where $z_{i,t-s}^L = [\Delta r_{i,t-s}, \Delta k_{i,t-s}]$, $s \geq 2$. Here, we use the first-difference of lagged revenue and capital (Δr and Δk), to instrument for the level equation.[59] Put together with our data, we have the moment condition

$$\mathbb{E}[Z_i' U_i] = 0, \quad \forall i,$$

where

$$Z_i = \begin{bmatrix} Z_i^D & \mathbf{0} \\ \mathbf{0} & Z_i^L \end{bmatrix} = \begin{bmatrix} r_{i,07} & k_{i,07} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & r_{i,07} \;\; k_{i,07} \;\; r_{i,08} \;\; k_{i,08} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \Delta r_{i,08} \;\; \Delta k_{i,08} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \Delta r_{i,08} \;\; \Delta k_{i,08} \;\; \Delta r_{i,09} \;\; \Delta k_{i,09} \end{bmatrix}$$

$$U_i = \begin{bmatrix} U_i^D \\ U_i^L \end{bmatrix} = \begin{bmatrix} \Delta m_{i,10} - \rho_\varepsilon \Delta m_{i,09} + (1-\theta)\Delta e_{i,10} \\ \Delta m_{i,11} - \rho_\varepsilon \Delta m_{i,10} + (1-\theta)\Delta e_{i,11} \\ (1-\theta)(1-\rho_\varepsilon)\omega_i + m_{i,10} - \rho_\varepsilon m_{i,09} + (1-\theta)e_{i,10} \\ (1-\theta)(1-\rho_\varepsilon)\omega_i + m_{i,11} - \rho_\varepsilon m_{i,10} + (1-\theta)e_{i,11} \end{bmatrix}$$

We then estimate θ and ρ_ε using GMM estimator.

[59] The identification of the *first-differenced* equation relies on the sequential exogeneity, as well as classical measurement error assumption; the identification of the *level* equation is that the changes in revenue and capital are uncorrelated to firm-specific permanent component and the measurement error.

E.1.3 Markup

In a simple monopolistic competitive model with constant markup – the assumptions we use to derive the profit function – we can map our estimate of θ into the markup. Recall that we can write the curvature of profit function (θ) as a function of other primitive parameters

$$\theta = \frac{\alpha(1-\sigma)\eta}{1-\eta[(1-\alpha)(1-\sigma)+\sigma]}, \tag{45}$$

where α is the share of capital out of value added, σ is the share of materials, and η is the degree of decreasing-return-to-scale (DRTS). The gross markup equals to $1/(1-\eta)$ regardless of how many inputs are in the production function. To be consistent with the empirical markup calculated from data, we instead consider the markup excluding capital cost which equals $1/\{(1-\eta)[(1-\alpha)(1-\sigma)+\sigma]\}$. Substitute η by θ using equation (45), and we can get

$$\text{markup}_{theoretical} = \frac{1}{\theta}\frac{\alpha(1-\sigma)}{(1-\alpha)(1-\sigma)+\sigma} + 1.$$

Given an estimate of θ, if we take a stand on the values of α and σ, we can calculate the markup. We set $\alpha = 1/2$ according to Bai et al. [2006], and $\sigma = 0.7$ to be in line with the number documented in Jones [2011]. In this case, the theoretical markup is 1.224.

In data, we calculate the markup by

$$\text{markup}_{empirical} = \frac{\text{total sales}}{\text{major business costs}}.$$

The average empirical markup is around 1.223.[60] It is reassuring that the theoretical markup calculated from our estimate of θ is comparable to the empirical markup from data.

E.2 Productivity Decomposition

In appendix section E.1.2, we described the estimation of profit function curvature θ and the persistence of firm idiosyncratic shocks ρ_ε. In this appendix section, we document details of productivity decomposition to obtain the standard deviation of firm idiosyncratic and permanent shocks $(\sigma_\varepsilon, \sigma_\omega)$, and the persistence and standard deviation of aggregate shocks (ρ_b, σ_b). We proceed in two steps. First, we construct revenue shocks using the estimate $\hat{\theta}$

$$\hat{a}^R_{it} = r_{it} - \hat{\theta} k_{it}.$$

[60] It is noteworthy that major business costs include cost of intermediate goods such as raw material, wage bills and depreciation of fixed assets (but not the capital cost). Thus, the empirical markup should be lower than the theoretical one excluding capital cost but higher than the one including capital cost.

Here we use "purified" revenue – projecting revenue on higher-order polynomials of capital and labor – to get rid of disturbances such as measurement errors. In the following analysis, we decompose those revenue shocks as we show in Appendix E.1.1 that the persistence and variance are the same for revenue shocks (a_{it}^R), profit shocks (a_{it}^Π), and productivity (a_{it}). So we refer to $\hat{a}_{it}$ as a shorthand for revenue shocks henceforth.

Having productivity $\hat{a}_{it}$ in hand, we again exploit the AR(1) property of ε_{it} to estimate (σ_ε, ρ_b, σ_b, σ_ω). In particular, we use $\hat{\rho}_\varepsilon$ estimated by the system GMM to difference out the permanent component in ε_{it}

$$\hat{a}_{it} - \hat{\rho}_\varepsilon a_{it-1} = b_t - \hat{\rho}_\varepsilon b_{t-1} + (1 - \hat{\rho}_\varepsilon)\omega_i + e_{it}, \tag{46}$$

where e_{it} is an innovation term of ε_{it} independently and identically distributed across firms and over time. Specifically, we run a regression of $\hat{a}_{it} - \hat{\rho}_\varepsilon \hat{a}_{it-1}$ on time dummies and firm fixed effect. Note that we can calculate the variance of ω_i and ε_{it} from the variance and covariance of residuals from the regression, i.e. $var(u_{it})$ and $cov(u_{it}, u_{it-1})$ where $u_{it} = (1 - \hat{\rho}_\varepsilon)\omega_i + e_{it}$, by the following equalities

$$\sigma_\omega^2 = \frac{cov(u_{it}, u_{it-1})}{(1 - \hat{\rho}_\varepsilon)^2} \quad \text{and} \quad \sigma_\varepsilon^2 = \frac{var(u_{it}) - cov(u_{it}, u_{it-1})}{(1 - \hat{\rho}_\varepsilon{}^2)}.$$

Standard deviations of firm idiosyncratic and permanent shocks are estimated to be 0.529 and 0.854, respectively.[61]

Lastly, we estimate (ρ_b, σ_b) using the coefficients on time dummies from the regression. Denote the coefficients by β_t. Then ρ_b and σ_b jointly solve the following equations

$$\begin{aligned} var(\beta_t) &= (-2\hat{\rho}_\varepsilon \rho_b + 1 + \hat{\rho}_\varepsilon{}^2)\sigma_b^2 \\ cov(\beta_t) &= [-\hat{\rho}_\varepsilon \rho_b^2 + (1 + \hat{\rho}_\varepsilon{}^2)\rho_b - \hat{\rho}_\varepsilon]\sigma_b^2 \end{aligned}$$

The persistence of the aggregate shock (ρ_b) is estimated to be 0.009 and its standard deviation (σ_b) is estimated to be 0.010.

E.3 Adjustment Cost Estimation

In this appendix section, we report additional results for estimation using method of simulated moments (MSM). We estimate three parameters using MSM – economic depreciation rate δ, and two adjustment costs, i.e. convex adjustment cost γ and the upper bound of fixed cost $\bar{\xi}$. The estimates $\hat{\phi} = \{\hat{\delta}, \hat{\gamma}, \hat{\bar{\xi}}\}$ minimizes the following criterion function

$$\hat{g}(\phi) = [\hat{m} - m(\phi)]' \hat{W} [\hat{m} - m(\phi)],$$

[61] The standard deviation estimates are adjusted by a factor of $1 - \hat{\theta}$.

where the moments $m(\phi)$ include six pre-reform static moments, as well as two investment responses from reduced-form analysis (see Section 5.2). The weighting matrix is identity matrix. Because of the large sample size, all moments have small standard errors, leading to precise parameter estimates. Table 7 shows the standard errors of the eight moments we use for MSM estimation. Here we report the full variance-covariance matrix, which is calculated using 100 bootstrap samples.

$$VC = 10^{-6} \times \begin{pmatrix} 1.29 & -2.33 & -2.13 & -1.77 & 2.50 & 1.56 & 1.25 & -1.24 \\ -2.33 & 7.26 & 4.32 & 2.92 & -4.58 & -1.69 & -1.44 & 1.30 \\ -2.13 & 4.32 & 4.68 & 3.30 & -2.90 & -2.14 & -2.19 & 1.56 \\ -1.77 & 2.92 & 3.30 & 3.39 & -1.03 & -2.02 & -2.57 & 1.39 \\ 2.50 & -4.58 & -2.90 & -1.03 & 169.13 & 4.21 & 0.46 & 0.33 \\ 1.56 & -1.69 & -2.14 & -2.02 & 4.21 & 2.57 & 1.71 & -1.95 \\ 1.25 & -1.44 & -2.19 & -2.57 & 0.46 & 1.71 & 105.93 & 14.59 \\ -1.24 & 1.30 & 1.56 & 1.39 & 0.33 & -1.95 & 14.59 & 17.21 \end{pmatrix}$$

We use grid-search to find the parameter values that minimize the criterion function $\hat{g}(\phi)$. Using the grid-search results as initial values, we further refine our estimates by pattern-search. To confirm our estimates minimizes the criterion function, we plot the loss function against each parameter in Figure F.5, holding the other two parameters at their estimated values. For example, Panel (A) plots log loss function $\log(g)$ against convex adjustment cost γ, with $\bar{\xi}$ held at its estimate $\hat{\bar{\xi}} = 0.119$ and δ held at $\hat{\delta} = 0.071$. The loss function is concave and rises steeply around our estimated value, confirming that our estimates minimize the criterion function.

Sensitivity Analysis

Lastly, we conduct sensitivity analysis using the measure proposed by Andrews et al. [2017]. Particularly, the sensitivity measure is as follows.

$$\Lambda = -(G'WG)^{-1}G'W \times g(m),$$

where G is the Jacobian matrix, W is the weighting matrix (identity matrix here), and $g(m)$ is a vector of moments with misspecification. Here, we consider the misspecification to be a 10% deviation from the true value. Table F.15 reports the complete sensitivity matrix.

We find the cross-sectional distribution of investment rate important in determining the adjustment frictions, especially share<0.1 (the fraction of firms with investment rate smaller than 0.1) and share<0.3 (the fraction of firms with investment rate smaller than 0.3). Here, share<0.1 captures the "inaction rate", i.e. the fraction of firms not investing or disinvesting. A

higher convex cost reduces the inaction rate in that firms would smooth out investment to avoid paying convex costs. On the contrary, a higher fixed cost makes firms invest less frequently to avoid paying fixed cost each time, thus leading to a larger the inaction rate. As showed in the second row, a 10% deviation of the fraction of firms whose investment rate are smaller than 0.1 would lead to 0.57 percentage points decrease in the convex adjustment cost γ which is around 40% of our estimate. Similarly, the same deviation would increase the estimate of the upper bound of fixed cost $\bar{\xi}$ by 0.02 percentage point which is around 18% of our estimate.

Share<0.3 captures the right-tail of investment distribution, which is opposite to share<0.1. A higher convex cost (lower fixed cost) reduces the fraction of lumpy investment, and thus increases the fraction of firms with investment rate smaller than 0.3. The fourth row of Table F.15 confirms this intuition.

Another moment worth discussing is the serial correlation of investment rate. Note that the fixed cost is paid as a fraction of optimal capital stock, the level of which is jointly determined by the convex cost γ. Thus, rising convex cost has two effects on serial correlation.[62] On one hand, a higher convex cost increases the serial correlation in that firms would like to smooth out investment over time. On the other hand, a higher convex cost suppresses the capital level, thus leading to a larger *actual* fixed cost which is negatively associated with serial correlation. Figure F.6 plots the serial correlation against convex cost γ, holding fixed cost $\bar{\xi}$ at the estimated value equal to 0.119. The serial correlation increases as γ increases at the beginning, where the first effect dominates; it then started decreasing as γ grows larger, where the second effect dominates. The row of serial correlation in Table F.15 shows that, around our moment value the second effect dominates: As serial correlation changes, the convex cost decreases. The magnitude, however, is modest: A 10% deviation of serial correlation leads to a 4% reduction of γ.

The adjustment costs are not very sensitive to the reduced-form investment responses. For example, a 10% deviation of diff-in-diff estimate at the intensive margin would reduces γ by less than 1% of our estimated value.

F Additional Simulation Results

This appendix section presents additional simulation results. First, we show that our baseline simulation results are robust to the following extensions: 1) allow for upward-sloping capital supply; 2) allow the net-of-tax resale price to be less than one; 3) aggregate productivity shocks; and 4) extend constant interest rate to weighted average cost of capital (WACC) which is affected by CIT cut.

[62] While the two effects exist for all moments, we find the serial correlation particularly affected.

F.1 UCC Elasticities are Not Sufficient Statistics

To show that UCC is not a sufficient statistics, Table F.14 displays the investment responses at the intensive margin (i.e. average investment rate) and the extensive margin (i.e. the fraction of firms investing), subject to various frictions, to different reforms resulting in the same UCC reduction. We set the convex adjustment cost to 0.1 and the upper bound of fixed cost to 0.01 for illustration. While the simulation results are specific to the particular frictions values but the key intuition persists: When investment is subject to various frictions, UCC is not sufficient to evaluate tax reforms.

Panel A reports the results with initial CIT rate at 15.4% and VAT rate at 17%. Two tax cuts reduce UCC by the same amount: a VAT cut from 17% to 14.2%, i.e. 2.8% drop in VAT rate, and a CIT cut from 15.4% to 5.4%, i.e. 10% drop in CIT rate. Investment is subject to partial irreversibility due to VAT.

- Absent other frictions, VAT cut effectively shrinks the inaction region and increases the average (non-negative) investment rate by 14.1 percentage that is almost twice as large as CIT cut. A major part of this response is driven by the extensive margin response: VAT cut increases the fraction of firms making positive investment increases by 8.8% compared to 4.3% for CIT cut.

- With fixed cost, the extensive margin responses flipped in this parameterization case. This is because the purchase price of capital decreases in VAT cut while it increases in CIT cut, leading to a smaller increase (if not decrease) in the slope of equation (3). While VAT shrinks the inaction region induced by partial irreversibility more effectively, in this case CIT cut is more effective in the presence of fixed cost.

- With convex adjustment cost, the optimal capital level and investment rate decreases. CIT cut is more effective to enhance the investment rate, mostly driven by the intensive margin: The average positive investment rate increases by 8.5%, compared to 6% in VAT cut.

- Put all frictions together, VAT and CIT cuts with 2.4% UCC reduction leads to similar investment rate increase at 11% with VAT cut more effective at the extensive margin.

Furthermore, how effective are tax tools also depends on existing frictions. Panel B display the results with initial CIT rate at 15.4% and VAT rate at 5% – i.e. less partial irreversibility distortion. In this case, two tax cuts reduce UCC by the same amount: a VAT cut from 5% to 2.5%, i.e. 2.5% drop in VAT rate, and a CIT cut from 15.4% to 5.4%, i.e. 10% drop in CIT rate. Reducing VAT to 2.5% almost eliminate the partial irreversibility, leading to larger responses in investment rate and thus the elasticity of investment with respect to UCC.

F.2 Robustness of Policy Simulations

We first show that our baseline simulation results are robust to the following extensions.

Upward-sloping Capital Supply

We explore the general equilibrium effect of increasing capital price by allowing the capital supply curve to be upward-sloping. Recall that in our baseline model, we assume that capital price – net of taxes – is constant. One concern is that capital price is endogenous and thus increases as the demand goes up. We relax the assumption of constant capital price by incorporating an upward-sloping capital supply. Particularly, we assume a functional form of capital supply, thus backing out the price change from the quantity change, i.e. investment response. The capital supply has constant elasticity:

$$p^K = I^{1/\varepsilon^s}, \tag{47}$$

where ε^s is the elasticity of capital supply with respect to pre-tax capital price. We set ε^s to be 10, for two reasons: first, in data we do not observe any substantial price increases for equipment investment, compared to price of total investment or price of investment in buildings and structures; second, the parameter lies within the range of estimates in the literature, e.g. House and Shapiro [2008][63] Using our difference-in-difference estimate for investment rate – 36% increase, we can get that the capital price increases by 3.6%.

We feed in a 3.6% increase in capital price to the model – both the purchase and resale price of capital – when the reform happens. In particular, VAT reform reduces the purchase price of capital from $(1-\tau p_v)(1+17\%)$ to $(1+3.6\%)\times(1-\tau p_v)$, and increases the resale price of capital from $1-\tau p_v(1+17\%)$ to $(1+3.6\%)\times(1-\tau p_v)$. Column (2) of Table F.16 reports the simulation results: It shows that, even with the general equilibrium effect, the reform stimulates a substantial investment. This is because while the drop in capital price is smaller, the reform removes the price gap between purchase and resale price as in the baseline case.

Resale Price

In our baseline model, we assume that the net-of-tax resale price is unity, which is the same as the net-of-tax purchase price of capital, to focus on the policy treatment. One concern is that the capital market for used capital is imperfect, so the resale price is smaller than the purchase price even without taxes. To explore this possibility, we reduce the resale price from one (as in the baseline model) to 0.95. As showed in column (3) of table F.16, the results do not change. Both

[63] House and Shapiro [2008] estimates the elasticity of supply to be between 6 and 14 using Bonus Depreciation in the US.

the pre-reform static moments and simulated investment responses i.e., average investment rate and the fraction of firms investing to various tax reforms are almost identical to our baseline results. This is because, even without the imperfect resale price of capital, VAT and fixed cost have induced large partial irreversibility. Lowering resale price thus has little impact on the overall investment patterns. One exception is the fraction of firms disinvesting: the percentage change is larger when the resale price is 0.95. However, the overall negative investment is less than 1 percent, so it does not affect our main simulation results.

Aggregate Productivity Shocks

VAT reform took place in 2009 as one of the measures to deal with the financial crisis, which might be reflected in an aggregate productivity drop. To explore the role of aggregate productivity in our model and simulation results, we feed in a one standard-deviation drop of aggregate productivity (permenant) at the same time of the tax reform. Column (4) of table F.16 reports the corresponding results. Most of the simulation results remain – slightly larger, if anyone, since the counterfactual investment is even smaller. The main reason is that the standard deviation of estimated aggregate shock is small – 0.0376; the autocorrelation of shocks is low – 0.009. As a result, aggregate shocks have little impact in our model.

Weighted Average Cost of Capital

Here, we extend the constant interest rate r to weighted average cost of capital (WACC). WACC considers two ways through which a firm raises capital – equity and debt. The cost of interest payments for debt financing, not for equity financing, is deductible from the tax base of corporate income tax (CIT). Therefore, changing CIT rate affects the cost of debt financing, and thus how firms discount future profit. In particular, WACC is defined as follows.

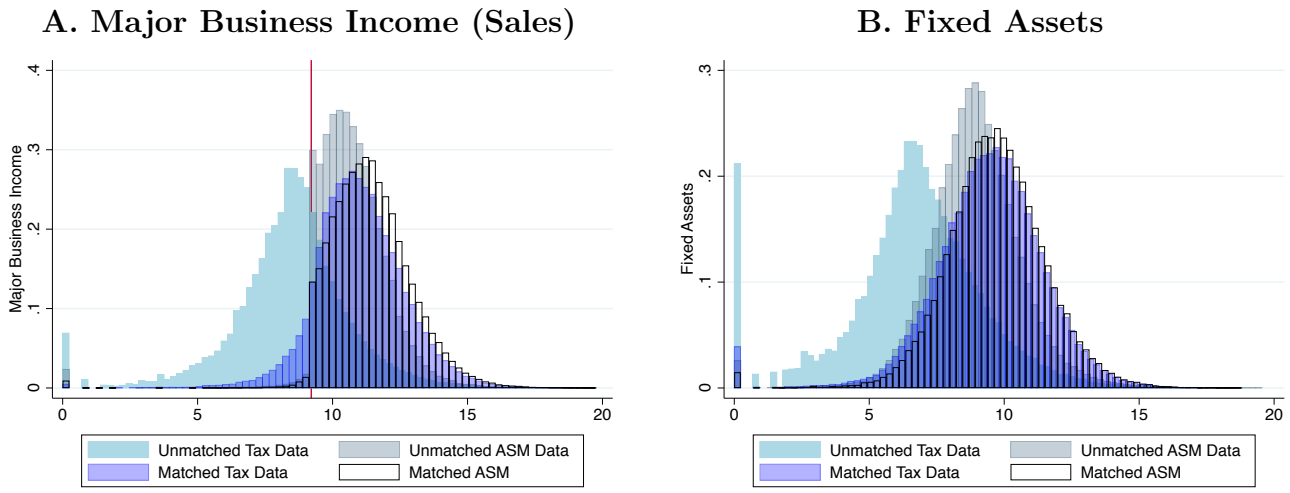
$$\text{WACC} = \text{Share}_{\text{debt}}(1-\tau)r + (1-\text{Share}_{\text{debt}})r_k,$$

where $\text{Share}_{\text{debt}}$ is the share of capital financed through debt and, accordingly, $(1-\text{Share}_{\text{debt}})$ is the share of capital financed through equity. r is the real interest rate and r_k is the capital return. In the simulation, we calibrate the share of debt financing to be 0.65 to match the average debt to capital ratio. To focus on how the policy – CIT rate here – we keep r and r_k constant and match baseline discount rate at 95%.

Table F.17 reports the simulation results of CIT cut with varying discount rate β through weighted average cost of capital (WACC), where $\beta = \frac{1}{1+\text{WACC}}$. In this case, CIT rate affects the cost of capital through two channels. First, the same as the baseline simulation with constant WACC, it reduces the after-tax price of capital $\frac{(1+\nu)(1-\tau p_v)}{1-\tau}$. Additionally, it increases the expected return on capital, $\frac{1}{\beta} - (1-\delta)$, by reducing the discount rate β. Column (3) reports the results

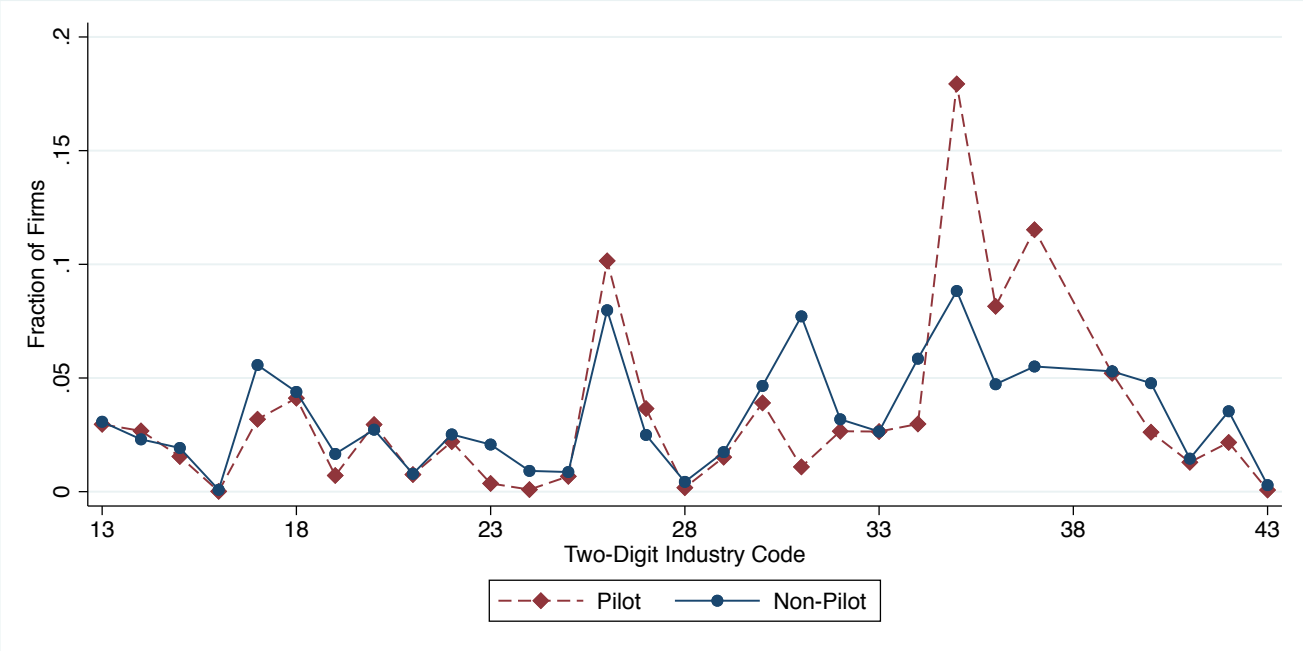
when CIT cut changes WACC and thus discount rate. Due to the second channel – increasing expected return of capital – which offsets the decreasing capital price, the response of investment rate is smaller. The tax revenue loss – mainly resulting from CIT loss – is larger, however, since the revenue increase is smaller with the same reduced tax rate. Similarly, the increase in firm value is smaller as well. As a result, the ratio of investment (firm value) to the tax revenue, i.e. elasticity of investment rate (firm value) with respect to tax revenue, is lower.

Figure F.1: **Comparison Of Matched And Unmatched Firms In Tax Data And ASM**



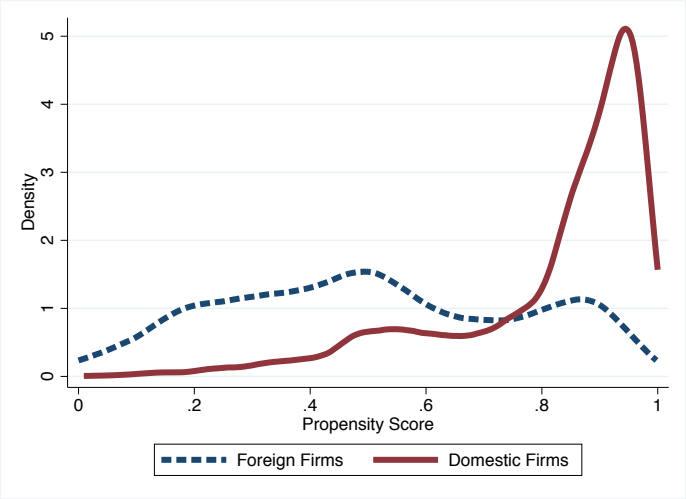
Notes: This figure compares major variable measures from the Tax Data to Annual Survey of Manufactures (ASM) using 2007 data sets. We compare the measured of three groups of firms: 1) unmatched Tax firms, i.e. firms existing only in the Tax data, 2) unmatched ASM firms, i.e. firms existing only in ASM, and 3) matched firms. Panel A shows the distribution of sales (in the inverse hyperbolic sine (IHS) transformation). The light blue area indicates the sales distribution of unmatched Tax firms. The grey area indicates the sales distribution of unmatched ASM firms. The dark blue color indicates the sales distribution of matched firms using the measure from Tax data; the transparent area with black borders indicates the distribution of matched firms using the measure from ASM. Similarly, Panel B shows the distribution of IHS measures of fixed assets.

Figure F.2: **Industry Distribution of Pilot versus Non-pilot Firms**



Notes: This figure shows the industry distribution for firms included in pilot program versus the rest of firms. On the x-axis is the 2-digit CIC code (comparable to 3-digit NAICS code); On the y-axis is the fraction of firms in the corresponding industry. Pilot firms had been allowed to deduct input VAT on equipment purchases since 2004. We use non-pilot firms for the main analysis, and use pilot firms for placebo tests.

Figure F.3: Distribution of Propensity Score



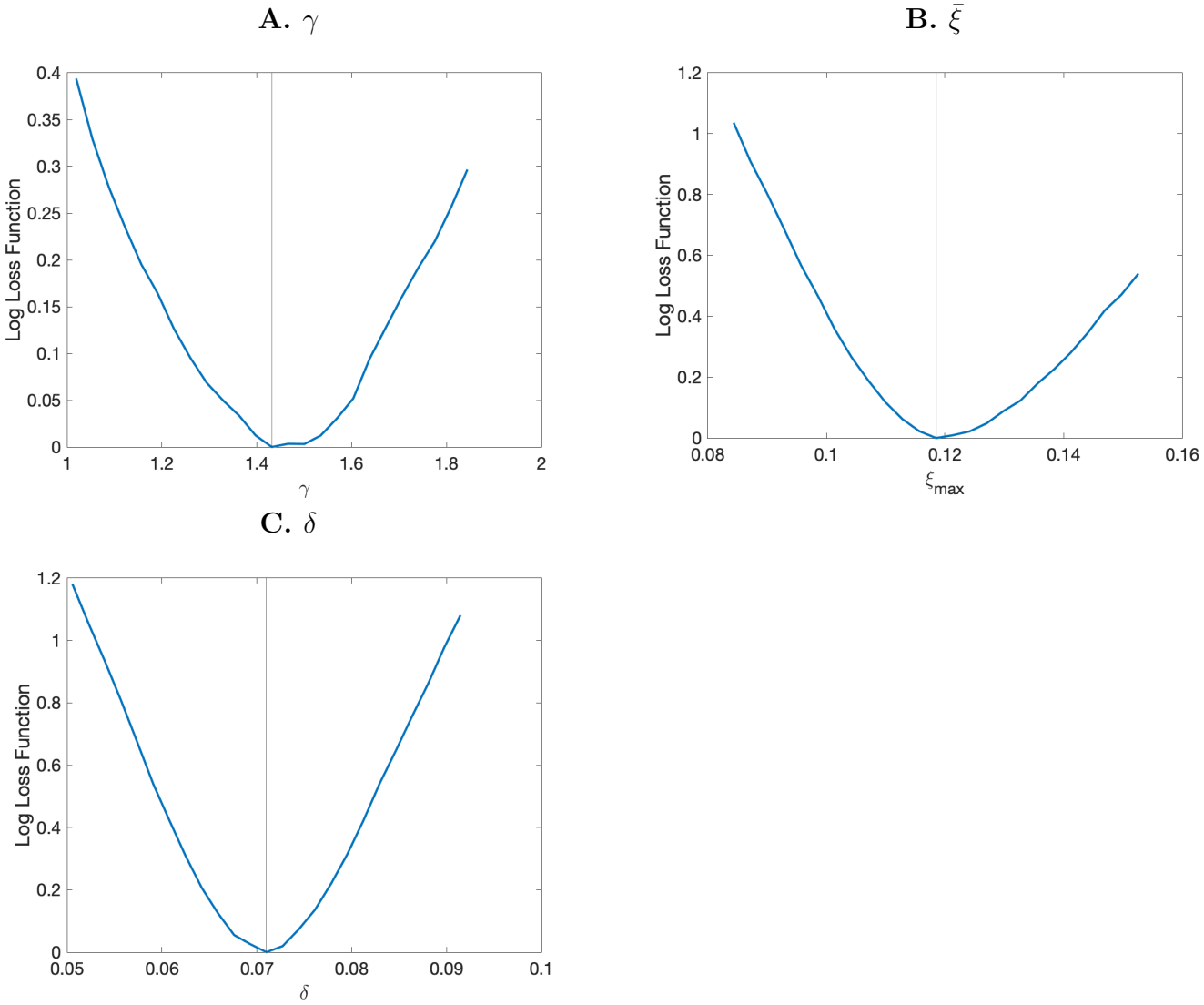
Notes: This figure plots the distributions of estimated propensity scores for domestic firms (solid line) and foreign firms (dash line), respectively. The propensity score is estimated using probit model (see equation (33)). The estimation results are reported in column (6) in Table F.6. The dependent variable is an indicator = 1 if a firm is in the treatment group, i.e. domestic firms. The regressors include: whether a firm had VAT preferential treatment, whether a firm had export VAT preferential treatment, whether it is an exporter, sales, logarithm of the number of workers, growth in the fraction of firms investing, growth in the investment rate, growth in the log investment, and growth in the IHS measure of investment. The regression is performed using pre-reform data form 2007 and 2008. All regressions include region and industry fixed effects, and firm fixed effects.

Figure F.4: **Mean Difference between Treatment and Control Groups**



Notes: This graph shows the difference in major variables between the treatment group (i.e. domestic firms) and control group (i.e. foreign firms). The left panel shows the differences before weighting; The right panel shows the differences using inverse probability weighting (IPW). The propensity score is estimated using probit model (see equation (33)). The estimation results are reported in column (6) in Table F.6.

Figure F.5: **Loss Function from Structural Estimation**

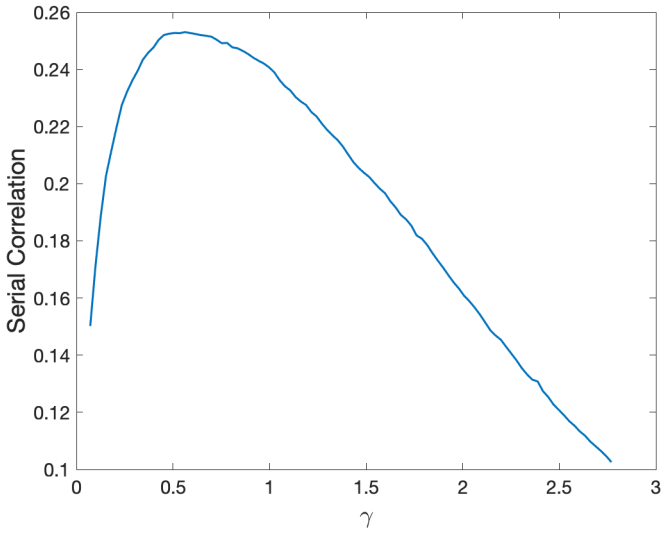


Notes: This graph displays the loss function against each parameter, holding the other two parameters at optimal values. The loss function is calculated by:

$$\hat{g}(\phi) = [\hat{m} - m(\phi)]' \hat{W} [\hat{m} - m(\phi)],$$

where the moments $m(\phi)$ include six pre-reform static moments, as well as two investment responses from reduced-form analysis (see Section 5.2). We use identity matrix and weighting matrix. Panel A plots log loss function against values of γ, holding $\bar{\xi}$ and δ at their optimal values. The vertical line indicates the estimated $\gamma = 1.432$. Panel B and C plot the log loss function against $\bar{\xi}$ and δ, respectively.

Figure F.6: **Correlation between Serial Correlation and Convex Adjustment Cost γ**



Notes: This graph plots simulated serial correlation against convex cost γ, holding the other two parameters at their estimated values, i.e. fixed cost $\bar{\xi} = 0.119$ and depreciation rate $\delta = 0.710$

Table F.1: **Summary Statistics of CIT Rate by Year and Ownership**

Year	Domestic Firms						Foreign Firms					
	N	Mean	SD	p25	p50	p75	N	Mean	SD	p25	p50	p75
2007	19,115	0.25	0.12	0.15	0.30	0.33	8,743	0.15	0.10	0.09	0.14	0.23
2008	27,285	0.26	0.15	0.19	0.25	0.28	10,232	0.20	0.13	0.13	0.18	0.26
2009	28,595	0.25	0.13	0.18	0.25	0.27	11,250	0.20	0.13	0.13	0.20	0.26
2010	29,837	0.24	0.11	0.18	0.25	0.27	13,123	0.20	0.10	0.13	0.22	0.26
2011	28,359	0.26	0.13	0.18	0.25	0.28	12,548	0.23	0.12	0.15	0.25	0.27
Total	133,191	0.25	0.13	0.17	0.25	0.30	55,896	0.20	0.12	0.13	0.20	0.26

Notes: This table displays summary statistics of corporate income tax (CIT) rate of domestic and foreign firms, respectively. The statistics are calculated using full balanced panel, i.e. firms existing for five years in the sample. CIT rate is calculated by τ = actual CIT payable/net profit, which is closer to the "effective" CIT rate. Here we report the summary statistics for firms with positive CIT rate.

Table F.2: **Changes in Tax Rate, Theoretical and Effective User Cost of Capital**

Year	CIT(%)	VAT (%)	User Cost of Capital		
			Theoretical	Sample Avg.	#Obs
	(1)	(2)	(3)	(4)	(5)
A. Domestic Firms					
2007	33	17	0.192	0.183	30,789
2008	25	17	0.187	0.184	44,893
2009	25	0	0.159	0.156	53,580
2010	25	0	0.159	0.156	56,579
2011	25	0	0.159	0.156	56,955
B. Foreign Firms					
2007	20	0	0.157	0.153	15,984
2008	25	0	0.159	0.156	16,842
2009	25	0	0.159	0.155	20,394
2010	25	0	0.159	0.155	20,596
2011	25	0	0.159	0.156	20,555

Notes: This table displays summary statistics of user cost of capital (UCC) of domestic and foreign firms, respectively. UCC is calculated by UCC $= (1+\nu)(1-\tau p_v)/(1-\tau)(r+\delta)$, where ν is VAT rate, τ is CIT rate, $p_v = 0.803$ is discounted present value of capital depreciation schedule, $r = 5\%$ is interest rate, and $\delta = 0.1$ is economic depreciation rate. Column (1) and (2) report the statutory rates of CIT and VAT for domestic and foreign firms, respectively. Theoretical UCC is calculated using statutory VAT and CIT rates. Sample average refers to the average UCC in data, which is calculated using statutory VAT rate but empirical CIT rate. The sample average statistics are calculated using full balanced panel, i.e. firms existing for five years in the sample. Empirical CIT rate is calculated by τ = actual CIT payable/net profit, which is closer to the "effective" CIT rate.

Table F.3: **Change in China Industry Classification Code at Two-Digit Level**

2002	Industry	2011	Change
13	Food processing	13	
14	Food manufacturing	14	
15	Drink manufacturing	15	
16	Tobacco manufacturing	16	
17	Textile	17	
18	Textile clothes, shoes and hats manufacturing	18	
19	Leather, fur, feather and their product manufacturing	19	
20	Timber processing	20	
21	Furniture manufacturing	21	
22	Papermaking and paper product manufacturing	22	
23	Printing and recording media	23	
24	Educational and sporting goods manufacturing	24	
25	Oil processing, coking and nuclear fuel processing	25	
26	Chemical materials and chemicals manufacturing	26	
27	Pharmaceutical manufacturing	27	
28	Chemical fiber manufacturing	28	
29	rubber products manufacturing	29	Rubber and plastic products manufacturing
30	plastic products manufacturing		
31	Non-metallic mineral products manufacturing	30	
32	Ferrous metal smelting and calendering	31	
33	Non-ferrous metal smelting and calendering	32	
34	Metal products manufacturing	33	
35	General equipment manufacturing	34	
36	Special equipment manufacturing	35	
		36	Automotive Manufacturing
37	Transportation equipment manufacturing	37	
39	Electrical machinery and equipment manufacturing	38	
40	communication device, computer and other electronic equipment	39	
41	Instrumentation and stationary manufacturing	40	
42	Crafts and others	41	
43	Recovery processing of waste resources and materials	42	
		43	Metal products, machinery and equipment repair

Notes: This table displays the concordance of 2002 China industry classification (CIC) code to the 2011 version. The concordance is at the 2-digit CIC level whch is comparable to 3-digit NAICS level.

Table F.4: **Descriptive Statistics of Pilot versus Non-pilot Firms**

	Pilot		Non-pilot	
	Mean	SD	Mean	SD
% Domestic Firms	0.832	0.374	0.750	0.433
% State-owned Firms	0.016	0.126	0.008	0.092
% Listed Firms	0.009	0.096	0.006	0.079
% Firms with General VAT Preferential Treatment	0.188	0.391	0.209	0.406
% Firms with Export VAT Preferential Treatment	0.212	0.409	0.317	0.465
Sales	143.2	442.3	151.7	418.6
N		43,700		383,415

Notes: This table displays summary statistics of firms in the pilot program versus the rest of firms. Pilot firms had been allowed to deduct input VAT on equipment purchases since 2004. We use non-pilot firms for the main analysis, and use pilot firms for placebo tests.

Table F.5: **Results of Merging the Tax Data with Foreign Direct Investment Data**

	Not Matched (%)	Matched (%)	
		Had Preferential Treatment	No preferential Treatment
	(1)	(2)	(3)
#Obs	18.07	26.18	55.75
Sales	18.52	31.43	50.11
% Firms Investing in Equipment	18.06	27.62	54.32
% Firms Investing in Building	18.60	29.40	52.00
Log Investment in Equipment	18.02	29.08	52.90
Log Investment in Building	18.37	30.25	51.38

Notes: This table displays results of merging foreign firms in the Tax data with foreign direct investment (FDI) data form the Ministry of Commerce. We compare three groups of firms: 1) unmatched firms, 2) matched firms with VAT preferential treatment, and 3) matched firms with no VAT preferential treatment. Each cell indicates the fraction of corresponding variable accounted for by each group. For example, 18.07% of observations in the Tax data are not matched; 31.43% of sales of foreign firms come from those matched foreign firms with VAT preferential treatment on equipment purchase.

Table F.6: **Estimates of Probit Model of Propensity Score**

	(1)	(2)	(3)	(4)	(5)	(6)
Had VAT PT	0.112***	0.106**	0.116***	0.131*	0.119***	0.107**
	(0.020)	(0.044)	(0.038)	(0.067)	(0.037)	(0.046)
Had Export VAT PT	-0.797***	-0.896***	-0.902***	-0.770***	-0.925***	-0.866***
	(0.042)	(0.094)	(0.085)	(0.130)	(0.083)	(0.097)
Exporter	-1.004***	-0.287**	-0.309***	-0.373**	-0.280***	-0.328***
	(0.250)	(0.112)	(0.100)	(0.157)	(0.098)	(0.115)
Sales	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Workers	-0.375***	-0.545***	-0.653***	-0.356***	-0.547***	-0.651***
	(0.024)	(0.045)	(0.050)	(0.101)	(0.045)	(0.050)
% Firms Investing Growth		-0.267				2.953
		(0.346)				(1.872)
Investment Rate Growth			-0.272			-1.049**
			(0.358)			(0.496)
Log Investment Growth				-0.020		
				(0.099)		
IHS Investment Growth					0.022	0.102*
					(0.019)	(0.058)
#Obs	77,939	21,433	20,172	5,836	21,422	20,170
Industry FE	Y	Y	Y	Y	Y	Y
Region FE	Y	Y	Y	Y	Y	Y

Notes: This table displays probit regression results for the propensity score estimation in equation (33). The dependent variable is an indicator = 1 if a firm is in the treatment group. The variables on the right hand side include: whether a firm had VAT preferential treatment, whether a firm had export VAT preferential treatment, whether it is an exporter, sales, logarithm of the number of workers, growth in the fraction of firms investing, growth in the investment rate, growth in the log investment, and growth in the IHS measure of investment. The regression is performed using pre-reform data form 2007 and 2008. All regressions include region and industry fixed effects, and firm fixed effects. Standard errors are clustered at the firm level.

Table F.7: **Estimates of Event Study**

	Extensive Margin			Investment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
2007	0.006	0.004	0.011	-0.000	-0.007	-0.005
	(0.013)	(0.014)	(0.014)	(0.006)	(0.006)	(0.006)
2008	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2009	0.069***	0.045***	0.055***	0.044***	0.043***	0.043***
	(0.013)	(0.013)	(0.013)	(0.005)	(0.005)	(0.005)
2010	0.051***	0.047***	0.050***	0.034***	0.032***	0.035***
	(0.014)	(0.015)	(0.015)	(0.005)	(0.005)	(0.006)
2011	0.064***	0.044***	0.049***	0.029***	0.027***	0.028***
	(0.014)	(0.015)	(0.015)	(0.006)	(0.006)	(0.006)
N	86870	86870	86870	81270	81270	81270
N_{firms}	17374	17374	17374	16254	16254	16254
R^2	0.009	0.015	0.019	0.008	0.007	0.011
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y

Notes: This table estimates event study regressions of the form:

$$Y_{it} = G_i \times \gamma_t + \mu_i + \varepsilon_{ijt},$$

where G_i is an indicator that equals one for domestic firms, and μ_i is firm fixed effects. Dependent variable Y_{ijt} is the investment measure for firm i in industry j at time t: Column (1) to (3) report the estimated γ_t ($t = 2007, \cdots, 2011$) at the extensive margin – i.e. the fraction of firms investing; Column (4) to (6) report the results at the intensive margin – i.e investment rate. In column (1) and (3) we control for industry-year fixed effects; in column (2) and (5) we control for province-year fixed effects; in column (3) and (6) we add both industry- and province-year fixed effects. Standard errors are clustered at the firm level.

Table F.8: **Event Study: Robustness Checks**

	Extensive Margin			Investment Rate		
	Baseline	IPW	Unbalanced	Baseline	IPW	Unbalanced
	(1)	(2)	(3)	(4)	(5)	(6)
2007	0.006	0.044	-0.001	-0.000	0.012	-0.003
	(0.013)	(0.028)	(0.011)	(0.006)	(0.011)	(0.005)
2008	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2009	0.069***	0.108***	0.058***	0.044***	0.045***	0.046***
	(0.013)	(0.026)	(0.010)	(0.005)	(0.009)	(0.004)
2010	0.051***	0.092***	0.058***	0.034***	0.032***	0.039***
	(0.014)	(0.032)	(0.010)	(0.005)	(0.011)	(0.004)
2011	0.064***	0.091**	0.059***	0.029***	0.030**	0.032***
	(0.014)	(0.045)	(0.010)	(0.006)	(0.013)	(0.004)
N	86870	82785	221069	81270	79195	215813
N_{firms}	17374	16557	60870	16254	15839	60513
R^2	0.009	0.053	0.006	0.008	0.034	0.005
Industry × Year FE	Y	Y	Y	Y	Y	Y

Notes: This table conducts robustness checks for the event study regressions of the form:

$$Y_{it} = G_i \times \gamma_t + \mu_i + \varepsilon_{ijt},$$

where G_i is an indicator that equals one for domestic firms, and μ_i is firm fixed effects. Dependent variable Y_{ijt} is the investment measure for firm i in industry j at time t: Column (1) to (3) report the estimated γ_t ($t = 2007, \cdots, 2011$) at the extensive margin – i.e. the fraction of firms investing; Column (4) to (6) report the results at the intensive margin – i.e investment rate. We report the baseline results (column (1) and (4)) In column (2) and (5) we adjust the regressions by inverse probability weighting (IPW, see Section D.1). In column (3) and (6) we use the unbalanced sample for the analysis (i.e. unbalanced at the variable level but balanced at the firm level). All regressions include industry-year fixed effects and firm fixed effects. Standard errors are clustered at the firm level.

Table F.9: **Estimates of Difference-in-Difference Regressions: UCC**

	UCC			Log UCC		
	(1)	(2)	(3)	(4)	(5)	(6)
Domestic × Post	-0.193***	-0.194***	-0.194***	-0.171***	-0.171***	-0.171***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	77677	77677	77677	77677	77677	77677
N_{firm}	17371	17371	17371	17371	17371	17371
R^2	0.735	0.736	0.737	0.762	0.762	0.763
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y

Notes: This table estimates difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + \varepsilon_{ijt},$$

where Y_{it} is the user cost of capital (UCC), G_i is the treatment indicator, and $Post_t$ is the post-reform indicator. Particularly, the dependent variable for column (1) to (3) is $UCC = (1+\nu)(1-\tau p_v)/(1-\tau)$ where ν is the statutory VAT rate, τ is the empirical CIT rate, and p_v is the discounted present value of capital depreciation schedule. The dependent variable for column (4) to (6) is the logarithm of UCC. Column (1) and (4) control for industry-year fixed effects. Column (2) and (5) control for province-year fixed effects. Column (3) and (6) include both fixed effects. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table F.10: **Robustness Check: Investment Including Leasing**

	Extensive Margin			Investment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
Domestic × Post	0.059***	0.044***	0.046***	0.035***	0.037***	0.038***
	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)	(0.004)
N	86870	86870	86870	81270	81270	81270
N_{firm}	17374	17374	17374	16254	16254	16254
R^2	0.010	0.016	0.020	0.008	0.007	0.011
Industry × Year FE	Y		Y	Y		Y
Province × Year FE		Y	Y		Y	Y

Notes: This table estimates difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + \varepsilon_{ijt},$$

where Y_{it} is a measure regarding investment spike, G_i is the treatment indicator, and $Post_t$ is the post-reform indicator. We construct an alternative investment measure to include leased equipment. The dependent variable for column (1) to (3) is a dummy variable set to 1 if the leasing-included investment rate is positive. The dependent variable for column (4) to (6) is leasing-included investment rate. Column (1) and (4) control for industry-year fixed effects. Column (2) and (5) control for province-year fixed effects. Column (3) and (6) include both fixed effects. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table F.11: **UCC Semi-Elasticity Regressions Results**

	OLS	IV						
	Year FE	Year FE	Industry-Year FE	Province-Year FE	Both FE	Cash Flow	Firm Controls	CIT Rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Dependent Variable: Dummy Variable if Firms Investing								
log UCC	-0.055*	-0.317***	-0.318***	-0.263***	-0.266***	-0.238***	-0.260***	-0.277***
	(0.031)	(0.058)	(0.060)	(0.062)	(0.064)	(0.064)	(0.064)	(0.074)
N	77677	77661	77661	77661	77661	74959	77265	77661
Panel B. Dependent Variable: Investment Rate								
log UCC	-0.056***	-0.198***	-0.208***	-0.215***	-0.220***	-0.217***	-0.201***	-0.217***
	(0.013)	(0.023)	(0.023)	(0.024)	(0.025)	(0.025)	(0.025)	(0.030)
N	73115	73102	73102	73102	73102	71731	72743	73102
Panel C. Dependent Variable: Log Investment								
log UCC	-0.945***	-2.406***	-2.401***	-2.209***	-2.235***	-2.244***	-2.136***	-2.122***
	(0.193)	(0.291)	(0.301)	(0.314)	(0.322)	(0.328)	(0.319)	(0.403)
N	19607	19607	19606	19604	19603	19164	19594	19603
Panel D. Dependent Variable: IHS Investment								
log UCC	-0.896***	-4.211***	-4.236***	-3.967***	-3.986***	-3.785***	-3.816***	-3.540***
	(0.231)	(0.501)	(0.515)	(0.526)	(0.535)	(0.542)	(0.533)	(0.616)
N	77677	77661	77661	77661	77661	74959	77265	77661

Notes: This table estimates (semi-)elasticity regression of the form:

$$Y_{it} = \beta \log(\text{UCC}_{it}) + \mu_i + \delta_{jt} + X_{it}'\gamma + \varepsilon_{it},$$

where UCC_{it} is the user cost of capital of firm i at time t. The dependent variables are an indicator of positive investment, investment rate, log investment and IHS measure of investment that are reported in Panel A to D, respectively. Column (1) uses OLS estimator. Column (2) to (8) uses theoretical UCC as instrument, where theoretical UCC is calculated by statutory tax rates. Column (1) and (2) controls for year fixed effects. Column (2) controls for industry-year fixed effects. Column (4) controls for province-year fixed effects. Column (5) to (8) add both industry- and province-year fixed effects. Column (6) controls for firm's cash flow (scaled by fixed assets). Column (7) controls for fourth-order polynomials of sales, profit margin (=profit/revenue) and age. Column (8) controls for statutory CIT rate. All regressions include firm fixed effects. Standard errors are clustered at the firm level.

Table F.12: **UCC Semi-Elasticity Regressions Heterogeneity Results**

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Extensive Margin: Fraction of Firms Investing						
log UCC	-0.27***	-0.28***	-0.28***	-0.28***	-0.31***	-0.32***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)
× Sales		0.08***				0.04*
		(0.02)				(0.02)
× Capital Intensity			0.11***			0.03
			(0.03)			(0.03)
× Debt-to-Capital Ratio				-0.16***		-0.13***
				(0.03)		(0.03)
× $\mathbb{I}$[Vat Credits > 0]					0.40***	0.36***
					(0.07)	(0.07)
N	77661	77654	77629	75697	74610	72723
N_{cluster}	17355	17355	17353	17246	17349	17232
Panel B. Intensive Margin: Investment Rate						
log UCC	-0.22***	-0.22***	-0.22***	-0.25***	-0.27***	-0.28***
	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
× Sales		0.01				-0.01
		(0.01)				(0.01)
× Capital Intensity			0.09***			0.07***
			(0.01)			(0.01)
× Debt-to-Capital Ratio				-0.12***		-0.10***
				(0.01)		(0.02)
× $\mathbb{I}$[Vat Credits > 0]					0.21***	0.20***
					(0.03)	(0.03)
N	73102	73095	73097	72125	70157	69262
N_{cluster}	16238	16238	16238	16234	16235	16226

Notes: This table estimates (semi-)elasticity regression with interactions to firm-level characteristics:

$$Y_{it} = \beta \log(\text{UCC}_{it}) + \alpha X_{it} + \gamma \log(\text{UCC}_{it}) \times X_{it} + \mu_i + \delta_{jt} + \varepsilon_{it},$$

where UCC_{it} is the user cost of capital of firm i at time t. Here we report coefficients β and γ. The dependent variable of Panel A is an indicator of positive investment. We consider heterogeneity along four dimensions: 1) size that is proxied by firm sales, 2) capital intensity = fixed assets/total assets, 3) financial constraint proxied by debt-to-capital ratio, and 4) tax position, i.e. if a firm has positive VAT tax credit. We normalize the four measures to the industry mean, i.e. $\hat{X}_{it} = (X_{it} - \overline{X_j})/\sigma_j$ where $\overline{X_j}$ and σ_j are the sample average and standard deviation, respectively, of variable X in industry j. Column (1) reports the baseline estimate from column (5) of Table F.11. In column (6) we interact log UCC with all the four firm characteristics. All regressions use the theoretical UCC as instrument, where theoretical UCC is calculated by statutory tax rates. All regressions include industry- and province-year fixed effects, and firm fixed effects. Standard errors are clustered at the firm level.

Table F.13: **Structural Estimation and Reduced-Form Moments of Investment Spikes**

	Extensive Margin % Firms Investing with $IK > 0.2$	Intensive Margin Spike Investment Rate
Data	0.073	0.035
Model	0.064	0.036

Notes: This table displays additional reduced-form moments regarding investment spike, complementing Table 7. The first row reports difference-in-difference estimates of investment spike responses (column (3) and (6) in Table 4). The extensive margin refers to the fraction of firms whose investment rate is larger then 0.2, i.e. $\mathbb{1}\{IK_{it} \geq 0.2\}$ where IK_{it} is the investment rate of firm i at time t. The intensive margin refers to the spike investment rate, i.e. $IK_{it}^{spike} = IK_{it} \times \mathbb{1}\{IK_{it} \geq 0.2\}$. The second row reports model simulated responses of investment spikes. We use the estimated frictions, i.e. $\gamma = 1.43$, $\bar{\xi} = 0.12$, for the simulation.

Table F.14: **Tax Cuts with Same UCC Reduction Through 10-Year Window**

Change in	VAT Cut	CIT Cut	
		Constant WACC	Varying WACC
	(1)	(2)	(3)
Panel A. Initial VAT = 17%, CIT = 15.4%			
Tax Rate (%)	-2.8	-10	-10
UCC (%)	-2.4	-2.4	-2.4
Average Investment Rate (Non-negative, %)	4.7	16.5	5.5
Fraction of Firms Investing (%)	2.3	11.1	4.1
Tax Revenue (%)	-2.9	-35.7	-41.9
Ratio of Investment Rate to Tax Revenue	1.62	0.46	0.18
Panel B. Initial VAT = 5%, CIT = 15.4%			
Tax Rate (pp.)	-2.5	-10	-10
UCC (%)	-2.4	-2.4	-2.4
Average Investment Rate (Non-negative, %)	4.1	17.7	6.9
Fraction of Firms Investing (%)	1.6	11.8	5.2
Tax Revenue (%)	-5.2	-52.8	-55.6
Ratio of Investment Rate to Tax Revenue	0.79	0.34	0.16

Notes: This table displays simulation results starting from different initial VAT rates. Panel A shows the results with initial VAT rate at 17% and CIT rate at 15.4%. We compare two reforms with the same reduction in UCC: 1) VAT reform cuts VAT from 17% to 14.2% (i.e. 2.8% rate reduction), and 2) CIT reform cuts CIT rate from 15.4% to 5.4% (i.e. 10% rate reduction). Those two reforms have the same impacts on UCC, reducing UCC by 2.4%. We use the estimated frictions, i.e. $\gamma = 1.43$, $\bar{\xi} = 0.12$, to simulate tax cuts. Panel B shows the results with initial VAT rate at 5% and CIT rate at 15.4%. VAT reform cuts VAT from 5% to 2.5%; CIT reform cuts CIT rate from 15.4% to 5.4%, leading to the same UCC reduction as VAT cut. In column (2) we simulate CIT cut with fixed interest rate. In column (3) we use weighted-average cost of capital (WACC) for simulation. WACC is calculated as

$$\text{WACC} = \text{Share}_{\text{debt}}(1-\tau)r + (1-\text{Share}_{\text{debt}})r_k,$$

where $\text{Share}_{\text{debt}}$ is the share of capital financed through debt and, accordingly, $(1-\text{Share}_{\text{debt}})$ is the share of capital financed through equity. We calibrate the share of debt financing to be 0.65 to match the average debt to capital ratio. We keep real interest rate r and capital return r_k constant to match baseline discount rate. Ratio of investment rate to tax revenue is calculated by dividing the percentage change in average investment rate by the percentage change in tax revenue.

Table F.15: Sensitivity Analysis of Structural Moments

Moments	10% Change		
	γ	$\bar{\xi}$	δ
Pre-Reform Static Moments			
Avg. Investment Rate	-0.0058	0.0007	0.0006
Share<0.1	-0.5705	0.0218	-0.0065
Share<0.2	-0.1568	-0.0011	-0.0098
Share<0.3	0.5000	-0.0322	-0.0108
Serial Correlation	-0.0562	-0.0052	0.0002
SD. Investment Rate	-0.0739	0.0047	0.0013
Reduced-Form Investment Responses			
Extensive DID	-0.0163	-0.0002	-0.0001
Intensive DID	-0.0118	0.0002	0.0000

Notes: This table displays sensitivity matrix:

$$\Lambda = -(G'WG)^{-1}G'W \times g(m),$$

where G is the Jacobian matrix, W is the weighting matrix (identity matrix here), and $g(m)$ is a vector of moments with misspecification. Here, we consider the misspecification to be a 10% deviation from the true value.

Table F.16: **Robustness of Simulating 17% VAT Cut Through 10-Year Window**

Change in	Baseline (1)	Upward-Sloping Capital Supply (2)	Resale Price $p_s = 0.95$ (3)	Aggregate Productivity Drop (4)
UCC	-0.145	-0.115	-0.145	-0.145
Average Investment Rate	0.290	0.231	0.290	0.294
Aggregate Investment Rate	0.290	0.232	0.290	0.294
Fraction of Firms Investing	0.098	0.090	0.098	0.102
Tax Revenue	-0.279	-0.277	-0.279	-0.277
Firm Value	0.114	0.090	0.114	0.114
Ratio of Investment to Tax Revenue	1.039	0.836	1.035	1.062
Ratio of Firm Value to Tax Revenue	0.410	0.325	0.409	0.413

Notes: This table displays simulation results for the baseline policy reform – 17% VAT cut – with the following extensions. Column (1) is the baseline simulation results. Column (2) assumes the capital supply is upward-sloping withe the functional form of $p^K = I^{1/\varepsilon^s}$. The elasticity of capital supply with respect to pre-tax capital price ε^s is set to 10. Column (3) assumes the net-of-tax resale price to be 0.95. In column (4), we feed in a one standard deviation permanent drop of aggregate productivity.

Table F.17: **Simulating Tax Reforms Through 10-Year Window Incorporating Weighted Average Cost of Capital (WACC)**

Change in	Baseline	CIT Cut 15.4% to 10%	
	17%	Constant WACC	Varying WACC
	(1)	(2)	(3)
UCC	-0.15	-0.01	-0.01
Average Investment Rate	0.29	0.09	0.03
Aggregate Investment Rate	0.29	0.10	0.04
Fraction of Firms Investing	0.10	0.06	0.02
Tax Revenue	-0.28	-0.19	-0.23
Firm Value	0.11	0.10	0.05
Ratio of Investment to Tax Revenue	1.04	0.54	0.18
Ratio of Firm Value to Tax Revenue	0.41	0.54	0.21

Notes: This table displays simulation results for CIT cut from 15.4% to 10% which changes weighted average cost of capital (WACC), and thus discount rate $\beta = \frac{1}{1+\text{WACC}}$. WACC is calculated as

$$\text{WACC} = \text{Share}_{\text{debt}}(1-\tau)r + (1-\text{Share}_{\text{debt}})r_k,$$

where $\text{Share}_{\text{debt}}$ is the share of capital financed through debt and, accordingly, $(1-\text{Share}_{\text{debt}})$ is the share of capital financed through equity. We calibrate the share of debt financing to be 0.65 to match the average debt to capital ratio. We keep real interest rate r and capital return r_k constant to match baseline discount rate.