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

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Abstract

We incorporate the lumpy nature of firm-level investment into the study of how tax policy affects investment behavior. We show that tax policies can directly impact the lumpiness of investment. Extensive-margin responses to tax policy are key to understanding the effects of different tax reforms and to designing effective stimulus policies. We illustrate these results by studying China’s 2009 VAT reform, which lowered the tax cost of investment and reduced partial irreversibility—the price gap between new and used capital. Using comprehensive tax survey data and a difference-in-differences design, we estimate a 36% relative investment increase that is driven by investment spikes. Using a dynamic investment model that fits the reduced-form effects of the reform, we show that policies that directly reduce the likelihood of firm inaction are more effective at stimulating investment.

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This paper improves our understanding of how tax policy affects investment behavior by incorporating the lumpy nature of investment. Lumpy investment behavior is evident in most microdata, with firms either replacing a considerable fraction of their existing capital (spikes) or not investing at all (inaction). The prevalence of lumpy investment patterns suggests that extensive-margin investment decisions—i.e., whether to invest or not—are important determinants of overall investment. This paper shows that extensive-margin responses to tax policy are key to understanding the effects of different tax reforms and to designing effective stimulus policies.

We illustrate theoretically, empirically, and quantitatively that tax policy can impact extensive-margin investment decisions and that the effects of tax policy are shaped by investment frictions. Firms invest in lumpy increments because adjusting the physical stock of capital can entail fixed disruption costs and because investment is partially irreversible—i.e., the price of new capital is greater than the resale price of used capital. We integrate various tax policies into a model with these frictions. Tax policies can be a source of partial irreversibility, since input taxes and tax credits impact the wedge between the purchase and resale prices of capital. Other policies, such as income taxes and depreciation deductions, indirectly affect lumpiness by changing the after-tax value of fixed disruption costs. Different tax incentives have distinct effects on the frictions that determine whether firms undertake investment projects. As a result, policies that change the user cost of capital by the same degree can have different implications for firm investment.

Our analysis is grounded in one of the largest tax incentives for investment in recent history: China’s 2009 value-added tax (VAT) reform. The reform unexpectedly allowed domestic firms to deduct input VAT on purchases of new equipment. This policy change lowered the user cost of capital by 15% and reduced the wedge between the after-tax prices of new and used capital. Understanding how tax policy impacts investment in China is of first-order importance since corporate investment comprises 30% of China’s GDP and since—as shown in Figure 1—investment in China has long surpassed investment levels in the United States and the European Union. We use comprehensive firm-level tax data to shed light on this stimulus program and to develop insights into how tax policy interacts with the frictions that generate lumpy investment.

We start by developing intuition for how tax policies interact with firm frictions in Section 1. We embed important tax policies—income tax, VAT, and depreciation deductions—into a standard model of dynamic investment that is rich enough to characterize our empirical setting. As in Cooper and Haltiwanger (2006), fixed costs and partial irreversibility rationalize lumpy investment patterns, and convex costs dampen investment responses to changes in taxes or productivity. We then provide intuition for how different tax policies interact with these frictions. While the VAT reform lowered the after-tax cost of capital and reduced the degree of partial irreversibility, it did

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1By way of comparison, the recent tax reform in the United States lowered the user cost of capital by about 4% (Barro and Furman, 2018). In the Chinese setting, eliminating the corporate income tax or allowing for immediate depreciation deductions (i.e., expensing) would lower the user cost of capital by 3.5%. 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.
not directly interact with adjustment costs. In comparison, while a corporate income tax cut has a smaller effect on partial irreversibility, it lowers the after-tax cost of capital and affects the after-tax value of adjustment costs. The model shows that to fully grasp how tax policy affects investment, it is necessary to account for the dual effects of tax policy on adjustment frictions and the cost of capital.

The second step of our analysis estimates the reduced-form effects of China’s 2009 VAT reform. As we discuss in Section 2, we evaluate the effect of the reform by comparing domestic and foreign firms, since foreign firms with preferential treatment were able to deduct input VAT on equipment prior to the reform. We implement this research strategy using a novel tax survey dataset from the Chinese State Administration of Tax. We describe these data in Section 3. As we show in Section 4, we find substantial effects of the reform on firm investment. On the extensive margin, relative to foreign firms, the fraction of domestic firms investing in equipment increased by 5 percentage points, or a 10% increase. On the intensive margin, relative investment increased by 3.6% of the existing capital stock, for a 36% increase in investment. We then highlight the importance of interactions between tax policies and the frictions that generate lumpy investment. Specifically, we find that the majority of the investment response was due to a surge in the number of firms that went from not investing to undertaking investment projects that were greater than 20% of their capital (i.e., investment spikes).

The validity of this research design rests on the assumption that, absent the reform, domestic firms would have had the same investment trends 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 are robust to a number of checks including using alternative measures of investment, different sample restrictions, reweighting the data to match the characteristics of foreign and domestic firms, and controlling for firm-level characteristics and other changes in tax policy. Finally, we conduct two placebo tests to further validate our identifying assumption. The first placebo test uses domestic and foreign firms that were included in a pilot program allowing firms to deduct input VAT from new investments starting in 2004. We find no evidence that the 2009 reform differentially affected foreign and domestic firms in the pilot program. This result suggests that there were no other time-varying shocks that differentially affected foreign and domestic firms and that might confound our estimates. In a second placebo test, we use the fact that the VAT reform did not impact the tax treatment of investment in structures. Because the reform did not differentially affect how foreign and domestic firms invested in structures, it is unlikely that our results are confounded by differential shocks to foreign and domestic firms. Additionally, triple-difference specifications that use these placebos as additional controls yield similar estimates of the reform. 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.

To quantify the interactions between investment frictions and tax policy, in Section 5 we estimate our dynamic model of investment. Our estimation relies on the method of simulated moments.
(MSM) to recover fixed and convex adjustment costs while allowing the VAT reform to influence partial irreversibility. Our model targets two sets of moments: (1) pre-reform statistics on investment patterns, such as measures of lumpiness and the autocorrelation of investment, and (2) the reduced-form estimates of the effects of the reform. We validate our model of investment by showing that it can match the reduced-form effects of an actual reform, including untargeted moments such as the effects of the reform on investment spikes. Simultaneously matching both of these sets of moments indicates that the VAT-induced price gap between used and new capital was the major source of partial irreversibility.2

We then use the model to compare the fiscal effectiveness of alternative tax policies in Section 6. We measure the effectiveness of a given policy by comparing the tax revenue cost to the change in investment. We find that policies that increase the likelihood of investment spells are more effective at stimulating investment. For instance, lowering the VAT distortion is more effective at stimulating investment than lowering the corporate income tax rate. One reason a corporate income tax cut is less effective is that a large fraction of firms are inframarginal to the tax cut—their investment is unaffected, but they benefit from the lower tax rate. In addition to having a large effect on the extensive margin of investment, policies that shrink the price gap between new and used capital—such as an investment tax credit—only benefit firms that increase their investment. For this reason, introducing an investment tax credit is just as effective as reducing the VAT distortion. We also find that China’s 2009 VAT reform stimulated more investment relative to lost tax revenue than a counterfactual policy that mirrors the 2017 Tax Cut and Jobs Act in the United States.3 Section 7 concludes by noting that this lesson is relevant for tax policy in other countries that rely on sales taxes, VATs, and investment tax credits since such measures directly impact the extensive margin of investment.

**Related Literature**

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,b; Moon, 2019).4 Papers that

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2While the empirical investment literature relies on the asymmetry between the positive and negative ranges of the investment distribution to separately identify fixed costs from partial irreversibility, the lack of asset sales in tax data makes this approach infeasible. We instead use a reform that reduced the price gap between new and used capital to measure the relative importance of partial irreversibility for extensive-margin investment decisions.

3While our analyses focus on a partial equilibrium setting, we show that our quantitative results are robust to alternative assumptions regarding the supply of capital goods and effects of the reform on interest rates, concomitant aggregate productivity shocks, additional sources of partial reversibility, and interactions between income taxes, adjustment costs, and interest costs.

4Our paper is also related to classic papers that follow a model-centric estimation approach. For instance, Abel (1980), Salinger and Summers (1981), Summers (1981), and Hayashi (1982) rely 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).
study how Chinese firms respond to tax incentives include Cai and Harrison (2019), Liu and Mao (2019), Chen, He and Zhang (2016), and Chen, Liu, Suárez Serrato and Xu (2019). The main contribution of our paper is to improve our understanding of how tax policy impacts investment by providing a coherent framework to interpret the intensive- and extensive-margin effects that have been documented in quasi-experimental studies. Deploying this framework to measure the effects of a large natural experiment using comprehensive tax data, we highlight the importance of investment spikes in understanding the effects of tax reforms as well as the potential for tax policy to generate partial irreversibility.

This paper also contributes to the investment literature by investigating a real-world tax reform through the lens of a workhorse model of investment (e.g., Caballero and Engel, 1999; Cooper and Haltiwanger, 2006; Gourio and Kashyap, 2007; Khan and Thomas, 2008; David and Venkateswaran, 2019; Lanteri, 2018; Winberry, 2020). Previous research in this literature has simulated the effects of tax policy changes through their effects on the after-tax cost of investment (e.g., Winberry, 2020). We highlight the importance of accounting for interactions between tax policy and the frictions that generate lumpy investment. In particular, we show that tax policies that have the same effect on the after-tax cost of capital can have different effects on firm investment. We also contribute to this literature by using quasi-experimental estimates of the effects of tax reform to estimate adjustment costs. As argued by Cummins, Hassett and Hubbard (1994), tax reforms generate large and plausibly exogenous shifts in economic fundamentals and are useful in uncovering the nature of investment frictions. Our unified approach is therefore well suited to simulating the effects of potential tax reforms and comparing their effectiveness at stimulating investment.

The results of this paper have implications beyond China. First, policymakers can introduce partial irreversibility through indirect taxation. This can occur when VATs do not allow for the deductibility of investment or when businesses pay indirect taxes on investment goods (e.g., Desai, Foley and Hines, 2004). In the United States, Cline, Mikesell, Neubig and Phillips (2005) document that businesses pay over $100 billion in state sales taxes on inputs, including investment purchases. Second, VATs can generate partial irreversibility when credits are not refundable. While China started refunding excess VAT credits in 2019 (Ministry of Finance, 2019), excess credits are not

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5Cai and Harrison (2019) and Chen et al. (2016) use manufacturing survey data to study the effects of the pilot reform in 2004. In concurrent work, Liu and Mao (2019) use tax data to study the reduced-form effects of the rollout of the reform from 2004 to 2009 using small taxpayers as a control for large domestic firms. Using different empirical strategies, we find comparable effects of the reform on investment. Relative to Liu and Mao (2019), this paper contributes to the literature by uncovering the importance of lumpy responses to the tax reform and by providing a coherent model that synthesizes the effects of different tax policies on the intensive and extensive margins of investment.

6The focus of this paper is the interaction between tax instruments and producer-level investment behavior. Recent papers (e.g., Khan and Thomas, 2008; Bachmann, Caballero and Engel, 2013; Winberry, 2020) have clarified the conditions under which micro-level investment frictions have aggregate implications in general equilibrium. In particular, Winberry (2020) shows that lumpy investments have aggregate implications when interest-rate dynamics match the observed covariance with productivity. In Appendix F, we show that our main conclusions are robust to allowing for potential equilibrium effects on the interest rate or on the price of capital goods.
refundable in 24 other countries (EY, 2017). Finally, interactions between different tax policies influence the effectiveness of different forms of stimulus. For instance, a corporate income tax cut can be more effective at stimulating investment when other policies, such as an investment tax credits (e.g., Chirinko and Wilson, 2008), are simultaneously used to lower the price gap between new and used capital.

1 Modeling Tax Policy and Lumpy Investment

Empirical models of investment use adjustment costs to rationalize two empirical features of investment data. First, the observed pattern of infrequent and lumpy investment suggests firms face fixed costs and partial irreversibility. Second, the sluggish response of investment to changes in economic fundamentals suggests that investment is subject to convex costs of adjustment. We first characterize how frictions that lead to lumpy investment 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 preexisting capital $K_0$, productivity $A$, and profit function $A^{1-\theta}K^{\theta}$, where $\theta < 1$ is the curvature of the profit function. The firm pays a corporate tax rate $\tau$ on profits. We model the after-tax price of capital $p = p_k(1 + \nu)(1 - \tau z)$, where $p_k$ is the capital goods price, $\nu$ is a tax wedge on the capital price, and $z \leq 1$ is the discounted present value of depreciation deductions. Prior to the 2009 reform, capital equipment was not deductible from the VAT base, so that $\nu$ equals the VAT rate. For simplicity, we refer to a reduction in this wedge as a VAT cut, with the understanding that this change is driven by partial or full deductibility of capital and not by the VAT rate. Absent additional frictions, the firm solves the problem:

$$\max_K (1 - \tau)A^{1-\theta}K^{\theta} - p(K - K_0) \iff K^* = A \left[ \frac{1}{\theta} \frac{p_k(1 + \nu)(1 - \tau z)}{(1 - \tau)} \right]^{\frac{1}{1-\theta}}. \quad (1)$$

Equation 1 implies that the firm will adjust its capital in response to all changes in taxes or productivity. There is no inaction or scope for an extensive-margin response. The user cost of

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7 Excess VAT credits correspond to the positive difference between input VAT payments and output VAT receipts.

8 $z$ is determined by the tax depreciation schedule of capital. We provide more details of how the tax depreciation schedule maps into $z$ in the dynamic model. While this static model abstracts away from how real depreciation impacts investment, this important force is present in our dynamic model, and we estimate the rate of depreciation in our structural model in Section 5.
capital (UCC) is given by \( \frac{p_k(1+\nu)(1-\tau z)}{(1-\tau)} \). The symmetric effect of \( p_k \) and the tax term of the user cost of capital \( \frac{(1+\nu)(1-\tau z)}{(1-\tau)} \) 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 the profit function and equals \( \frac{-1}{1-\theta} \).

**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 increase partial irreversibility and have been shown to affect the investment of US firms (e.g., Desai et al., 2004). 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 pre-2009 VAT system increased the purchase price of capital by a factor of \( (1 + \nu) \), where \( \nu \) is the VAT rate. Firms selling used capital could not charge the VAT rate. The effective after-tax purchase price is then \( p^b = p_k(1 + \nu - \tau(1 + \nu)z) \) and the sales price is \( p^s = p_k(1 - \tau(1 + \nu)z) \).

Partial irreversibility generates inaction—a range of productivity in which 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 marginal product of their existing capital falls in the range \( [p^s, p^b] \). The dashed line in Panel A of Figure 2 shows how the marginal product of capital increases with productivity. The two horizontal lines denote \( p^b \) and \( p^s \). The inaction region is the range of productivity where the marginal product of capital falls between these two lines and is given by:

\[
[A, \bar{A}] \equiv \left[ \left( \frac{p^s}{\theta(1-\tau)} \right)^{\frac{1}{1-\theta}} K_0, \left( \frac{p^b}{\theta(1-\tau)} \right)^{\frac{1}{1-\theta}} K_0 \right].
\]

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:

\[
\bar{A} - A = \left( \frac{\text{UCC}}{\theta} \right)^{\frac{1}{1-\theta}} \left[ 1 - \left( \frac{1 + \nu - \tau z}{1 - \tau z} \right)^{\frac{1}{1-\theta}} \right] K_0.
\]

According to this equation, a reduction in \( \nu \) will narrow the inaction region both by lowering the user cost of capital and by closing the price gap \( \left[ 1 - \left( \frac{1 + \nu - \tau z}{1 - \tau z} \right)^{\frac{1}{1-\theta}} \right] \). In contrast, increasing \( z \) has

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\(^9\)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 \( \frac{1}{1-\theta} = 4 \).

\(^{10}\)Note that the VAT also increases the value of depreciation deductions.
two countervailing effects on the inaction region. While increasing \( z \) lowers the user cost of capital, this change also widens the price gap. Thus, changes in tax policies with the same impact on the user cost of capital can have different extensive-margin responses.

**Fixed Costs**

In addition to partial irreversibility, fixed costs also generate inaction. Following the literature (e.g., Caballero and Engel, 1999; Cooper and Haltiwanger, 2006), we interpret fixed costs as technological constraints, including production disruptions and short-run capacity limits that firms face when they replace machinery. We therefore assume that the firm has to pay a non-tax-deductible fraction \( \xi \) of its desired capital stock \( K^* \) to adjust its capital stock. To highlight the role of fixed costs, we abstract from partial irreversibility by assuming that \( p^s = p^b = p_k(1 + \nu - \tau (1 + \nu)) \).

A firm decides to adjust its capital if its profits after making the adjustment, \( (1 - \tau)A^{1-\theta}K^* - p(K^* - K_0) - \xi K^* \), 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:

\[
\begin{align*}
\text{Profit conditional on adjusting to optimal capital } K^* & = \left[ \frac{(1 - \theta)}{\theta} \frac{UCC}{1 - \tau} - \frac{\xi}{1 - \tau} \right] \left[ \frac{\theta}{UCC} \right]^{1/(1 - \theta)} A + UCCK_0 = K_0^\theta A^{1-\theta},
\end{align*}
\]

The inaction region is characterized by the two values \( A \) and \( \bar{A} \) that satisfy this indifference condition. The solid black line in Panel A of Figure 3 plots the after-tax profit in the case of no adjustment costs. The fixed cost \( \xi \) flattens the slope and rotates this line clockwise (shown by the dot-dashed line). The inaction region \([A, \bar{A}]\) is defined by the intersection of this rotated line and the curved profit line (in dashes) 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 3 can be used to illustrate the dual effects of tax policy on the cost of capital and adjustment frictions. Consider first a policy that reduces the user cost of capital through changes in \( z \) or \( \nu \). These policies would shrink the inaction region by lowering the intercept and increasing the slope. A cut in \( \tau \) that lowers the user cost of capital by the same amount as changes in \( z \) or \( \nu \) will shrink the inaction region more by reducing the after-tax value of the fixed cost.

As Equations 2–3 show, in an environment with lumpy investment, the user cost of capital is not a sufficient statistic to capture the extensive-margin effects of tax policy changes. Because fixed costs and partial irreversibility have different interactions with tax policies, measuring the relative importance of these frictions is crucial for understanding the effects of tax policy.\(^\text{11}\) The fact that tax policy can directly influence firms’ extensive-margin investment decisions should be taken into

\(^{11}\)Appendix A.1 further describes how convex adjustment costs interact with tax parameters in this static setting.
account when modeling the effects of tax policy changes.

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 built on Cooper and Haltiwanger (2006) that is rich enough to characterize our empirical setting.\(^\text{12}\)

**Pre-Tax Profit Function**

Firms have a profit function given by:

\[
\Pi(K, A^\Pi) = (A^\Pi)^{1-\theta} K^\theta, \tag{4}
\]

where \(K\) is the predetermined capital stock and \(A^\Pi\) is a profit shock that is realized at the beginning of the period.\(^\text{13}\) \(a_{it} \equiv \log(A^\Pi_{it})\) denotes a firm’s log profitability, which has three components:

\[
a_{it} = b_t + \omega_i + \varepsilon_{it}, \tag{5}
\]

where \(b_t\) is an aggregate shock, \(\omega_i\) captures firm-specific permanent heterogeneity, and \(\varepsilon_{it}\) is an idiosyncratic transitory shock. Firms draw \(\omega_i\) from a normal distribution. The aggregate shock \(b_t\) and the transitory shock \(\varepsilon_{it}\) follow AR(1) processes.

**Taxes**

Firms pay the VAT rate \(\nu\) on purchases of new equipment. Consistent with the Chinese institutional setting, we assume that new capital purchases cannot be deducted from output VAT. Firms pay corporate income tax at rate \(\tau\) on profits and depreciate a fixed fraction \(\hat{\delta}\) of the end-of-year book value of the capital stock in each period. We summarize the impact of the depreciation schedule on the effective capital purchase price with the sufficient statistic \(z\): the present discounted value of depreciation deductions.\(^\text{14}\) The depreciation schedule interacts with both \(\tau\) and \(\nu\) since depreciation is deductible from the corporate income tax base and the VAT affects the book value of capital.

\(^{12}\)To focus on the role of adjustment costs and lumpy investment, we abstract from the role of financial frictions. Combining financial frictions and lumpy investment raises additional modeling and identification challenges. Recent models that focus on financial frictions but abstract from lumpy investment include Hennesy and Whited (2007); Arellano, Bai and Zhang (2012); Ottonello and Winberry (2019).

\(^{13}\)We view this as a reduced-form way to model the profit function, but it is easy to microfound it as the result of a static profit-optimization problem. We give an example using a decreasing-returns-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.

\(^{14}\)By abstracting from the depreciation schedule, this assumption allows us to study the firm’s problem recursively. \(z = \delta + (1 - \delta)\beta E[z']\). Assuming a fixed and exogenous real interest rate \(r\), \(\beta E[z'] = \frac{1}{1+r}\). This formulation builds on arguments in Winberry (2020). We show that this result holds in our setting in Appendix A.3.2.
Adjustment Costs

Firms face three types of adjustment frictions: a convex adjustment cost, a fixed disruption cost, and partial irreversibility. We assume that the only source of irreversibility is the non-deductible VAT on equipment purchases, so the resale price is set to one. Firms incur a fixed disruption cost $\xi K^*$ when adjusting the capital stock. $\xi$ is assumed to be independent and identically distributed (i.i.d.) across firms and over time and is drawn from the distribution $G(\xi)$. Finally, the convex cost follows the quadratic form $\frac{\gamma}{2} \left( \frac{i}{k} \right)^2 k$.

Normalization and Recursive Formulation

We normalize the firm problem relative to a given permanent productivity by defining $k = K'/\exp(\omega)$. This normalization reduces the state space to $(k, b, \varepsilon, \xi)$. In any given period, the firm’s value is the maximum of the value from buying capital, selling capital, or inaction:

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

where

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

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

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

where $k' = (1 - \delta)k + i$, $\delta$ is the economic rate of depreciation, and where the ex ante value function (before the fixed cost draw is realized) is given by:

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

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15 Partial irreversibility arises naturally from the fact that firms need to pay VAT to sellers when purchasing capital but do not retain VAT payment when selling capital. Section 6 shows our results are robust to allowing for additional sources of partial irreversibility.

16 We represent the units of the fixed disruption cost in terms of the “desired capital level” $K^*$, as in the frictionless benchmark in Equation 1. In the dynamic setting, $K^* = \mathbb{E}[A'|A] \left[ \frac{p_k(1 + \rho)(1 - \tau z)}{1 - \tau} \right]^{-1/(1 - \theta)}$ with $p_k = r + \delta$, where $r$ is the interest rate defined by $r = 1/\beta - 1$, and $\delta$ is the economic depreciation rate.

17 This normalization allows us to account for firm-level permanent heterogeneity in firm-level productivity or unmodeled frictions (see, e.g., David and Venkateswaran, 2019). This result follows from the fact that the profit function (Equation (4)) 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.

18 As in Cooper and Haltiwanger (2006), our model does not allow for “vintage effects,” so that firms would never have positive and negative investment spells at the same time.
\( v^b(k, b, \varepsilon, \xi) \) is the value function conditional on investing. The costs of investing include convex and fixed adjustment costs, as well as the VAT-inclusive price of capital \((1 + \nu)\) minus depreciation deductions \(\tau z(1 + \nu)\). When the firm decides to disinvest, the value function \( v^a(k, b, \varepsilon, \xi) \) differs by not including \(\nu\) in the resale price. This difference 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 profits.

**Implications for Policy Reform**

We now solve the model numerically to characterize how different policies affect the investment policy function and to confirm that many of the lessons from the static model are applicable in the dynamic setting.

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. 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 \(\theta\) and the persistence of the idiosyncratic shock \(\varepsilon\).

The dashed 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 create 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 and partial irreversibility prevent firms from directly adjusting to the optimal capital level, which gives the policy function a flatter slope with respect to productivity shocks.

Panels B-D compare the effects of different tax policies on the firm’s policy function. For comparability, we consider three policies that have the same impact on the tax term of the user cost of capital. The red solid line in Panel B of Figure 4 shows a VAT cut from 17% to 12.9%.\(^{19}\) The VAT cut directly reduces the user cost of capital, which affects investment along the intensive margin. Additionally, the VAT cut reduces the asymmetry between the purchase and sale price of capital. This change 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 red inaction region but that would otherwise be inside the black dashed inaction region.

In Panel C, we report the policy function following a corporate income tax cut. To match the user cost of capital effect of the small VAT cut in Panel B, we consider the effect of reducing \(\tau\) from the average effective rate in our data from 15.4% to 0%. Relative to Panel B, the corporate income...
tax cut has a smaller effect on the inaction region, primarily driven by the lack of response by firms with low productivity shocks.

Panel D reports the effects of a policy of bonus depreciation—which accelerates the timing of depreciation deductions and increases the value of \( z \). By shifting the red line to the left, this reform affects the investment decisions of firms with low and high productivity shocks. Consistent with our theoretical insight, the inaction region does not narrow considerably, and a significant fraction of firms do not respond to this incentive. Panels B, C, and D show that, relative to a corporate income tax cut and bonus depreciation, a VAT cut would lead to stronger responses along the extensive margin.

Extensive-margin responses also drive the fiscal effectiveness of different policies. Because all firms—even those in the inaction region—benefit from a corporate income tax cut, the government collects less revenue from a large fraction of firms that do not undertake new investment projects. In contrast, only firms that invest benefit from a VAT cut or from bonus depreciation. Tax revenues are also impacted by dynamic effects of different policies on future profit flows.

While the red lines in Figure 4 compare reforms with similar effects on the user cost of capital, the blue line in Panel B shows the effects of the actual VAT reform. By lowering the UCC, the VAT reform would increase investment along the intensive margin by shifting the policy function to the left. At the same time, by eliminating a margin of partial irreversibility, the reform shrinks the inaction region. An insight from this figure is that investment spikes should play an important role in explaining the investment effects of the reform. In Section 5, we estimate an empirical version of this model that is consistent with the reduced-form effects of the reform to quantitatively compare the effects of alternative tax policies. Based on this discussion, an important test that our model correctly measures the relative importance of fixed costs and partial irreversibility is whether it matches the extensive-margin effects of China’s VAT reform, including spikes in investment.

2 Policy Background: China’s 2009 VAT Reform

China’s 2009 reform was one of the largest tax incentives for investment in recent 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 22% and 8% of tax revenue, respectively (NBS China, 2018). 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.\(^{20}\)

\(^{20}\)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 affected by the reform face a 17% rate.
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 (Ebrill, Keen, Bodin and Summers, 2001). 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. This lack of deductibility discouraged investment, which works against 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. Because this reform was part of long-term central government plans dating to 2003, firms deemed the chance of policy reversal to be extremely low.\footnote{The Chinese government announced the gradual transition from the production-based VAT to consumption-based one at the Third Plenary Session in October 2003. Plenary sessions are among the highest-level government meetings. Decisions made at these meetings are meant to be permanent and are very rarely revoked.}

The Chinese government experimented with this transition starting in 2004. The reform was first piloted on firms in selected industries in Northeastern China.\footnote{The initial provinces included Heilongjiang, Jilin, Liaoning, and the city of Dalian. From 2004 to 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 (2019) and Chen et al. (2016) study the effects of the pilot reform.} As with most other reforms in China, the reform was designed to follow a slow rollout to allow for trial and error. However, the government unexpectedly announced on December 19, 2008, that the reform would be extended nationwide in 2009. This announcement broke with existing expansion plans. Prior to this announcement, authorities had last announced on July 30, 2008, that the rollout of the program would continue in two additional provinces. Starting on January 1, 2009, all firms were able to deduct the input VAT on equipment from the VAT on sales.\footnote{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.}

The reform was an unexpected and permanent change to firms’ after-tax cost of investment. Because the timing of the reform was unexpected, it is unlikely that firms delayed their investment plans in anticipation of the reform. Because the reform was permanent, the effects we measure are likely not due to other forms of inter-temporal substitution.

The reform generated a natural experiment since it had no effect on the after-tax cost of investment for a group of foreign firms. Specifically, foreign firms in industries categorized by the government as\textit{ encouraged} had previously been allowed to deduct equipment purchases from VAT on sales.\footnote{Qualified foreign firms were able to deduct input VAT on purchases of equipment starting in 1999. Starting on April 1, 2002, the government classified foreign investment projects as\textit{ encouraged},\textit{ allowed},\textit{ restricted} or\textit{ prohibited}. The\textit{ Catalogue for the Guidance of Foreign Investment Industries} lists the encouraged, restricted and prohibited projects. If a foreign project is not included in the previous three categories in the\textit{ Catalogue}, it is considered as falling within the allowed category. Additionally, firms participating in the Midwest Advantageous Project list also}

Our research strategy uses foreign firms in encouraged industries as a 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. Since foreign firms were able to deduct equipment purchases from the VAT base prior to the reform, we would expect a higher fraction of these firms to invest in any given year and for foreign firms to have a higher investment rate, on average. We would then expect to see some degree of convergence in the investment patterns of domestic and foreign firms after the reform.

One set of potential concerns is related to the fact that the Chinese government implemented a broad stimulus package in responses to the financial crisis, which was colloquially known as the 4 trillion yuan package. Through this program, the central government provided low-cost credit through the local financing vehicles of regional governments. As Bai, Hsieh and Song (2016) show, these loans were used for railways, roads and other infrastructure (38%), reconstruction following the Wenchuan earthquake (25%), affordable housing (10%), and social welfare projects (27%). Importantly, these loans did not target the manufacturing sector. In contrast, the 2009 VAT reform—which was also part of this stimulus package—directly affected the manufacturing sector. For these reasons, we do not expect that other aspects of the stimulus package would confound the effects of the VAT reform.

Nevertheless, we conduct a number of checks to ensure that our results are driven by the VAT reform and not by other aspects of the stimulus package that may differentially affect foreign and domestic firms. First, because the credit provision was channelled through regional governments, we control for province-by-year fixed effects in our baseline specifications. Second, because Cong, Gao, Ponticelli and Yang (2019) show that the credit expansion disproportionately benefited state-owned enterprises (SOEs), we show that our results are robust to excluding SOEs or listed firms. Third, we also find similar effects for firms in industries that have weak input-output linkages to the industries that benefited the most from the stimulus package. Finally, we conduct two sets of placebo tests to show that we are capturing the effects of the VAT reform. Because the reform did not impact the investment incentives of domestic firms that were part of the 2004 pilot, we would not expect investment in these firms to be affected by the reform. Similarly, we leverage the fact that, apart from minor affiliated structures, the VAT reform did not change the tax treatment of investment in major structures. We find that the 2009 reform did not significantly impact investment in pilot firms or on major structures. Additionally, we obtain similar results in triple-difference analyses relative to these placebos. We provide more details behind this identifying variation in Section 4, where we also discuss different strategies that support the assumption that foreign firms’ investment is a suitable counterfactual for domestic firms’ investment.25

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.

25An alternative research strategy would be to use small-scale taxpayers as controls since the reform only targeted general taxpayers (as in Liu and Mao, 2019). 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. Because small-scale taxpayers only constitute 0.58% of the data, we do not expect to find significantly different results by including these observations.

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The VAT and the After-Tax Cost of Investment

To see how the reform affected the 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 948 RMB. 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 797.3 RMB. In total, the reform lowered the after-tax cost of investment by close to 15%.

The results of Table 1 can also be expressed by extending the framework of Hall and Jorgenson (1967) to include the effect of the VAT:

\[ TUCC = (1 + \nu) \frac{1 - \tau z}{1 - \tau}, \]  

(6)

where TUCC is the tax component of the user cost of capital, which depends on the VAT rate \( \nu \), the corporate income tax rate \( \tau \), and the present value of depreciation deductions \( z \). 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, \( (1 + \nu) \tau z \).

While Equation 6 is not a sufficient statistic for tax policy, we can use it to compare the VAT reform to potential policies and recent reforms. As illustrated by the example in Table 1, the VAT reform lowers the TUCC by 15% even if we ignore the impact of the reform on the resale price gap. Another approach to lowering the TUCC is to accelerate the depreciation schedule with the goal of increasing \( z \). However, even setting \( z = 1 \) through a policy of expensing (or 100% bonus depreciation) only lowers the TUCC by 6%. Recent bonus depreciation policies in the US decreased the TUCC by 2.4%–3.8% (Zwick and Mahon, 2017). Alternatively, consider the effects of changing the corporate income tax. Eliminating the income tax would only lower the TUCC by 6%. Barro and Furman (2018) calibrate that the recent US tax reform reduced the average TUCC by 4%. Finally, consider that undoing the effect of the VAT distortion on the TUCC would require an investment tax credit of 13.6%. This rate is greater than the last federal investment tax credit in

\[ \text{This calculation assumes a discount rate of 5%. According to Chinese accounting standards, the book value of the asset would be depreciated over 10 years using the straight-line depreciation method.} \]

\[ \text{Equivalently, the non-deductibility of investment purchases (prior to the reform) raised the after-tax cost of investment by 17%, relative to the post-reform value.} \]
the US (the 8% investment tax credit was eliminated in 1986, Cummins et al., 1994) as well as current state-level investment tax credits (which average 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 highlight the importance of studying the effects of indirect taxes on investment (e.g., Desai et al., 2004; Cline et al., 2005).

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, it had almost no effect on the TUCC of foreign and domestic firms. We observe almost no change in the TUCC of foreign and domestic firms before 2008. In 2009, we see that the VAT reform lowered the TUCC of domestic firms by 15%. The fact that the TUCC is not affected by the corporate income tax reform is reassuring for our analysis focused on the VAT reform. In addition, we report robustness checks that control for firms’ corporate income tax rates in our empirical analysis.

### 3 National Tax Survey Database

The main dataset we use comes from the National Tax Survey Database of the Chinese State Administration of Tax (SAT) from 2007 to 2011. The sampling of our dataset ensures that large firms are included every year and that smaller firms are included on a rotating basis. This dataset contains detailed information on VAT payments and investment in fixed assets. 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. 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. Appendix C provides additional details on our data sources.

Table 2 reports summary statistics of the firms in our sample, where we winsorize all variables at the 1% level. Our sample includes data on close to 315,000 firm-year observations. Because our main analysis relies on a balanced panel of firms that stay in the data for all five years and that have non-missing investment in all years, the number of observations used in our estimations is smaller. For robustness, we compare our results with a sample that also includes firms with missing investment spells. Average total investment is 4.7 million RMB. The policy we study 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 investment

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28Table F.1 shows these calculations by year and ownership. We implement Equation 6 using firms’ effective tax rates. We also assume $r = 5.26\%$, which implies $z = 80\%$. The TUCC for foreign firms increases from 1.023 to 1.035 between 2007 and 2009, a 1% difference. In contrast, the TUCC of domestic firms drops from 1.22 to 1.042.
As in many other countries, 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 a given year. In addition, 17% of firms replace more than 20% of their capital stock in a given year. These lumpy data patterns suggest that investment decisions are subject to fixed costs or partial irreversibility and motivate our study of how taxes affect lumpy investment decisions. By way of comparison, Zwick and Mahon (2017) report that 34% of firms in the US replace less than 1% of their capital and that 16% of firms replace more than 20%. As in other settings that rely on tax data to measure investment, we do not observe equipment sales.

Panel B of Figure 5 shows that, despite the large number of firms that do not invest in a given year, the investment rate has a serial correlation of 0.20. The positive correlation suggests firm investment is also subject to convex adjustment costs. The comparable number for the US is 0.40 (Zwick and Mahon, 2017), which reflects a lower likelihood of inaction.

Table 2 also reports data on firm sales, fixed assets, cash flow, and debt for both domestic and foreign firms. We use these variables as controls in some specifications. Since these variables show that foreign firms are larger than domestic firms, we follow Yagan (2015) by showing that our results are robust to 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.2, this inverse probability weighting (IPW) method ensures that our treatment and control groups are comparable (see Appendix D.1 for details).

We complement these tax data with two additional datasets. First, we use data on foreign direct investment records from the Ministry of Commerce (MOC). This dataset covers the universe of foreign firms in China and contains information on the type of foreign firms: 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 enjoyed the preferential VAT prior to the reform. Second, we merge our tax return data with survey responses from the Chinese Annual Survey of Manufacturing (ASM) from 2005 to 2006. This merge allows us to confirm that foreign and domestic firms have similar investment trends for a longer period of time.

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29The 10% average investment rate is unconditional on whether firms invest or not.
30Similarly, Levinsohn and Petrin (2003) report that 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 tax data as opposed to plant-level data, the statistics from Zwick and Mahon (2017) are more comparable to our setting.
31One concern is that this limits us from studying the role of partial irreversibility. However, as we discuss in Section 1, the VAT reform reduced partial irreversibility by decreasing the gap between the purchase and resale price of equipment. We use the fact that this change in partial irreversibility impacts the fraction of firms that make large investment decisions to quantify the role of partial irreversibility in lumpy investment decisions.
32The Chinese Annual Survey of Manufacturing (ASM) focuses on large firms with annual sales over 5 million RMB. In contrast, the National Tax Survey Database covers a wide range of firms, especially small firms. Appendix C provides more details on matching the ASM and the foreign direct investment records with the tax data.
Finally, we discuss the role of SOEs in the Chinese economy. SOEs make up 8.4% of all firms, account for 4% of large manufacturing firms (those with 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 now estimate the reduced-form effects of the reform on investment. Our main results rely on a difference-in-differences research strategy that exploits the different policy treatments of domestic and foreign firms prior to the reform. As detailed in Section 2, most domestic firms were not able to deduct input VAT on equipment before 2009. In contrast, foreign firms in encouraged sectors enjoyed preferential treatment that allowed them to deduct equipment from VAT. For this reason, the reform significantly reduced the investment cost for domestic firms, but it did not affect foreign firms. As with any difference-in-differences estimation, the identifying assumption that control and treated firms would have followed the same investment trends absent the reform is fundamentally untestable. While there may be reasons that foreign and domestic firms differ in their initial investment levels, we provide a battery of robustness checks that allay concerns that could confound the identification strategy. In addition, we show that our main results are robust to two alternative triple-differences strategies that rely on pilot firms and investment in non-eligible structures as additional controls. Finally, we provide evidence that extensive margin responses were important drivers of the effects of the reform. The combined evidence from these analyses limits the risk that our results are driven by other shocks that differentially impact foreign and domestic firms in this period.

4.1 Estimation Strategy and Baseline Results

We begin our analysis by estimating the following difference-in-differences specification:

$$Y_{ijt} = G_i \gamma_t + \mu_i + \delta_{jt} + X_{it}' \beta + \epsilon_{ijt},$$

where $Y_{ijt}$ is a firm-level measure of investment for firm $i$ in industry $j$ in year $t$. We measure extensive-margin responses with the fraction of firms with positive investment and intensive-margin responses with the investment rate. $G_i$ is an indicator for treatment that takes a value of 1 for domestic firms and 0 for foreign firms. The parameters of interest—$\gamma_t$—measure whether domestic

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33We use CIC (Chinese Industrial Classification) codes, which are comparable to 3-digit NAICS (North American Industry Classification System) codes.

34Our main specification only includes foreign firms with preferential treatment and excludes domestic firms in the pilot program.
and foreign firms have different trends prior to the reform as well as how investment in domestic firms is affected by the reform. \( \mu_i \) is a firm fixed effect that controls for firm-specific unobservables. Industry-year fixed effects \( \delta_{jt} \) control for industry-specific trends, which 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. These fixed effects assuage concerns that differential growth rates across provinces—e.g., due to differential concentrations of foreign and domestic firms—impact our results. Finally, we also show that our results are robust to including firm-level controls, \( X_{it} \), which include lagged cash-flow measures and corporate income tax rates, as well as quartic expansions of sales, firm age, and profit margin. We cluster standard errors at the firm level.

The key identifying assumption is that no other unobserved ownership-year-specific shocks coincide with the reform. We first show graphical evidence that domestic and foreign firms had similar investment trends before the reform. 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 (shown in red) and foreign firms (shown in navy) had similar trends prior to the reform. Panel B plots the same figure for the investment rate.\(^{35}\) Panels C and D report the coefficients \( \gamma_t \) in Equation 7 and show that the parallel trends observed in Panels A and B result in statistically insignificant estimates before 2009.\(^{36}\) These parallel trends are consistent with our assumption that domestic and foreign firms would have had the same investment trends absent the reform. After the reform, however, we see that domestic firms are more likely to invest (Panels A and C) and that their overall investment rate is also higher (Panels B and D). The red and navy lines in Panels A and C show that the likelihood of investing and the investment rate of domestic firms got closer to those of foreign firms after the reform.

To quantify the effects of the reform, Table 3 provides estimates of the following difference-in-differences regression using our tax data:

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

The first three columns in Panel A show that the reform increased the fraction of domestic firms reporting positive investment by close to 5 percentage points. To connect these results with the visual evidence in Figure 6, the light blue lines in Panels A and B normalize investment measures of foreign firms to those of domestic firms in 2008. These graphs show that the difference between the red and light blue lines line up very well with our regression estimates. Relative to a base participation of 50%, this change represents a 10% increase in the fraction of firms with positive investment. Given this large effect on the extensive margin of investment, it is crucial to have a

\(^{35}\)To create this figure, we use tax data that has information on equipment investment for years 2007 to 2011 as well as total investment data in the ASM from 2005 to 2006. Since the ASM only reports total investment, this figure assumes that firms invest in equipment and other assets proportionately. Finally, the light blue lines normalize investment outcomes to domestic levels in 2008.

\(^{36}\)We report the coefficients in Figure 6 in Table F.5. Table F.6 shows that these results are robust to the same robustness checks performed in our difference-in-differences analysis.
model that accounts for firms’ decisions to undertake new investment projects. 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%, the estimate from Table 3 represents a 36% increase in investment and implies a user-cost elasticity of 2.4 (≈ 36%/15%).

An important caveat is that our data measure capital expenditures, including both increases in the quantity of equipment capital and changes in the pre-tax price of investment goods. Since we do not see an increase in the aggregate price index of fixed asset investments, we conduct a simple decomposition of investment responses, assuming that part of the tax cut is passed through to capital suppliers. Using the passthrough estimate in Goolsbee (1998) of 56%, a back-of-the-envelope calculation implies that the 36% investment increase was driven by a 9.52% increase in the price of investment goods and a 24% increase in the quantity of investment.

4.2 Robustness Checks
Panel B of Table 3 shows that these results are robust to the set of firms used in our estimation. First, columns (1) and (4) show that our results are robust to weighting observations to ensure that foreign and domestic firms have similar observable characteristics. The remaining columns of Panel B show that our results are robust to including observations missing investment spells (Unbalanced) or to using all foreign firms (and not just those in preferential industries) as controls.

Panel C further shows that our results are robust to the set of firms used in our estimation. Since foreign firms are also more export intensive, one concern is that they are more severely affected by the financial crisis. Columns (1) and (4) show that we obtain similar estimates when we restrict the sample to non-exporters. Another concern is that SOEs differentially benefited from the stimulus.

\[ \text{In Appendix D, we also estimate the effect of TUCC changes on investment outcomes. We find that the tax-driven reduction in the cost of capital increased the investment-to-capital ratio by 0.19. This estimate is significantly lower than the recent estimate of 1.6 for the US (Zwick and Mahon, 2017) and the range of [0.5, 1] used by Hassett and Hubbard (2002) to summarize previous studies. One possibility is that recent estimates using variation from bonus depreciation find larger effects due to interactions with liquidity constraints. In contrast, the VAT reform does not impact the timing of firms’ cash-flow obligations. In Appendix D.4, we show that firms in industries with higher external finance dependence do not see larger increases in investment. Additionally, it may be possible that tax coefficients are not constant and that our smaller estimate is related to the much larger change in the TUCC, relative to prior studies.}

\[ \text{The decomposition is } 1 + 36\% = (1 + 9.52\%) \times (1 + 24\%).\]

\[ \text{Goolsbee (1998) finds that capital prices increased by 5.6\% when investment tax credits increased by 10\%, implying a 56\% pass-through rate to capital suppliers. House et al. (2017) redo these estimations using updated data over a longer period and find little evidence of price increases.}

\[ \text{We describe this inverse-probability weighting (IPW) strategy in Section 3. See Appendix D.1 for more details.} \]
program. Columns (2) and (4) show that we find very similar effects when we exclude SOEs from the estimation. Finally, our estimates are robust to also excluding publicly listed firms, as we show in columns (3) and (6).

Panel D of Table 3 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 corporate income tax rate 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. 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.

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%, which is close to the 36%–38% increase 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, with increases of 63%–72%. However, because the derivative of the IHS is greater near zero, these estimates place 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 on equipment. It is unlikely that firms could evade this tax since China’s VAT system with third-party reporting makes it likely that firms would get caught misreporting, especially when it comes to a large purchase, such as production equipment. One potential worry is that firms could avoid paying this tax by leasing instead of owning equipment. To explore this possibility, we estimate the effects of the reform on a measure of capital utilization that includes changes in leased equipment and investment. Table F.8 reports the results of these estimates and finds similar estimates to those

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41 Table F.7 additionally shows that we obtain similar estimates on firms with weak links to industries that benefited the most from the stimulus package.

42 This result is also visible in Figure 6, since there is no change in investment patterns in 2008.

43 When a firm acquires the equipment by financial leasing, the lease payment is measured by Minimum Lease Payment; that is, either the fair value of the leased assets or the discounted present value of rental payments over the lease term (including the value of purchase option if applicable), whichever is smaller. In data, around 1.4% of firms report positive leasing payments.
of Panel A of Table 3. This result suggests that evasion and avoidance are not important concerns for the interpretation of our reduced-form results.

4.3 Placebo Tests and Triple-Differences Analyses

To further explore our identifying assumption, we conduct two sets of placebo tests on firms and types of investment that were not affected by the reform. We first compare foreign firms and 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 have affected their investment decisions. Columns (2) and (5) of Table 4 report 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 precisely estimated and can rule out our main effects in columns (1) and (4). These results show that foreign and domestic firms did not face differential shocks at the time of the reform.

Our second placebo test uses the fact that the tax treatment of investment in structures was not affected by the reform. Column (3) of Table 4 estimates the extensive-margin effect of the reform on structures.\textsuperscript{44} We find small effects on the extensive margin that are less than half of those on equipment investment. These results suggest firms may need to retrofit existing structures through minor investments to accommodate new equipment. Consistent with this conjecture, column (6) of Table 4 finds no impact on the intensive margin of investment in structures. These results show that foreign and domestic firms had similar investment patterns in assets that were not affected by the reform.

We now expand our specification in Equation 8 by including our two placebo groups as additional controls. The advantage of these triple difference specifications is that—they ensure that the effects of the reform are not confounded by shocks that specifically affect foreign or domestic firms. Columns (2) and (3) of Table 5 report our triple-difference estimates on the extensive margin of investment. Relative to pilot firms and investment in structures, we find effects on equipment investment that are in the range of those in Table 3. Columns (5) and (6) also show that we obtain very similar estimates on the intensive margin as in our baseline difference-in-differences specification. Taken together with the two placebo tests, these results support our identifying assumption that foreign and domestic firms did not face differential shocks that would confound the effects of the reform.

\textsuperscript{44}To focus on major investment in structures and exclude minor investments in affiliated facilities to buildings (e.g., pipes and elevators), we define the extensive margin of investment on structures in Table 4 as expansions of the capital stock by more than 1%. Table F.9 shows that our results are robust to using different thresholds to define the extensive margin.
4.4 Tax Policy and Investment Spikes

We now provide further evidence that the effects of the VAT reform were driven by interactions between tax policy and the frictions that generate lumpy investment. Specifically, we show that the majority of the investment increase was due to the stimulus of additional investment spikes. We follow the literature (e.g., Cooper and Haltiwanger, 2006; Gourio and Kashyap, 2007) in defining investment spikes as events when the investment rate is greater than 20%. We generate three new measures of investment responses to measure the importance of spikes. First, we define a dummy variable that takes the value of 1 when the investment rate is greater than 20% (i.e., $D_{it}^{\text{spike}} = 1\{IK_{it} \geq 0.2\}$) to capture the effect of the reform on the likelihood of an investment spike. Second, we define the spike investment rate as the product of the investment rate and the investment spike dummy, i.e., $IK_{it}^{\text{spike}} = IK_{it} \times 1\{IK_{it} \geq 0.2\}$. Finally, we also consider the non-spike investment rate, i.e., $IK_{it}^{\text{non-spike}} = IK_{it} \times 1\{IK_{it} < 0.2\}$.

Table 6 reports difference-in-differences estimates of the effects of the reform on these outcomes. Columns (1)–(3) show that the fraction of firms undergoing investment spikes increased by 7.3 percentage points, which is greater than the effect on the likelihood that firms report positive investment (4.6 percentage points). This effect increases the spike rate from 16.6% to 23.9%. Columns (4)–(6) report effects on the spike investment rate and columns (7)–(9) report effects on the non-spike investment rate. Algebraically, the sum of the effects on the spike and non-spike investment rates add up to the total effect in Panel A of Table 3 (columns (4)–(6)). Comparing the spike investment rate to the total effect, we find that the 23.9% of firms with a spike are responsible for 86%–92% ($\approx 0.861$ to $0.872$) of the effect on the investment rate. These results further show the importance of accounting for extensive-margin responses when studying the effects of tax policy on investment behavior.\footnote{In the Appendix D.5, we provide two pieces of evidence that these effects might be driven by the impact of the reform on partial irreversibility. First, we use the fact that firms with excess VAT payments continued to face a gap between the purchase and resale prices of capital. The reform had much smaller effects on the extensive-margin response of these firms. Second, we test whether the reform had different effects on industries that rely on specifically tailored assets. We show that, since the pre-reform price wedge induced by the VAT was less important in industries with more asset specificity, the reform leads to smaller effects on investment in these industries.}

Overall, the results of this section show that China’s 2009 VAT reform had a large effect on the investment of domestic firms. Relative to the magnitude of the reform, however, the estimates imply elasticities in the lower range of the previous literature (Hassett and Hubbard, 2002). Moreover, we find that spikes in investment account for the majority of the investment response to the reform. While these estimates evaluate the current reform, the results from Section 1 suggest that the estimated effects are not sufficient to evaluate the effects of other reforms.
5 Estimating a Dynamic Investment Model

The previous section provides evidence that taxes interact with investment frictions. To quantify the importance of these interactions and to study the fiscal effectiveness of alternative policy tools, we now estimate the dynamic model of investment outlined in Section 1. We estimate this model in two steps. First, we use the dynamic panel data model of Blundell and Bond (2000) to estimate the parameters that govern firms’ static profit functions and productivity processes. Second, we estimate adjustment frictions using a simulated method of moments approach that targets pre-reform investment statistics as well as the reduced-form effects estimated in Section 4. By showing that our model can reproduce the effects of an actual reform, we ensure that the model predicts reasonable investment responses to tax changes.

5.1 Estimating the Profit Function and Decomposing Productivity

Recall that our model of firm profit (Equations 4–5) implies:

\[ \pi_{it} = \theta k_{it} + (1 - \theta)a_{it} = \theta k_{it} + (1 - \theta)(b_t + \omega_i + \varepsilon_{it}), \]

where \( \pi_{it} \) is log profit and \( k_{it} \) is log capital. The profitability term \( a_{it} \) is composed of an aggregate term \( b_t \), an idiosyncratic transitory shock \( \varepsilon_{it} \), and a firm-specific permanent term \( \omega_i \). \( \omega_i \) captures unobserved firm-level heterogeneity as well as unmodeled frictions. \( \varepsilon_{it} \) follows an AR(1) process with persistence and standard deviation \( (\rho_{\varepsilon}, \sigma_{\varepsilon}) \). \( b_t \) also follows an AR(1) process with parameters \( (\rho_b, \sigma_b) \). \( \omega_i \) is normally distributed with mean zero and standard deviation \( \sigma_{\omega} \). The main parameters of this equation are the curvature of the profit function, \( \theta \), and the parameters governing productivity \( (\rho_{\varepsilon}, \sigma_{\varepsilon}, \rho_b, \sigma_b, \sigma_{\omega}) \).

Two sets of challenges prevent us from estimating Equation (9) directly. First, it is hard to measure economic profit using accounting data. To overcome this issue, we follow Cooper and Haltiwanger (2006) by assuming that profits are proportional to revenue.\(^{46}\)

A second set of concerns with Equation (9) is that capital may be measured with error and that it may also be correlated with productivity. We address these concerns by using the system GMM estimator of Blundell and Bond (2000). This estimator uses the assumption that the idiosyncratic productivity term \( \varepsilon_{it} \) is an AR(1) process to rewrite Equation (9) in a more favorable form. Specifically, using the fact that \( \varepsilon_{it} = \rho_{\varepsilon}\varepsilon_{i,t-1} + e_{it} \), where \( e_{it} \) is an innovation term independently and identically distributed across firms and over time, and that \( \varepsilon_{i,t-1} \) can be expressed as a function of

\(^{46}\)Appendix A.2 gives examples where this assumption holds either with a DRTS production function and perfect competition or with constant-elasticity-of-substitution (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 \( a_{Rit} = b_t + \omega_i + \varepsilon_{it} \). When logarithms are taken, the profit and revenue shocks differ by a constant, which implies that \( a_{Rit} \) and \( a_{it} \) have the same persistence and variance.
lagged capital and revenue, we obtain the following equation:

\[ r_{it} = \rho_r r_{i,t-1} + \theta k_{i,t} - \rho_m \theta k_{i,t-1} + b_{i,t} + \omega_i + m_{i,t} - \rho_r m_{i,t-1} + (1 - \theta) e_{it}, \tag{10} \]

where we replaced \( \pi_{it} \) with \( r_{it} \) (log-revenue), where \( m_{it} \) is a classical measurement error (or an unexpected optimization error), and where \( b_{i,t} \) and \( \omega_i \) are year and firm-level fixed effects.\(^{47}\) We can then write this equation in first differences to obtain:

\[ \Delta r_{it} = \rho_r \Delta r_{i,t-1} + \theta \Delta k_{i,t} - \rho_m \theta \Delta k_{i,t-1} + \Delta b_{i,t} + \Delta m_{i,t} - \rho_r \Delta m_{i,t-1} + (1 - \theta) \Delta e_{it}. \tag{11} \]

To avoid problems arising from endogenous capital, we instrument this equation using lagged revenue \( \Delta r_{it-s} \) and capital \( k_{it-s}, \ s \geq 3 \). Finally, to avoid potential problems of weak instruments, we use the system GMM estimator of Blundell and Bond (2000), which jointly estimates Equation (10) using changes in lagged revenue \( \Delta r_{it-s} \) and capital \( \Delta k_{it-s}, \ s \geq 2 \) as additional instruments.\(^{48}\)

Panel B of Table 7 reports the results of this estimation. This procedure delivers an estimate of \( \theta = 0.734 \). To better understand how \( \theta \) affects the curvature of the profit function, we compute the implied markup in a simple model of monopolistic competition. Our estimate of \( \theta \) yields a markup of 1.224, which is comparable to values used in the literature.\(^{49}\) We use this estimate of \( \theta \) to compute firm-level productivity \( \hat{a}_{it} = r_{it} - \hat{\theta} k_{it} \).

The system GMM estimator also delivers an estimate of the persistence coefficient \( \rho_e \) of 0.860.\(^{50}\) We then recover the distributions of \( b_t, \omega_i, \) and \( \varepsilon_{it} \) by decomposing the variance of the estimated productivity \( \hat{a}_{it} \)—see Appendix E.3 for more details. Due to the short panel nature of our data, aggregate shocks play a relatively small role. Our estimate of the standard deviation of aggregate shocks \( \sigma_e \) is 0.010, and the estimate of its persistence \( \rho_e \) is 0.009. Nonetheless, including aggregate productivity shocks in our framework allows us to consider counterfactual scenarios where changes to tax policy coincide with shocks to aggregate productivity. We estimate that the standard deviation of transitory shocks \( \sigma_e \) equals 0.529 and that the permanent heterogeneity term has a standard deviation of \( \sigma_w = 0.854 \). As a result, a large fraction of the dispersion in profitability comes from permanent heterogeneity across firms.\(^{51}\) However, despite the fact that the distributions of the

\(^{47}\)This follows from writing Equation (9) in terms of revenue \( (r_{it} = \theta k_{it} + (1 - \theta) b_i + (1 - \theta) \omega_i + (1 - \theta) \varepsilon_{it} + m_{it}) \), replacing \( \varepsilon_{it} \) with \( \rho_r \varepsilon_{i,t-1} + \varepsilon_{it} \), then replacing \( \varepsilon_{i,t-1} \) with \( (r_{it-1} - \theta k_{it-1})/(1 - \theta) - b_{it-1} - (1 - \theta) \omega_{it} - m_{it-1}/(1 - \theta) \), and finally setting \( b_{i,t} = (1 - \theta)b_{i,t} - \rho_r (1 - \theta) b_{i,t-1} \) and \( \omega_{it} = (1 - \theta)(1 - \rho_e) \omega_i \). See Appendix E for more details.

\(^{48}\)The exclusion restriction is that \( \Delta e_{it} \) is uncorrelated with the twice-lagged values of revenue and capital and that \( e_{it} \) is uncorrelated with the twice-lagged changes in revenue and capital.

\(^{49}\)We show this in Appendix E.2 by assuming that the firm has a CRS production function and faces CES demand. In this case, the markup excluding the capital cost is constant and equals \( \frac{1}{\theta} \left( \frac{\alpha (1 - \sigma)}{(1 - \sigma) + \sigma} \right) + 1 \), where \( \alpha \) is the share of capital in value added and \( \sigma \) is the share of materials. Assuming \( \alpha = 0.5 \) (Bai, Hsieh, Qian et al., 2006) and \( \sigma = 0.7 \) (Jones, 2011), the implied markup is 1.224. For comparison, the ratio of total sales to major business costs in the data is 1.223.

\(^{50}\)Cooper and Haltiwanger (2006) estimate a value of 0.85, and Winberry (2020) fixes this parameter at 0.9.

\(^{51}\)As in David and Venkateswaran (2019), accounting for permanent heterogeneity is important when estimating investment models with adjustment costs.
capital stock and firm size depend on permanent heterogeneity, investment dynamics are mostly determined by transitory shocks.

5.2 Estimating Adjustment Costs

We now estimate the adjustments costs of investment using the method of simulated moments (MSM). This approach simulates the investment decisions of a large number of firms by numerically solving the dynamic investment model in Section 1 subject to the profit function and productivity shocks estimated in the previous section. We simulate these firms until the distribution reaches the steady state. We then measure key investment statistics in the simulated data, and we also simulate a VAT reform mirroring the difference-in-differences research design of Section 4.\textsuperscript{52} Finally, the estimated adjustment cost parameters are those that best reconcile the simulated data with the actual data.

Before we detail the MSM estimator, we first discuss three sets of fixed parameters. First, we set the discount factor $\beta$ to 0.95. Second, we set the corporate income tax rate to the average effective rate in the data, 15.4%, and we set the VAT rate to 17%—the statutory rate before the reform. Third, we set the present value of depreciation deductions $z$ to 0.803.\textsuperscript{53}

We estimate two models that differ by the distribution of fixed costs. The first model is based on Cooper and Haltiwanger (2006) and assumes a degenerate distribution $G(\xi)$ with a single mass point at $\bar{\xi}$. The second model assumes that $\xi$ is drawn from a uniform distribution over the interval $[0, \bar{\xi}]$, as in Caballero and Engel (1999); Khan and Thomas (2008); Winberry (2020). We estimate three parameters for each model: the economic rate of depreciation $\delta$, the convex adjustment cost parameter $\gamma$, and the parameter of the fixed cost distribution $\bar{\xi}$.

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 simulated moments. The estimate $\hat{\phi}$ minimizes the criterion function:

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

We include two sets of moments in $\hat{m}$:

1) The first set of moments ($m^4$) is based on pre-reform stationary moments (as in Figure 5):

(a) the mean and the standard deviation of the investment rate;

(b) the empirical distribution of the investment rate, defined by the fraction of firms with an investment rate below 10%, 20% (i.e., 1-spike rate), and 30%; and

\textsuperscript{52} We simulate two sets of 10,000 firms for the simulated difference-in-differences: a set of treatment firms that experience a drop in the VAT rate from $\nu = 17\%$ to zero and a set of control firms unaffected by the reform. We assume the reform is unexpected and permanent and occurs at the initial steady state. To match our empirical analysis, the simulated difference-in-differences measure effects on investment over a three-year period.

\textsuperscript{53} This value follows from using an interest rate $r = 5.26\% (= 1/\beta - 1)$ to depreciate deductions using a straight-line depreciation rule over a 10-year period.
(c) the 1-year autocorrelation of the investment rate.

These moments are widely used to identify adjustment costs in the investment literature. As in other settings that rely on tax data (e.g., Zwick and Mahon, 2017; Winberry, 2020), we do not observe equipment sales. Since asset sales are often used to disentangle the roles of fixed costs and partial irreversibility (e.g., Cooper and Haltiwanger, 2006), a potential concern is that excluding sales data will impact our estimates of fixed costs. Because China’s 2009 VAT reform reduced partial irreversibility by lowering the purchase price of equipment, we use the effects of the reform on the intensive and extensive margins of investment to overcome this concern.

2) The second set of moments \( m^B \) is based on the difference-in-differences (DID) estimates reported in Table 3:

(a) the DID estimate of the effect of the reform on the investment rate; and

(b) the DID estimate of the effect of the reform on the fraction of firms with positive investment.

We use these reduced-form moments to validate our adjustment-cost estimates based on the moments in \( m^A \) and as a way to provide overidentifying restrictions.

To compute the simulated moments, \( m(\phi) \), we simulate the investment statistics for each value of \( \phi \). Similarly, we mirror the actual reform by measuring the effects of a simulated VAT reform for three years after the tax change.

We use the identity weighting matrix in our estimation. This allows the estimate \( \hat{\phi} \) to be informed by both \( m^A \) and \( m^B \).

Identification

We briefly discuss the identification of the model parameters since they follow standard arguments in the investment literature. The first set of stationary moments \( m^A \) is sufficient to identify the three structural parameters. The economic depreciation rate \( \delta \) is closely tied to the average investment rate.

The convex adjustment cost \( \gamma \) affects investment moments through two channels. First, a higher \( \gamma \) increases the serial correlation of investment by incentivizing firms to smooth investment over

\(^{54}\)For example, among other moments, Cooper and Haltiwanger (2006) use the spike rate and the autocorrelation coefficient; Winberry (2020) uses the standard deviation of the investment rate and the spike rate; and Clementi and Palazzo (2016) use the standard deviation and autocorrelation of the investment rate.

\(^{55}\)Models that rely on \( m^A \) moments result in similar estimates when \( W \) is the identity matrix or when we use the bootstrapped variance-covariance matrix of the moments. While the moments \( m^B \) are precisely estimated (with t-stats around 4 or 8), the cross-sectional moments in \( m^A \) have very small variances (with t-stats between 100-500). For this reason, models that weight \( m^A \) and \( m^B \) using the variance-covariance matrix give very little weight to the moments in \( m^B \).
time. It also decreases the likelihood of an investment spike. Second, a higher \( \gamma \) lowers firms’ steady-state capital levels and—by increasing the relative importance of fixed costs—leads to less frequent investment spells. When \( \gamma \) is sufficiently large, the second channel dominates and a higher \( \gamma \) leads to a smaller serial correlation of investment (see Figure F.4). In contrast, a higher \( \bar{\xi} \) increases the fraction of firms with lumpy investment as well as the standard deviation of the investment rate. At the same time, a higher \( \bar{\xi} \) also reduces the serial correlation of investment.

One concern is that additional sources of partial irreversibility may bias our estimates of \( \gamma \) and \( \bar{\xi} \) that only rely on the moments in \( m^A \). The reduced-form moments \( m^B \) help assuage this concern. As we discuss in Section 1, \( \gamma \) and \( \bar{\xi} \) both lower the effect of a VAT cut on the investment rate. In addition, a lower \( \bar{\xi} \) would increase the effect of the reform on the extensive margin. By simultaneously matching a reform that eliminated an important source of partial irreversibility, these moments help us evaluate the robustness of our estimates.

As a complement to this discussion, we conduct a systematic analysis of how these moments affect \( (\hat{\delta}, \hat{\gamma}, \hat{\bar{\xi}}) \) in Appendix E.4 by calculating the sensitivity measure proposed by Andrews, Gentzkow and Shapiro (2017).

### Estimates of Adjustment Costs

Table 8 reports estimates of the adjustment costs \( \gamma \) and \( \bar{\xi} \) and the depreciation rate \( \delta \) and compares the data moments with the simulated moments. The second row reports estimates from a model that only uses the pre-reform stationary statistics \( m^A \) as target moments and where \( \xi \) is fixed at a single value. While this model does a relatively good job of matching the spike rate and the average investment rate, it overpredicts the fraction of firms with an investment rate below 10% as well as the standard deviation of the investment rate. The low convex cost and high fixed cost in this model result in a “bang-bang” investment function where firms either do not invest at all or replace more than 30% of their capital. Notably, there are no firms with investment rates in the 10%-30% range. As a consequence, the model predicts that the VAT reform would have increased both the fraction of firms investing and the investment rate by 15 percentage points. These effects are 3–4 times larger than our reduced-form estimates.

The third row of Table 8 reports estimates of a model that only targets pre-reform stationary statistics \( m^A \) and that allows \( \xi \) to be i.i.d. with a uniform distribution. The estimate of \( \bar{\xi} \) implies a larger upper bound for the fixed costs, and we also estimate a larger value of \( \gamma \) relative to the first model. The randomness of the fixed cost lowers the serial correlation of investment and results in an overall better match of the whole investment rate distribution. In particular, the model implies that 14% of firms have investment rates between 10% and 30% (relative to 17% in the data).

One potential concern is that the lack of data on equipment sales makes it hard to estimate fixed costs separately from the role of partial irreversibility. Because the VAT reform decreased partial irreversibility, it is important to match cross-sectional investment patterns to characterize the role of lumpy investment in aggregate impulse response functions to a policy reform.

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56Baley and Blanco (2019) show that it is important to match cross-sectional investment patterns to characterize the role of lumpy investment in aggregate impulse response functions to a policy reform.
irreversibility by lowering the price of new equipment, we can validate our baseline model estimates using the reduced-form effects of the reform. While this model does not target the difference-in-differences estimates, it does a relatively good job of matching the effects of the reform. The model predicts slightly smaller increases in the fraction of firms investing (3 percentage points) and in the investment rate (2.8 percentage points) than those measured in the data.\footnote{The data moments in Table 8 characterizes the investment behavior of domestic firms. As we show in Figure 6, foreign and domestic firms have similar investment rates after the reform, but foreign firms continue to have a higher propensity to invest. In Appendix F.3, we show that our model results in similar simulated difference-in-differences estimates when we allow foreign firms to have different fixed costs that rationalize preexisting differences in investment patterns. These results show that accounting for differences in fixed adjustment costs explains cross-sectional differences between domestic and foreign firms, and that these level differences do not impact our difference-in-differences estimates.}

The fourth row of Table 8 reports estimates of a model that targets both $m^A$ and $m^B$. This model results in very similar estimates of the structural parameters. However, the small changes in the estimates result in an improved fit of the standard deviation and the serial correlation of investment. Not surprisingly, the model results in a slightly better fit of the moments $m^B$.\footnote{Figure F.3 shows that the criterion function is concave and rises sharply around the estimated parameters.} The model predicts an increase of 3.6 percentage points in the fraction of firms investing and an increase of 3 percentage points in the investment rate. It is worth noting that the last two models have slightly lower average investment rates. Overall, relative to the average investment rate, the last two models predict that the VAT reform would increase investment by 35\%–40\%, which is remarkably close to our reduced-form estimates.

As we discuss in Section 4, the majority of the increase in the investment rate following the reform was due to additional investment spikes. We use the estimated effect of the reform on investment spikes as additional overidentifying moments. Table F.17 reports that the model predicts a 5.8-percentage-point increase in the likelihood of an investment spike (relative to a measured 7.3 percentage points). Similarly, the model predicts an increase in the spike investment rate of 3.3 percentage points (relative to a measured 3.5 percentage points). These results show that our model is able to quantitatively match the empirical finding that the extensive margins of investment are key determinants of the effects of the VAT reform. Moreover, because the effects of tax policy depend on the relative magnitudes of fixed costs and partial irreversibility, this overidentification check is evidence that our estimated model properly captures the importance of these frictions.

Finally, we now consider the economic magnitude of the estimated adjustment costs. The estimated convex cost parameter $\hat{\gamma}$ is 1.434. Given the model’s average investment rate of 8\%, the convex adjustment cost at the average investment rate would amount to $0.46\%(= \frac{1.434}{2} \times (0.08)^2)$ of capital. To grasp the magnitude of the fixed adjustment, note that the estimated upper bound of 0.118 implies an average fixed cost of 5.95\% of the desired capital stock. However, since firms select into investment, the average fixed cost paid by firms with positive investment is only 2.4\% of the desired capital stock. Table 7 collects all of the parameters that define our model.

Overall, the model does a remarkable job of matching stationary investment statistics and the
effects of an actual tax reform as well as untargeted moments that highlight the importance of investment spikes. Given these results, we expect the estimated model to provide a solid foundation to compare the effects of alternative tax policies.

6 Simulating Alternative Tax Reforms

As we show in Section 1, the effectiveness of different types of tax incentives at stimulating investment depends on how tax policies impact the extensive margin of investment. We now use the estimated dynamic model to quantify which policies are more effective at stimulating investment and firm value relative to their total fiscal cost. We first build intuition by studying the effects of different changes to the VAT cut and the corporate income tax rate and by considering the introduction of an investment tax credit.\(^{59}\) We then quantify the effects of potential reforms that are closely modeled on the recent US tax reform. Throughout, we consider the effects of unexpected and permanent tax policy changes.

6.1 Extensive-Margin Responses and Fiscal Effectiveness

One of the benefits of our model is that it allows us to provide a menu of policy options for government officials who want to stimulate investment. Figure 7 allows a government official to compare reforms that result in a similar loss of tax revenue. Panel A of Figure 7 compares the effects on investment of a corporate income tax cut versus those of a VAT cut. The solid blue line reports the effects of reducing the corporate income tax rate from 15.4% to 1%. Each marker in the line represents the simulated effects of reducing the corporate income tax rate to a given rate, where we calculate the effects over a 10-year window. For example, the x-axis shows that reducing the corporate income tax rate to 10% results in a tax revenue loss of 20% (which includes VAT and corporate income tax revenue). The y-axis shows that this reform results in an investment increase of close to 15%. The dashed red line allows us to compare this corporate income tax cut with a VAT cut that has the same effect on tax revenue. Specifically, cutting the VAT rate to 3% would result in a similar revenue loss as the corporate income tax cut discussed above, but would increase investment by 35%.

By comparing investment and tax revenues, Figure 7 helps us determine which policies are more effective at stimulating investment.\(^{60}\) The blue line in Panel A shows that the effect on investment

\(^{59}\)As in Section 1, we refer to a VAT cut as a reduction in the wedge driven by the lack of capital deductibility from the VAT base, not by a change in the VAT rate. For this reason, our simulated effects on VAT revenue only include the effect of allowing for this deductibility.

\(^{60}\)In contrast, approaches that rely on TUCC elasticities to forecast the effects of different stimulus policies may not correctly capture extensive-margin responses. This result is partly driven by the fact that policies with similar effects on the TUCC can lead to different extensive-margin effects. As we show in Appendix F, VAT and corporate income tax cuts with the same TUCC change can have different investment elasticities and differ in their fiscal effectiveness.
is always smaller than the effect on tax revenue and implies an investment-to-tax-revenue elasticity
of close to 0.67.\(^{61}\) Because the dashed red line is always above the 45-degree line, the investment-to-
tax-revenue elasticity is always greater than one. These simulations show that a VAT cut is more
effective at stimulating investment for a given revenue cost than a corporate income tax cut.

The superior fiscal effectiveness of the VAT reform is driven by extensive-margin responses, as
they impact both the cost of these reforms and their effects on investment. First, extensive-margin
responses drive the costs of different policies. Appendix Figure F.5 decomposes the changes in tax
revenues into direct tax losses and tax revenues from additional investment. This figure shows that
total tax revenue changes are primarily driven by direct tax losses, which are larger than additional
tax revenues from behavioral responses. Corporate income tax cuts are more costly since they
benefit all firms—even those in the inaction region—while only firms that invest benefit from a
VAT cut. Second, following the intuition from Figure 4 in Section 1, cuts to the VAT rate narrow
the inaction region, leading more firms to undertake new investment projects. To illustrate the
importance of this mechanism, we use our simulated data to study the composition of investment
responses. In the case of the VAT reform (setting \(\nu = 0\)), of the overall 43% increase in investment,
64% was driven by extensive-margin responses. In contrast, while cutting the corporate income tax
rate to 7.4%—at the cost of a similar impact on revenue—increases investment by 20%, only 34% of
this increase was due to extensive-margin responses.

Panel B of Figure 7 compares the effects of a VAT cut to those of introducing an investment tax
credit.\(^{62}\) In contrast to Panel A, this graph shows that the effects of an investment tax credit mirror
those of a VAT cut very closely. The reason for this result is that the investment tax credit also
lowers the partial irreversibility of investment.\(^{63}\) This result is important for settings that feature
additional sources of partial irreversibility, such as those driven by imperfections in the market for
used capital. This graph shows that the lessons of China’s 2009 VAT reform are applicable to other
countries since an investment tax credit can lessen these distortions.

### 6.2 Simulating Tax Reforms

We now build on the intuition from Figure 7 by studying a broader menu of policy alternatives,
including ones recently enacted as part of the US tax reform. We consider the effects of the following
policies:

1. the VAT reform with a 17% tax rate reduction (our baseline);

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\(^{61}\)Given that the different corporate income tax cuts fall in a straight line, this investment-to-tax-revenue elasticity
is constant across the different rate cuts.

\(^{62}\)We model the effect of an investment tax credit on the purchase price of capital as follows: 
\(TUCC = \frac{(1+\nu)(1-\tau_z)}{1-\tau} - ITC\). Note that an investment tax credit does not affect the book value of capital or its resale price.

\(^{63}\)The slight difference in the effectiveness of these policies is due to the fact that the VAT cut reduces the value
of depreciation deductions while the investment tax credit does not.
2. a corporate income tax cut from the current effective tax rate of 15.4% to 10%;

3. 100% bonus depreciation (expensing), which allows firms to deduct capital expenditures immediately;

4. a version of the Tax Cuts and Jobs Act (TCJA) that combines expensing with the corporate income tax cut; and

5. a 17% investment tax credit.

Table 9 simulates the effects of these policies on investment, firm value, and tax revenues. Column (1) shows that the baseline VAT cut increased aggregate investment by 43%. We also find a relatively large increase of 10% in the fraction of firms investing and an increase of 11% in firm value. Because the VAT on equipment purchases raised a considerable amount of revenue, this simulation entails a revenue loss of 28%. To compare the fiscal effectiveness of different policies, we also report the ratios of the percentage changes in investment and firm value to the percentage change in tax revenue. In the case of the VAT reform, we find that investment increases by 1.6% for every 1% loss in tax revenue. Similarly, firm value increases by 0.41% for a 1% loss in tax revenue.

We now consider the effects of tax policies that are modeled after the recent US tax reform but that have a similar tax cost to the VAT reform. Column (2) reports the effects of a corporate income tax cut, which has smaller effects on both investment and the fraction of firms that invest in any given year. Column (3) studies the effects of a bonus depreciation policy that allows firms to immediately deduct the full cost of investment. This policy has similar effects on investment to those of the corporate income tax cut but is less effective at raising firm value. Column (4) combines the effects of a corporate income tax cut and bonus depreciation, mirroring the TCJA in the US. This policy increases aggregate investment by roughly half of the effect of the VAT reform, even though the tax revenue losses from both policies are similar. This result shows that addressing distortions that generate partial irreversibility may be more important for emerging economies like China than lowering the tax cost of investment.

The last policy we consider is an investment tax credit of 17%. As shown in Figure 7, this policy is very closely related to a VAT cut since it also reduces the partial irreversibility of investment. For this reason, it is no surprise that column (5) reports ratios of investment and firm value to the tax revenue loss that are comparable to those of the VAT cut. This again shows that the result that tax policy can directly affect the lumpiness of investment is applicable outside the case of China.

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64 This 35% reduction in $\tau$ is comparable to the decrease in the corporate income tax following the TCJA in the US.

65 As in Winberry (2020), firm value is the sum of the value function and the tax value of depreciation allowances. Figure F.6 compares the effects of different VAT, corporate income tax, and investment tax credit incentives on firm value.

66 Bonus depreciation has a smaller effect on firm value than a corporate income tax cut since this policy only benefits firms that invest. Our simulated TCJA raises overall investment by less than the sum of the corporate income tax cut and bonus depreciation, since the tax cut lowers the value of depreciation deductions.
6.3 Model Robustness

We now show that our baseline simulation results are robust to a number of extensions.\textsuperscript{67} First, we explore the general equilibrium effects of increasing capital prices or interest rates. In our baseline model, we assume that the pre-tax price of capital goods is constant. One concern is that the price of capital increases as demand goes up (e.g., Goolsbee, 1998). We relax this assumption by calibrating an upward-sloping capital supply curve at different supply elasticities that range from 2.54 to 14, where 2.54 is based on a 56\% pass-through rate in Goolsbee (1998) and 14 is the upper bound elasticity estimated in House and Shapiro (2008).\textsuperscript{68} Table F.18 shows that a smaller supply elasticity results in a smaller aggregate effect on investment. When the supply elasticity is 2.54, which is translated into a 9.52\% increase in the pre-tax capital price, the aggregate investment response and investment-to-tax revenue is around two-fifths of our baseline simulation result. Nevertheless, a supply elasticity at 10 leads to similar, though slightly smaller, results compared to our baseline simulation.\textsuperscript{69} Additionally, we also consider the possibility that borrowing rates increase as a result of the VAT cut. To allow for this possibility, we assume that interest rates have a proportional increase to the TUCC. Table F.20 simulates the effects of the VAT cut assuming interest rate elasticities with respect to the TUCC that range from -0.05 to -0.25. We find slightly smaller effects when we allow for this mitigating effect. However, even for the largest effect of the TUCC on interest rates, the increase in investment is 80\% of the baseline increase. While a full general equilibrium calculation is beyond the scope of this paper, these extensions show that our main results are not sensitive to allowing for changes in interest rates or in the price of capital goods.

As a second extension, we consider the role of imperfections in the used capital market. A potential concern is that the resale price is smaller than the purchase price, even without taxes. To explore this possibility, we increase the degree of partial irreversibility by reducing the resale price from 1 (as in the baseline model) to 0.80 (as in Cooper and Haltiwanger, 2006; Ramey and Shapiro, 2001). Column (3) of Table F.19 shows that our results are virtually unaffected by this change.

While we have shown that our empirical results in Section 4 are not affected by other stimulus policies, it may be important to account for aggregate productivity shocks related to the financial crisis in our counterfactual analysis. Column (4) of Table F.19 shows that our results are very similar when the reform coincides with a (permanent) one-standard-deviation drop in aggregate productivity.\textsuperscript{70}

\textsuperscript{67}Appendix F.1 provides additional discussion of these extensions.

\textsuperscript{68}Using updated data over a longer period, House et al. (2017) redo the regressions in Goolsbee (1998) and find little or no equipment price increases in response to tax incentives, indicating that the supply elasticity of capital goods is larger than earlier literature suggests. The authors argue that the supply of capital goods is more elastic in an open economy where firms can purchase equipment abroad.

\textsuperscript{69}Equilibrium effects on capital prices would likely impact both domestic and foreign firms. In Appendix F.3, we show that our simulated difference-in-differences estimates are similar when we allow for the reform to impact equipment prices.

\textsuperscript{70}While the effects of the VAT reform are robust to coincidental productivity shocks, we do not study whether the effectiveness of fiscal policy depends on the business cycle (Winberry, 2020) or on whether other forms of partial
Finally, we address the fact that our simulations of the effects of corporate income tax cuts on investment abstracted from interactions between the corporate income tax rate and both adjustment costs and borrowing costs. First, we modify our model to consider the possibility that adjustment costs are tax deductible. In this case, a corporate income tax cut directly impacts the importance of fixed and convex adjustment costs, making the pre-tax value of these costs larger. Following this intuition, Table F.21 shows that we find smaller effects following a corporate income tax cut when we assume that adjustment costs are deductible. Second, we now consider the fact that debt is a preferred form of financing since interest payments are tax deductible (Graham, 2000). Because a corporate income tax cut reduces the value of tax-deductible financing, accounting for this effect on the after-tax cost of financing may reduce the effectiveness of corporate income tax cuts at stimulating investment. Table F.21 confirms that when a corporate income tax cut affects a firm’s financing costs (through the weighted average cost of capital, WACC), it is less effective at stimulating investment. Therefore, our main result—that policies that directly impact the extensive margins of investment are more effective at stimulating investment—is only strengthened by assuming that adjustment costs or interest costs are tax deductible.

7 Conclusion

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

First, in models with frictions that generate lumpy investment, the user cost of capital is not a sufficient statistic for how tax policy affects investment. Accounting for how tax policy interacts with investment frictions is necessary to obtain a complete picture of the effects of tax policy on investment behavior.

Second, we analyze an important tax policy change in China that reduced the after-tax cost of investment by close to 15%. We use comprehensive tax data and a difference-in-differences research design to document that, as a result of the reform, domestic Chinese firms increased investment by 36% relative to foreign firms. We also find that the majority of the increase in investment was due to extensive-margin responses, including additional investment spikes.

Finally, we estimate an empirical dynamic model of investment that embeds adjustment frictions and relevant tax parameters. We use the reduced-form estimates of the reform to show that the model can reproduce the effects of an actual tax reform. The model shows that policies that have larger extensive margin responses, such as eliminating a tax on investment or subsidizing it through an investment tax credit, are more effective at stimulating investment than policy tools that simply lower the cost of investment, such as a corporate income tax cut. Because other policies—such as irreversibility endogenously respond to fiscal policy (Lanteri, 2018).

Note that these assumptions do not affect our estimation or our simulation of changes to the VAT system. However, they impact the simulation of changes to the CIT.
investment tax credits and sales taxes—can directly impact extensive-margin investment decisions, these results have important implications for tax policy beyond China.

By showcasing the importance of lumpy investment for tax policy, this paper also identifies important questions for future research. First, in this paper we focus on the short-term effects of tax policy changes. Accounting for how tax policy interacts with the frictions that generate lumpy investment may also impact the long-run effects of tax reform (e.g., through allocative efficiency, as in Baley and Blanco, 2021). Second, our model abstracts from capital-embodied technological change. Extending models of lumpy investment to account for this force could help evaluate the government’s mission to use tax policy as a way to incentivize technology upgrading, and may explain documented effects of the reform on productivity growth (e.g., Liu and Mao, 2019).

Data Availability Statement
The data underlying this article were provided by Fudan University by permission. For the purpose of replication, researchers can contact the data center director at Fudan University, Yiyi Xin at econdata@fudan.edu.cn. Authors will assist with any reasonable replication attempts following publication. Please contact Zhikuo Lin at lzhikuo@gmail.com. However, all replication scripts and detailed information on data construction, empirical estimation, and computation are available at DOI: https://doi.org/10.5281/zenodo.6349325.

References


Figure 1: Cross-Country Comparison of Investment

Notes: This figure displays investment in the United States, the European Union, and China from 2000 to 2017 as reported by the OECD. The figure shows that investment in China has long surpassed investment levels in the US and the European Union and that it has increased drastically since 2000.
Figure 2: Effects of Partial Irreversibility

A. Marginal Product of Capital

![Graph showing the marginal product of capital (MPK) against productivity.]

Notes: These figures plot the marginal product of capital and the optimal capital level 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 dashed 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 against productivity.
Figure 3: Effects of Fixed Costs

A. Optimal Profit

![Graph showing the optimal profit against productivity with fixed costs.]

**Notes:** These figures plot the optimal profit and capital against productivity in a simple static model with fixed costs only. In Panel A, the solid line indicates the optimal profit without any frictions (\(\Pi^*\)). The dot-dashed line indicates the optimal profit net of fixed cost (\(\tilde{\Pi}^* = \Pi^* - \xi k^*\)). The dashed line indicates the profit evaluated at the initial capital level (\(\Pi^0\)). The red line indicates the upper envelope of \(\tilde{\Pi}^*\) and \(\Pi^0\), which is the optimal profit in the presence of fixed costs. In Panel B, the dot-dashed line indicates the frictionless optimal capital level (\(k^*\)) against productivity. The dashed line indicates the initial capital \(k_0\). The red line indicates the optimal capital level taking into account the fixed costs.
**Figure 4: Effects of Tax Policy and Investment Frictions on Policy Functions**

**A. Pre-reform**

**B. VAT Reform (17% to 12.9%)**

**C. Corporate Income Tax Reform (15.4% to 0)**

**D. Bonus Depreciation (10 years to 1 year)**

*Notes: These figures display the policy functions against productivity in a dynamic investment model before and after the VAT reform, a corporate income tax reform, and the introduction of bonus depreciation, respectively. The three reforms generate the same reduction in the tax component of the user cost of capital. In Panel A, the dotted straight line indicates the optimal policy (the logarithm of the capital stock in the next period as a function of productivity) in the frictionless case. The dashed line indicates the optimal policy before the reform in the presence of all investment frictions—convex costs, fixed costs and partial irreversibility. Panel B adds the policy function (the red line) after reducing the VAT rate from 17% to 12.9%; Panel C plots the policy function after reducing the corporate income tax rate from 15.4% to 0; Panel D plots the policy function after a bonus depreciation policy that fully accelerates the timing of depreciation deductions.*
Figure 5: Distribution and Autocorrelation of the Investment Rate

A. Distribution of the Investment Rate

B. Autocorrelation of the Investment Rate

Notes: These figures display notable features of the investment in our tax data. Panel A plots the distribution of the investment rate of domestic firms before the reform. We winsorize the investment rate at the top 5%. Panel B plots the investment rate against the one-period-lagged investment rate. We group the lagged investment rate into equally sized bins from 0 to 1 and then calculate the average investment rate for each bin. The red line is the OLS linear fit line.
Figure 6: Reduced-Form Effects of China’s 2009 VAT Reform

A. Extensive Margin

Before Reform

After Reform

B. Investment Rate

Before Reform

After Reform

C. Extensive Margin

D. Investment Rate

Notes: These figures show the effects of the VAT reform on the investment of domestic and foreign firms. Panel A plots the fraction of firms investing in equipment in each year for domestic firms (the treatment group) and foreign firms (the control group). The red line represents investment of domestic firms, the navy blue line represents investment of foreign firms, and the light blue line represents the investment of foreign firms that is normalized to that of domestic firms in 2008. To construct the figure, we first use tax data to calculate the fraction of firms investing in equipment for each year from 2007 to 2011 for domestic and foreign firms. In addition, we complement the tax data with Chinese Annual Survey of Manufacturing (ASM) data. That is, we merge the 2005-2006 ASM data with the tax data and calculate the fraction of firms with positive total investment for each year for domestic and foreign firms, which allows us to extend the pre-reform investment to 2005. For easier comparison, we set 2008 as the base year and align the fraction of firms investing in equipment for foreign firms to that for domestic firms in 2008, as showed in the light blue line. Similarly, Panel B plots the average investment rate of equipment for each year for domestic and foreign firms. Panel C plots the differences in the fraction of firms investing between domestic and foreign firms. The red dots correspond to the estimates from the tax data from 2007 to 2011; The blue dots correspond to the estimates from the extended data with ASM. Again, for easier comparison, we set 2008 as the base year. That is, we subtract the difference in the fraction of firms investing between domestic and foreign firms in 2008 from the difference of each year. Similarly, Panel D plots the differences in average investment rate in equipment between domestic and foreign firms.
Figure 7: Simulating Alternative Tax Reforms: Elasticity of Investment to Tax Revenue

A. VAT Cuts vs. Corporate Income Tax Cuts

B. VAT Cuts vs. Investment Tax Credit

Notes: These figures plot the simulated percentage change in aggregate investment to the percentage loss in tax revenue at different rates of VAT cut, corporate income tax cut and investment tax credit policies. For each tax rate, we solve the model, simulate investment and tax revenue, and calculate the corresponding changes in each outcome. Panel A plots the percentage change in aggregate investment against the percentage change in tax revenue. The red solid curve corresponds to VAT cuts from 17% to different rates. The blue dotted line corresponds to corporate income tax cuts from 15.4% to different rates. Similarly, Panel B compares the percentage change in tax revenue from VAT cuts with that from an investment tax credit.
### Table 1: VAT Reform and Investment Costs: Example of a 1,000 RMB Equipment Purchase

<table>
<thead>
<tr>
<th></th>
<th>Pre-reform</th>
<th>Post-reform</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAT-Included Cost</td>
<td>1170</td>
<td>1170</td>
<td></td>
</tr>
<tr>
<td>Deductible from VAT</td>
<td>0</td>
<td>170</td>
<td>+ 170</td>
</tr>
<tr>
<td>Book Value</td>
<td>1170</td>
<td>1000</td>
<td>-170</td>
</tr>
<tr>
<td>PV of Total Depreciation</td>
<td>948.6</td>
<td>810.8</td>
<td>-137.8</td>
</tr>
<tr>
<td>Deductible from Corporate Income Tax</td>
<td>237.2</td>
<td>202.7</td>
<td>-34.5</td>
</tr>
<tr>
<td>After-Tax Cost of Investment</td>
<td>932.8</td>
<td>797.3</td>
<td>-135.5</td>
</tr>
</tbody>
</table>

*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.
Table 2: Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>All Firms</th>
<th>Domestic Firms</th>
<th>Foreign Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>N</td>
</tr>
<tr>
<td>Equipment Investment (million RMB)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>3.15</td>
<td>12.37</td>
<td>221,069</td>
</tr>
<tr>
<td>Investment Rate</td>
<td>0.10</td>
<td>0.19</td>
<td>215,813</td>
</tr>
<tr>
<td>Log Investment</td>
<td>6.50</td>
<td>2.31</td>
<td>118,913</td>
</tr>
<tr>
<td>Other Characteristics (million RMB)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Investment</td>
<td>4.70</td>
<td>17.27</td>
<td>258,736</td>
</tr>
<tr>
<td>Fixed Assets</td>
<td>33.77</td>
<td>100.32</td>
<td>310,003</td>
</tr>
<tr>
<td>Sales</td>
<td>133.80</td>
<td>390.83</td>
<td>314,595</td>
</tr>
<tr>
<td>Cash Inflow</td>
<td>126.74</td>
<td>384.06</td>
<td>283,694</td>
</tr>
<tr>
<td>Debt</td>
<td>85.13</td>
<td>241.28</td>
<td>313,074</td>
</tr>
</tbody>
</table>

Notes: This table presents summary statistics of equipment investment and other variables from tax data that are used in the analysis. Investment is reported in million RMB and deflated by the national price index of equipment investment. The investment rate is defined as the ratio of investment to the capital stock measured in terms of the book value of net fixed assets, unconditional on investing. Total investment includes investments in equipment, buildings and structures, and other productive capital. Fixed assets are measured in terms of the book value, deflated by the national price index of fixed-asset investment. Sales are the total sales including domestic and export sales. Cash flow is the business cash inflow from the cash-flow statement. Debt is the total debt at the end of the year. Variables are winsorized at the 1% level.
### Table 3: Estimates of Difference-in-Difference Regressions

<table>
<thead>
<tr>
<th></th>
<th>Extensive Margin: % Firms</th>
<th>Intensive Margin: Investment Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>A. Main Results</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.058***</td>
<td>0.044***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>N</td>
<td>86870</td>
<td>86870</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>B. Robustness Checks: Sample Selection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.066***</td>
<td>0.053***</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>N</td>
<td>82785</td>
<td>221069</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>C. Robustness Checks: Different Samples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.067***</td>
<td>0.046***</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>N</td>
<td>61195</td>
<td>83653</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>D. Additional Firm-Level Controls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.043***</td>
<td>0.048***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>N</td>
<td>83418</td>
<td>86284</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>E. Alternative Investment Measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.449***</td>
<td>0.404***</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.054)</td>
</tr>
<tr>
<td>N</td>
<td>20720</td>
<td>20720</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Notes:** This table uses tax data to estimate difference-in-difference regressions of the form:

\[ Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + X_{it}'\beta + \epsilon_{ijt}, \]

where \( Y_{it} \) is equipment investment, \( G_i \) is the treatment indicator set to 1 for domestic firms and 0 for foreign firms, and \( Post_t \) is the post-reform indicator set to 1 for years since 2009. \( \mu_i \) is the firm fixed effect. Panel A reports the baseline results. The dependent variable for columns (1)–(3) is a dummy variable set to 1 if a firm makes an investment; the dependent variable for columns (4)–(6) is firm’s investment rate. Columns (1) and (4) control for industry-year fixed effects. Columns (2) and (5) control for province-year fixed effects. Columns (3) and (6) include both fixed effects. Panel B reports robustness checks: column (1) weights observations by the inverse probability weighting (IPW); column (2) uses an unbalanced panel; column (3) uses all foreign firms as the control group. Panel C reports another set of robustness checks: column (1) exclude exporters; column (2) exclude state-owned firms (SOEs); column (3) excludes public firms. Panel D augments the regression with additional controls. Column (1) controls for firms’ net cash flow scaled by the capital stock. Column (2) adds quadratics in sales, profit margin, and age. Column (3) adds the statutory corporate income tax rate. Panel E runs the baseline specification with the 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 Placebo Tests

<table>
<thead>
<tr>
<th></th>
<th>Extensive Margin: % Firms Investing</th>
<th></th>
<th>Intensive Margin: Investment Rate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Baseline</td>
<td>(2) Pilot</td>
<td>(3) Structures</td>
<td>(4) Baseline</td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.046***</td>
<td>-0.010</td>
<td>0.023**</td>
<td>0.038***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.032)</td>
<td>(0.011)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>N</td>
<td>86870</td>
<td>13932</td>
<td>81270</td>
<td>81270</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Notes: This table uses tax data to estimate difference-in-difference regressions of the form:

\[ Y_{it} = \gamma G_i \times Post_t + \mu_i + \delta_{jt} + \eta_{st} + \epsilon_{it}, \]

where \( Y_{it} \) is a measure of investment, \( G_i \) is the treatment indicator set to 1 for domestic firms and 0 for foreign firms, and \( Post_t \) is the post-reform indicator set to 1 for years since 2009. \( \mu_i \) is the firm fixed effect. \( \delta_{jt} \) and \( \eta_{st} \) are industry-year and province-year fixed effects, respectively. Column (1) and (4) report the baseline results, where the non-pilot domestic firms are the treatment group and foreign firms with preferential treatment are the control group. Column (2) and (5) use domestic firms and foreign firms in the pilot program as the treatment and control groups, respectively. Column (3) and (6) use investment in buildings/structures as dependent variables, and the treatment and control groups are the same as those in the baseline analysis. The dependent variable for column (1) and (2) is a dummy variable set to 1 if a firm makes an investment in equipment; the dependent variable for column (3) is a dummy variable set to 1 if a firm makes an investment in structures with investment rate larger than 1 percent. The dependent variable is firm’s equipment investment rate for column (4) and (5), and is firm’s structures investment rate for column (6). All regressions include firm fixed effects as well as industry-year and province-year fixed effects. Standard errors are clustered at the firm level.
### Table 5: Estimates of Triple-Differences Regressions

<table>
<thead>
<tr>
<th></th>
<th>Extensive Margin: % Firms Investing</th>
<th>Intensive Margin: Investment Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Baseline</td>
<td>Pilot</td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.046***</td>
<td>-0.036</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>Domestic × Post × Non-Pilot</td>
<td>0.080**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td></td>
</tr>
<tr>
<td>Domestic × Post × Equipment</td>
<td>0.036**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td></td>
</tr>
</tbody>
</table>

| N                       | 86870        | 100040 | 162540     | 81270        | 92875 | 162540     |
| Industry × Year FE      | Y           | Y      | Y          | Y            | Y     | Y          |
| Province × Year FE      | Y           | Y      | Y          | Y            | Y     | Y          |

**Notes:** This table uses tax data to estimate triple-differences regressions. For comparison, columns (1) and (4) report the baseline estimates from difference-in-difference regressions. Columns (2) and (5) use firms in the pilot program as an additional control group and estimate the triple-differences regression of the form:

\[ Y_{it} = \gamma_1 G_i \times Post_t + \gamma_2 P_i \times Post_t + \gamma_3 G_i \times P_i \times Post_t + \mu_i + \delta_{jt} + \eta_{st} + \epsilon_{it}, \]

where \( Y_{it} \) is equipment investment, \( P_i \) is an indicator set to 1 for pilot firms and 0 for non-pilot firms, \( G_i \) is the treatment indicator set to 1 for domestic firms and 0 for foreign firms, and \( Post_t \) is the post-reform indicator set to 1 for years since 2009. \( \mu_i \) is the firm fixed effect. \( \delta_{jt} \) and \( \eta_{st} \) are industry-year and province-year fixed effects, respectively. Columns (3) and (6) use investment in structures as an additional control group and estimate the triple-differences regression of the form:

\[ Y_{kit} = \gamma_1 G_i \times Post_t + \gamma_2 A_k \times Post_t + \gamma_3 G_i \times A_k \times Post_t + \gamma_4 G_i \times A_k + \mu_i + \delta_{jt} + \eta_{st} + \epsilon_{kit}, \]

where \( k \) denotes the investment type, i.e., equipment and structures. \( A_k \) is an indicator set to 1 for investment in equipment and 0 for investment in structures. The other variables are defined the same as above. The dependent variable for columns (1)–(3) is a dummy variable set to 1 if a firm makes an investment; the dependent variable for columns (4)–(6) is the firm’s investment rate. All regressions include firm fixed effects as well as industry-year and province-year fixed effects. Standard errors are clustered at the firm level.
Table 6: Estimates of Difference-in-Difference Regressions: Investment Spikes

<table>
<thead>
<tr>
<th></th>
<th>Extensive Margin:</th>
<th>Intensive Margin:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Firms Investing with $IK \geq 0.2$</td>
<td>Spike Investment Rate</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Domestic × Post</td>
<td>0.070***</td>
<td>0.071***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>N</td>
<td>81270</td>
<td>81270</td>
</tr>
<tr>
<td>Industry × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Province × Year FE</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Notes: This table uses tax data to estimate difference-in-difference regressions of the form:

$$Y_{it} = \gamma G_i \times \text{Post}_t + \mu_i + \delta_{jt} + \eta_{st} + \epsilon_{it},$$

where $Y_{it}$ is a measure regarding investment spikes, $G_i$ is the treatment indicator set to 1 for domestic firms and 0 for foreign firms, and $\text{Post}_t$ is the post-reform indicator set to 1 for years since 2009. $\mu_i$ is the firm fixed effect. $\delta_{jt}$ and $\eta_{st}$ are industry-year and province-year fixed effects, respectively. The dependent variable for columns (1)–(3) is a dummy variable set to 1 if the investment rate is larger than 0.2, i.e., $D^{\text{spike}}_i = 1\{IK_{it} \geq 0.2\}$, where $IK_{it}$ is the investment rate of firm $i$ at time $t$. The dependent variable for columns (4)–(6) is the spike investment rate, defined by $IK^{\text{spike}}_i = IK_{it} \times 1\{IK_{it} \geq 0.2\}$; the dependent variable for columns (7)–(9) is the nonspike investment rate, defined by $IK^{\text{non-spike}}_i = IK_{it} \times 1\{IK_{it} < 0.2\}$. All regressions include firm fixed effects. Standard errors are clustered at the firm level.
Table 7: Summary of Assigned and Estimated Parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Value (S.E)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A. Fixed Parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta$ 0.950</td>
</tr>
<tr>
<td>VAT rate</td>
<td>$\nu$ 0.170</td>
</tr>
<tr>
<td>CIT rate</td>
<td>$\tau$ 0.154</td>
</tr>
<tr>
<td>PV depreciation schedule</td>
<td>$z$ 0.803</td>
</tr>
<tr>
<td><strong>Panel B. Parameters Estimated via System GMM</strong></td>
<td></td>
</tr>
<tr>
<td>Profit curvature</td>
<td>$\theta$ 0.734 (0.031)</td>
</tr>
<tr>
<td>Persistence firm transitory shocks</td>
<td>$\rho_\varepsilon$ 0.860 (0.011)</td>
</tr>
<tr>
<td>SD firm transitory shocks</td>
<td>$\sigma_\varepsilon$ 0.529 (0.005)</td>
</tr>
<tr>
<td>SD firm permanent shocks</td>
<td>$\sigma_\omega$ 0.854 (0.007)</td>
</tr>
<tr>
<td>Persistence aggregate shocks</td>
<td>$\rho_\omega$ 0.009 (0.152)</td>
</tr>
<tr>
<td>SD aggregate shocks</td>
<td>$\sigma_\omega$ 0.010 (0.001)</td>
</tr>
<tr>
<td><strong>Panel C. Parameters Estimated by MSM</strong></td>
<td></td>
</tr>
<tr>
<td>Convex cost</td>
<td>$\gamma$ 1.434 (0.066)</td>
</tr>
<tr>
<td>Upper bound of fixed cost</td>
<td>$\bar{\xi}$ 0.118 (0.004)</td>
</tr>
<tr>
<td>Economic depreciation rate</td>
<td>$\delta$ 0.071 (0.001)</td>
</tr>
</tbody>
</table>

Notes: This table summarizes the parameters from Section 5. Panel A displays the parameters we set (i.e., those not estimated) to simulate the model. Specifically, we set tax parameters to their empirical counterparts. Panel B summarizes the estimated parameters from the first-stage production function estimation and productivity decomposition. In particular, we estimate the profit curvature ($\theta$) and the persistence of firm transitory shocks ($\rho_\varepsilon$) using system GMM. Standard errors are reported in parentheses. The rest of the parameters in Panel B are the results of the productivity decomposition (see Section 5.1). The standard errors of those parameters (i.e., $\sigma_\varepsilon$, $\sigma_\omega$, $\rho_\omega$, and $\sigma_\omega$) are calculated from 100 bootstrap samples. Panel C displays the estimated adjustment frictions and depreciation rate using the method of simulated moments (MSM) (see Section 5.2). Standard errors of those parameters (i.e., $\gamma$, $\bar{\xi}$, and $\delta$) are calculated from 100 bootstrap samples.
<table>
<thead>
<tr>
<th>Model</th>
<th>Parameters</th>
<th>Moments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma$</td>
<td>$\bar{\xi}$</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Data</td>
<td>0.102</td>
<td>0.720</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Fixed</td>
<td>0.427</td>
<td>0.074</td>
</tr>
<tr>
<td>(A)</td>
<td>(0.141)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Uniform</td>
<td>1.594</td>
<td>0.118</td>
</tr>
<tr>
<td>(A)</td>
<td>(0.090)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Uniform</td>
<td>1.434</td>
<td>0.118</td>
</tr>
<tr>
<td>(A+B)</td>
<td>(0.066)</td>
<td>(0.004)</td>
</tr>
</tbody>
</table>

Average Fixed Cost (conditional on investing): 0.024

Notes: This table displays estimates of the convex adjustment cost $\gamma$, upper bound of fixed cost $\bar{\xi}$, and economic depreciation rate $\delta$ using the method of simulated moments. Columns (4)–(11) show the simulated moments: 1) Set A includes pre-reform static moments, namely, the average investment rate; the fraction of firms with an investment rate smaller than 0.1, 0.2 and 0.3, the one-period serial correlation of the investment rate, and the 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 the pre-reform static moments. Meanwhile, we simulate another counterfactual economy where the reform does not take place using the same productivity shocks. 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 parentheses calculated using 100 bootstrap samples. The second row assumes the fixed cost is non-random and uses the pre-reform static moments for estimation. The third and the fourth rows (i.e., Uniform (A) and Uniform (A+B)) assume 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 a positive investment. The standard errors of the estimates are reported in parentheses below the point estimates.
Table 9: Simulating Tax Reforms

<table>
<thead>
<tr>
<th>Percentage Change in</th>
<th>Corporate Tax Cuts</th>
<th>Bonus Depreciation</th>
<th>Tax Cuts and Jobs Act: (2)+(3)</th>
<th>Investment Tax Credit: 17%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline 17%</td>
<td>15.4% to 10%</td>
<td>(2)+(3)</td>
<td>17%</td>
</tr>
<tr>
<td>Aggregate Investment</td>
<td>0.434</td>
<td>0.147</td>
<td>0.099</td>
<td>0.217</td>
</tr>
<tr>
<td>Fraction of Firms Investing</td>
<td>0.098</td>
<td>0.062</td>
<td>0.032</td>
<td>0.084</td>
</tr>
<tr>
<td>Tax Revenue</td>
<td>-0.279</td>
<td>-0.191</td>
<td>-0.131</td>
<td>-0.286</td>
</tr>
<tr>
<td>Firm Value</td>
<td>0.114</td>
<td>0.103</td>
<td>0.017</td>
<td>0.116</td>
</tr>
<tr>
<td>Ratios of Investment to Tax Revenue</td>
<td>1.559</td>
<td>0.769</td>
<td>0.753</td>
<td>0.757</td>
</tr>
<tr>
<td>Firm Value to Tax Revenue</td>
<td>0.410</td>
<td>0.540</td>
<td>0.134</td>
<td>0.407</td>
</tr>
</tbody>
</table>

Notes: This table displays the simulated responses to five scenarios: column (1) considers a reduction of the VAT rate from 17% to zero, i.e., our baseline reform; column (2) considers a reduction of the effective corporate income tax rate from 15.4% to 10%; column (3) considers a policy that allows firms to fully depreciate capital expenses immediately, i.e., bonus depreciation; column (4) considers a combination of a corporate income tax cut and bonus depreciation, i.e., a version of the Tax Cuts and Jobs Act (TCJA); and column (5) considers a policy granting a 17% investment tax credit. We report percentage (%) changes in the outcomes of interest. For instance, our baseline 17% VAT cut increases aggregate investment by 43% over a 10-year window.