

Capital Gains Taxation and Investment Dynamics*

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Abstract

This paper quantifies the long-run effects of reducing capital gains taxes on aggregate investment. We develop a dynamic general equilibrium model with heterogeneous firms, which face discrete capital gains tax rates based on their firm size. We calibrate our model by targeting important micro moments as well as the difference-in-differences estimate of the capital elasticity based on our institutional setting in Korea. We find that the firm-size reform that reduced the capital gains tax rates from 24 percent to 10 percent for the affected firms increased aggregate investment by 1.61 percent in the steady state, with the short-run effects overstating the effects by 1 percentage points. Additionally, a counterfactual analysis where we set the uniformly low tax rate of 10 percent reveals that aggregate investment rose by 6.89 percent in the long-run. We also find that general equilibrium effects through prices are substantial in our simulation. Taken together, our findings suggest that reducing capital gains tax rates would substantially increase investment in the short-term, and accounting for dynamic and general equilibrium responses is important for understanding the aggregate effects of capital gains taxes.

JEL Codes: E22, E62, G11, H25, O16.

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1 Introduction

A central question in the study of fiscal policies is the degree to which tax incentives affect aggregate investment to stimulate growth and job creation in the economy. While there is mixed empirical evidence on how much investment responds to lower corporate tax rates (Desai and Goolsbee (2004); House and Shapiro (2008); Yagan (2015); Zwick and Mahon (2017)), a recurring topic that features prominently in policy debates is the extent to which a reduction in capital gains tax rates would stimulate the economy by inducing corporate investment (Rappeport 2017).

Assessing the tax effects on investment is challenging in part because it is difficult to find large and exogenous variation in tax rates across firms. To control for business cycle effects, we need variation in the tax rates across firms, but capital gains tax rates vary at the investor level in most settings. Furthermore, quantifying the aggregate effects of capital gains taxes is challenging in a reduced-form analysis as it is difficult to account for general equilibrium and dynamic effects without a structural model.

In this paper, we quantify the effects of reducing capital gains taxes on aggregate investment by estimating a dynamic general equilibrium model. Building upon a standard investment model, we micro-found its main features based on our institutional setting, where capital gains tax rates vary across firms, and a policy reform that reduced the tax rates for firms affected by the new regulations. We discipline our model's key parameters using our difference-in-differences estimate of the capital stock elasticity with respect to capital gains taxes. We then use the model to reproduce the short-run investment response after the reform and to predict the long-run effects of reducing capital gains taxes on aggregate investment.

To recover the reduced-form estimates used in our model, we leverage the setting in Korea, where capital gains tax rates vary by firm size, mainly determined by revenue and labor thresholds prior to the reform in 2014. An investor in a small firm faces a tax rate of 10 percent when selling a stock, while an investor in a big firm faces a tax rate of 24 percent. In 2014, the government unexpectedly changed the regulations on firm size by eliminating the labor threshold and setting a new revenue cutoff based on the average over the past three years. From this change, a large number of firms that were above either of the old cutoffs, but below the new threshold, became reclassified as small firms, while firms above the new cutoff were unaffected by the reform. To identify the tax effects on real outcomes, we compare firms that experienced a tax reduction with unaffected firms in a difference-in-differences framework using proprietary firm-level data.

Comparing firms that experienced a reduction in tax rates from 24 percent to 10 percent with unaffected firms, we find that the affected firms increased investment by 36 percent and capital stock by 9 percent within three years after the reform. The estimates suggest that affected firms increased investment by roughly 1.6 billion dollars, which is 3 percent of total investment in the economy after the reform. We show that our results are internally consistent by providing the evidence of the parallel pre-trends on the key outcomes and a set of robustness checks and placebo tests.

To quantify the aggregate effects, we develop a dynamic general equilibrium model with heterogeneous firms building on a framework by [Gourio and Miao \(2010\)](#). We extend their model by incorporating three important features to match the key empirical moments and the institutional setting in Korea. First, our model incorporates a discrete change in capital gains tax rates based on firm size to be consistent with the institutional feature in Korea. Second, we introduce the state-of-the-art random fixed costs of capital adjustments as in [Khan and Thomas \(2008\)](#) to capture lumpy investment at the micro-level. Third, we assume a Poisson process for shocks to productivity as in [Midrigan \(2011\)](#) and [Bachmann and Bayer \(2014\)](#), which is a key element for matching the empirical estimate of the capital stock elasticity with respect to capital gains tax rates.

Based on this framework, we structurally estimate the capital adjustment costs and an idiosyncratic productivity process using a simulated method of moments (SMM). We target micro moments of the investment to capital ratio, firms' revenues, and the difference-in-differences estimate of the capital stock elasticity. Although firm density is not targeted, our model generates a set of firms bunching below the thresholds that determine the tax rates, consistent with our observation in the data.

One primary feature that distinguishes our model from the existing models ([Gourio and Miao 2010](#)) is that our model targets the difference-in-differences estimate of the capital stock elasticity with respect to capital gains tax rates based on the reform in 2014.¹ To match this moment, we conducted the same policy reform in our model to calculate the average response of treated firms in the short-run partial equilibrium. The partial equilibrium framework is appropriate for calibration because the reform in 2014 affected a small portion of firms in the economy, whose aggregate investment response comprised only 3 percent of total investment in the economy.

A key finding from our model is that the effect of reducing capital gains taxes depends

¹There are studies that discipline structural models based on empirical estimates using natural policy experiments to analyze the effectiveness of other policy instruments. [Kaplan and Violante \(2014\)](#) examine the 2001 tax rebate episode in the US; [Buera, Kaboski and Shin \(2012\)](#) evaluate the micro-finance programs in India and Thailand.

on the persistence of firm size. In each period, firms expand or shrink in size, creating firm-size dynamics around each threshold. We calibrate a productivity process more persistent than an AR(1) process with Gaussian shocks by allowing productivity shocks to arrive infrequently with a Poisson probability as in [Midrigan \(2011\)](#) and [Bachmann and Bayer \(2014\)](#). The Poisson probability makes the conditional distribution of the next period's productivity have more peakedness around the mean with heavier tails. The "peakedness effect" increases the probability of a treated firm becoming a large firm again, while the "heavy tail effect" does the opposite. Our simulation shows that the former effect dominates the latter. Consequently, our model with Poisson shocks generates much larger capital responses than does the model by [Gourio and Miao \(2010\)](#).

Using these key moments, we conduct a counterfactual analysis of extending the scope of the 2014 reform to the overall economy to assess the aggregate effects of reducing capital gains taxes. In the partial equilibrium setting, the reform had a large impact on the economy, increasing aggregate consumption, output, capital, and labor by 2.4, 2.6, 3.6, and 2.8 percent, respectively, in the long run.

In the general equilibrium framework, which reflects the interest rate and wages responses, we find that the overall effects were much more dampened, with aggregate consumption, output, capital, and labor increasing by only 0.40, 0.60, 1.61, and 0.21 percent, respectively. Therefore, ignoring the general equilibrium effects of the interest rate and wage would overstate the aggregate responses. The reform also features rich dynamics of aggregate variables along the transitional path. In the short run, aggregate consumption drops by 0.14 percent, labor supply increases by 0.55 percent, and investment increases by 2.57 percent. Hence the consumption equivalent welfare increases by 0.18 percent along the transitional dynamics, compared to 0.3 percent in the steady state.

Moreover, we conduct two related counterfactual policy analyses. One analysis is eliminating the tax differences based on firm size by imposing a uniform capital gains tax rate of 10 percent. This counterfactual analysis relates to a large literature on how distortionary policies may reduce aggregate productivity. [Restuccia and Rogerson \(2008\)](#) show that policies distorting prices faced by individuals and firms could lead to large reductions in aggregate output and productivity. [Guner, Ventura and Xu \(2008\)](#) find size-dependent policies could be costly to the economy. [Garicano, Lelarge and Van Reenen \(2016\)](#) and [Gourio and Roys \(2014\)](#) estimate the costs of a size-dependent policy that regulates firms with 50 employees or more in France. In this paper, we find that eliminating distortions created by the size-dependent capital gains tax system would increase aggregate consumption, output, capital, and labor by 1.92, 2.81, 6.89, and 1.10 percentage

points. Additionally, in the second counterfactual analysis where we set the capital gains tax rate to zero, aggregate consumption, output, capital, and labor increased by 2.78, 4.50, 12.39, 1.50 percentage points compared to the pre-2014 steady state.

We show that matching micro moments in the data is crucial for our model and for policymakers. If we completely eliminate size thresholds that determine capital gains tax rates, a model without Poisson shocks that does not match our difference-in-differences estimate of the capital elasticity would under-predict the increases in aggregate capital, labor, consumption, and output by 42 percent, 32 percent, 38 percent, and 37 percent, respectively. Therefore, targeting the difference-in-differences estimate of the capital stock response is crucial for building a general equilibrium model to quantify the aggregate effects of capital gains taxes. Policymakers designing an effective capital tax system may benefit from the implication of our key finding that model-based predictions might severely understate (or overstate) the true aggregate responses if they do not target the micro moments based on both cross-sectional and time-series variation in tax rates.

This paper's main contribution is twofold. First, to the best of our knowledge, this paper is the first to incorporate both firm-level and time-series variation in capital gains tax rates into a dynamic general equilibrium model, which has the main advantage of identifying the model's key parameters based on the institutional setting. Second, this paper's findings contribute to the long-standing academic and policy debates on how much capital taxation affects aggregate investment, providing supporting evidence for a class of the "traditional-view" models predicting that lowering capital tax rates would increase investment by reducing the marginal cost of investment (Feldstein 1970; Poterba and Summers 1983).

Our paper bridges the gap between a strand of studies that rely solely on reduced-form methods to estimate the tax effects on investment, and another strand of structural papers that consider the aggregate responses without fully capturing firm dynamics at the micro-level. By bridging this gap, our model not only matches the short-term firm responses to a change in capital gains tax rates in the partial equilibrium, as we see in the data, but also consistently predicts the long-run aggregate responses that reflect the general equilibrium price effects and dynamic effects from adjustment frictions.

The remainder of the paper is organized as follows. Section 2 describes the institutional background for the capital tax system in Korea. In Section 3, we present our reduced-form strategy and data to estimate key moments in our model. We describe our model in Section 4, present estimation results in Section 5, and conduct welfare analyses in Section 6. In Section 7, we discuss policy implications of our findings. Section 8 concludes.

2 Institutional Background

This section provides a brief overview of the institutional background on the capital gains tax system and the policy reform in Korea.² The main institutional features are that the tax rate varies by firm size and that the government unexpectedly changed the regulations on firm size in 2014, reducing the tax rates for firms that became re-classified as small due to the new regulations. Note that we use a conversion ratio of 1000 Korean Won to 1 U.S. dollar throughout our paper to describe the setting and interpret the findings.

In Korea, capital gains tax rates differ mainly based on firm size. An investor in a large firm faces a capital gains tax rate of 24 percent on average, depending on his ownership rate, while an investor in a small firm faces a flat tax rate of 10 percent regardless of his share.³ In 2014, the government changed the regulations on firm size, which generated time-series variation in the tax rates within a given firm affected by the rule change. To identify the effects of capital gains taxes on corporate outcomes, we compare the outcomes of firms affected by this reform with the outcomes of unaffected firms for our identification strategy.

Until 2014, the government enforced the following rules for firm size. For the main sectors (manufacturing, construction, production and information services) used in our analysis, a firm has to jointly satisfy the following criteria to be classified as small: total revenues below 100 million dollars and average employees below 300. In 2014, the government unified the regulations on firm size by eliminating the labor threshold and by setting a new threshold, namely, "average revenue" over the past years. The primary intention of the reform was to simplify the rules on firm size. This reform was discussed by government officials and policymakers in early 2014, its approval was announced in August, 2014, and the reform was implemented by the end of 2014; therefore, this policy change came as a shock to affected firms. Moreover, investors did not know which firms were actually affected by this reform until firm size was publicly announced through annual audit reports in the first quarter (March) of 2015. This is evidenced by stock price responses for affected firms, as compared to unaffected firms (Moon 2018). We describe how we use this reform for identification in Section 3.

Although the reform eliminated the labor threshold and changed the revenue threshold into an average over the past three years for all sectors, it increased the average revenue

²Additional details on the institutional background can be found in Moon (2018).

³In Korea, investors pay capital gains taxes on their realized gains when they sell their stock, whether publicly or privately, and when firms initiate share purchases. More details on the historical capital gains tax rates in Korea can be found at this website: www.nts.go.kr/eng.

threshold to 150 million dollars only for the manufacturing sector. Even though the average revenue threshold did not increase to 150 million dollars for the construction or the production and information service sectors, many firms within these sectors became reclassified as small firms because these sectors had many firms above the labor cutoff, but below the revenue cutoff, prior to the reform. Furthermore, the manufacturing, construction, and production and information services sectors account for about 80 percent of firms in our sample period, and hence we use these as the main sectors.

An important thing to note is that, when measuring a firm's accounting variables, such as revenue and labor size, for tax purposes, a parent firm's accounting values are measured as follows if the firm has at least one subsidiary firm. If the parent firm has at least 50 percent ownership of the subsidiary firm, then the subsidiary's accounting variables are directly added to the parent firm. However, if the parent firm has less than 50 percent ownership, then the subsidiary's accounting variables are added by multiplying their values by the ownership rate. The subsidiary's accounting variables also account for the parent firm's accounting values in the same way, except the double counting. Moreover, if the parent firm owns another subsidiary through its subsidiary, then the parent firm's ownership of that firm is calculated by multiplying the two ownership rates together. We include more details on this in Appendix [A.2](#).

3 Reduced-Form Evidence

This section describes our empirical strategy and data to identify the effects of capital gains taxes on real corporate outcomes. The capital tax system in Korea provides a unique empirical framework, where the capital gains tax rates differ across firms based on firm size. Until the reform in 2014, firm size was mainly determined by the revenue threshold of 100 million dollars and the average employee threshold of 300. If a firm has an incentive to minimize capital gains taxes, then one would expect to see firms sorting below each threshold.⁴

⁴Panel A of Figure A.1.1 in Appendix [A](#) illustrates firm density around the labor cutoff, conditional that the firms are below the other thresholds. We use average employees of five as the bin size. In this figure, we observe not only a jump in firm density at the cutoff but also that the [McCrary \(2008\)](#) test rejects the null hypothesis that the jump is statistically not different from zero at the 5 percent significance level. Panel B of Figure A.1.1 illustrates firm density around the revenue cutoff, conditional that the firms are below the other thresholds. We use $\log(\text{revenues})$ of 0.05 as the bin size. Similarly, we observe a jump in firm density at the cutoff, and the [McCrary \(2008\)](#) test rejects the null hypothesis that the jump is statistically not different from zero at the 5 percent significance level. These density graphs provide suggestive evidence that firms want to avoid facing higher tax rates by trying to stay below each of the cutoffs, although we observe some firms right above the cutoff, either because of adjustment costs or inability to control firm size precisely.

3.1 Estimating Tax Effects on Main Outcomes

To identify the tax effects on corporate outcomes, we compare firms that became reclassified as small and experienced a tax reduction of 14 percentage points after the reform in 2014 with unaffected firms. To define the treated and control groups, we exploit the reform on firm size regulations in 2014, which brought three major changes. First, it eliminated the labor threshold, so firms above the labor cutoff but below the revenue threshold experienced a 14 percentage point reduction in their tax rates. Second, the revenue threshold became the average of revenues over the past three years. Lastly, the average revenue cutoff increased from 100 million to 150 million dollars, so firms initially above the original revenue threshold but below the new average revenue cutoff experienced a 14 percentage point drop in their tax rates.⁵ We define these firms that got a reduction in capital gains tax rates from 24 percent to 10 percent as the main type of treated firms for the main results.

Furthermore, due to this reform, firms below and close to the labor and original revenue cutoffs may face an incentive to increase investment, since there was evidence of bunching at both thresholds. If labor and capital were complementary, then eliminating the labor constraint should provide a similar tax incentive to increase investment as a reduction in the tax rate. Hence, we define these firms that were close to the labor cutoff, but 5 percent below it, as the second type of treated firms.⁶ Similarly, firms that were close to the old revenue cutoff, but 10 percent below it, fall into the second type of treated firms because they were bunching precisely to avoid higher tax rates; so, removing this cutoff may provide an incentive to increase investment.

On the other hand, firms whose size was unaffected by the reform serve as the control group, given that there was no change in their incentive to invest.⁷ Therefore, our main analysis sample consists of the first type of treated firms that experienced a reduction in capital gains tax rates of 14 percentage points, while the control firms were unaffected by the reform because they were above the new threshold and still remained large firms after

⁵The new revenue threshold did not increase to 150 million dollars for certain industries within the manufacturing sector and other sectors. Therefore, firms in these excluded industries that were above the initial revenue cutoff, but below the new revenue threshold, are defined as part of the control group. More details on how the reform affected different industries can be found in [Moon \(2018\)](#).

⁶We chose firms 5 percent below the labor cutoff and 10 percent below the revenue cutoff as part of the additional treated group. The reason is that the growth rate of labor size for firms below the labor cutoff was about 5 percent on average, and the growth rate of revenues for firms below the revenue cutoff was about 10 percent on average prior to the reform. Our results are qualitatively similar if we use a larger or smaller sample below each cutoff to define this additional treated group.

⁷Firms that were above, but close to, the new cutoff might have an incentive to decrease investment to go below the threshold. Therefore, we drop 5 percent of firms above the new average revenue cutoff to mitigate this potential issue.

the reform. We run a separate analysis for the second type of treated (bunching) firms in Appendix B, along with the analysis where we combine both types of treated firms. Figure 1 illustrates the reform, and the two types of treated groups and the control group.

To validate our empirical design and visually show the reform effects on firms' real outcomes, we estimate the following model:

$$y_{it} = \sum_{\tau=2009}^{2017} \theta_{\tau} \mathbb{1}[t = \tau] \times Treated_i + \alpha_i + \alpha_t + X_{it}\beta + \epsilon_{it} \quad (1)$$

where α_i and α_t are firm and year fixed effects, $Treated_i$ is a dummy equal to 1 if the firm experienced a reduction in capital gains tax rate from 24 percent to 10 percent, and X_{it} is a vector of firm characteristics, which consists of (1) basic controls, such as quartics in firm age and industry dummies interacted with year dummies, and (2) additional controls, such as dummies for each pre-reform (2014) operating profit quintile interacted with dummies for each year.⁸ We include quartics in age to control for baseline financial constraints of firms among treated and control groups. Furthermore, industry composition is different between treated and control firms, so we include industry dummies interacted with year dummies to flexibly control for any time-varying industry-specific shocks. Additionally, to absorb any non-tax trends driven by baseline differences in productivity across groups, we include dummies for pre-reform (2014) operating profits (revenues minus operating costs) quintiles interacted with dummies for each year. We cluster standard errors at the firm-level. Each coefficient θ_{τ} measures the change in the outcome variable y_{it} for affected firms relative to unaffected firms in the τ -th year before or after the reform became effective in 2014. Note that θ_{2014} is normalized to be zero.

We compute and summarize the main estimates of the average tax effects on firms' real outcomes by estimating the following difference-in-differences model:

$$y_{it} = \alpha + \theta Treated_i \times Post_t + \alpha_i + \alpha_t + X_{it}\beta + \epsilon_{it} \quad (2)$$

where $Post_t$ is a dummy equal to 1 if it is after the reform year of 2014, and all the other

⁸We fix the dummy for $Treated_i$ at the time of the reform. In theory, treated firms in our sample may cross the new threshold within three years after the reform and face a higher capital gains tax rate again, which could attenuate our estimates since they may not increase investment as much as they would have had they remained small throughout the post-reform period. Furthermore, control firms in our sample may go below the new cutoff and face a lower capital gains tax rate, which could also attenuate our estimates, since they may increase investment after a tax cut. If either of these cases were prevalent, then our difference-in-differences estimates would give us a lower bound on the investment elasticity by holding the definition of $Treated_i$ fixed throughout the sample period.

variables are as defined in equation (1). We report the estimates from this equation (1), as well as the ones from the equation (2) in Section 3.5.

The main identifying assumptions behind our difference-in-differences design is that the affected and unaffected firms' outcomes would have trended similarly in the absence of the policy change. The key threat to this design is that time-varying shocks may coincide with the reform. We present three reasons why this threat is minimal. First, we show that the parallel trend assumption is satisfied prior to the reform. Second, stock price responses show that the reform was unexpected (Moon 2018), and there was no evidence of sorting at the new cutoff for the first three years after the reform. Lastly, we conduct placebo tests defining a reform date with a year prior to the actual reform date and defining treated groups with random cutoff values. We fail to reject the null hypothesis that the effects are not statistically different from zero in each of these tests.

3.2 Data and Analysis Sample

For empirical analysis, we use firm-level data on publicly listed and private firms in Korea from 2009 to 2017, where we observe detailed accounting information about the firms. We acquired this data set from a data company called Korea Listed Company Association (KLCA). We focus on the following sectors: (1) Manufacturing, (2) Construction, and (3) Production and Information Services. We focus on this time period because the rules for determining firm size remained the same, except in 2014. In our sample period, firms in these sectors account for about 90 percent of all publicly listed companies and 80 percent of all private firms. Furthermore, firms in these sectors account for about 80 percent of total revenues in the economy. Moreover, for private firms, expenditures on physical capital assets are easier to measure and observe for these sectors compared with other sectors, such as retail. We run a separate analysis including firms in other sectors and find qualitatively similar results (see Appendix B).

We also use an accounting data set for private firms, which we acquired from another data company called Korea Information Service (KIS). The main difference between this and the other data set is the coverage rate: because private firms report this information only when they have assets worth at least 10 million dollars and are audited by the government, we have missing information on accounting variables for certain firms and for certain years. Another difference is that for private firms, many variables related to firms' capital structure, such as equity issuance or payouts, are missing, so we use private firm data primarily to analyze the tax effects on investment, employment, and

total revenues. Finally, we use data on firms' ownership rates of their subsidiaries to compute accounting values for firm size.

3.3 Variable Definitions

The main data set contains accounting variables necessary for empirical analysis: assets, revenues, average employees, physical capital (tangible) assets, expenditures on physical capital assets, profits, and total capitals.

The key outcome variables are physical capital assets and investment. We define physical capital assets as the total book value of tangible assets (plants, properties, and equipment) as they appear in firms' balance sheets. We define investment as the log of the firm's capital expenditures on physical capital assets. We winsorize main outcome variables at the 99 percent level, and do robustness checks by winsorizing main outcomes at the 95 percent level in Appendix B.

3.4 Descriptive Statistics

We summarized the main variables, such as revenue, asset, labor size, and capital expenditure in Table 1. There are economically and statistically significant differences in these variables between treated and control firms. An important thing to note is that treated firms' revenues are below 150 million dollars on average, while the control firms' revenues are above 150 million dollars on average. Even though expenditures on physical capital assets are lower for treated firms than for control firms, the difference in their expenditures scaled by lagged physical capital assets is not statistically different from zero.

3.5 Results

This subsection shows the results from the estimation of the difference-in-differences models in Section 3.1 and presents additional tests supporting the interpretations of the results.

Panel A in Figure 2 plots the coefficients θ_τ , where $\tau \in (2009, \dots, 2017)$, for $\log(\text{investment})$ as in equation (1). As the graph shows, the parallel trend on investment between the affected and unaffected firms is satisfied, as the coefficient estimates are close to zero prior to the reform. Moreover, positive and statistically significant coefficients after the year

2014 indicate that lower tax rates induced the affected firms to increase investment.

Panel B in Figure 2 plots the coefficients θ_τ , where $\tau \in (2009, \dots, 2017)$, for $\log(\text{tangible assets})$ as in the equation (1). As the graph shows, the parallel trend on investment between the affected and unaffected firms is satisfied, as the coefficient estimates are close to zero prior to the reform. Moreover, positive and statistically significant coefficients after the year 2014 indicate that lower tax rates induced the affected firms to increase the size of tangible assets.

Table 2 presents the difference-in-differences estimation results on investment, tangible assets, net investment, and investment rate, using the sample of both listed and private firms. We winsorize (top-code) the main outcomes at the ninety-ninth percentile. Column (1) shows the coefficient is 0.356 for $\log(\text{investment})$, with the 95% confidence interval of (0.223,0.489), implying that firms that experienced a reduction in capital gains tax rates from 24 percent to 10 percent increased investment by 36 percent, compared to unaffected firms. Column (2) shows the coefficient is 0.087 for $\log(\text{tangible assets})$, with the 95% confidence interval of (0.01,0.167), implying that firms that experienced a drop in capital gains tax rates from 24 percent to 10 percent increased tangible assets by 9 percent, compared to unaffected firms.

We compute the implied capital stock elasticity with respect to the net of tax rates in the following way:

$$\epsilon_{y,1-\tau} = \frac{\% \Delta y}{\% \Delta(\text{net of tax rate})} = \frac{\Delta y}{y_0} * \frac{(1 - \tau_0)}{\Delta \tau} \quad (3)$$

The estimated elasticity is 0.47, which implies that a one percent increase in the net of tax rate would increase physical capital stocks by a half percent. Our results are consistent with a class of the “traditional-view” models (Feldstein 1970; Poterba and Summers 1983) that lowering capital tax rates would induce investment by increasing the marginal returns on investment.

3.6 Robustness and Internal Validity

We conduct several robustness checks to strengthen the internal validity of our results. First, we repeat the main analysis in equation (2) without any basic or additional controls and with only basic controls and find qualitatively similar results. Second, we repeat the analysis using different levels of winsorizing and find that the results are quantitatively

similar when winsorizing at the 95 percent level. Third, we repeat the main analysis using a balanced panel and find results that are qualitatively similar. Fourth, we repeat the main analysis by including firms in other sectors and find results that are qualitatively similar. Results from these robustness tests are reported in Appendix B.

A potential threat to the internal validity of our empirical strategy is that contemporary changes to other tax policies might affect the results. To account for this potential bias, we conduct a placebo test defining the reform year as the year 2012, instead of the year 2014, and fail to reject the null hypothesis that the effects on the main outcomes are not statistically different from zero. We also conduct another placebo test defining treated firms with random cutoff values and fail to reject the null hypothesis that the effects are not statistically different from zero. Results from these placebo tests are included in Appendix B.

4 Model

In this section, we build a dynamics general equilibrium model with heterogeneous firms based on a framework by [Gourio and Miao \(2010\)](#). We extend their model by incorporating (1) our institutional feature that firms face discrete average capital gains tax rates based on their firm size, (2) lumpy investment, and (3) a productivity process with Poisson shocks as in [Midrigan \(2011\)](#).

4.1 Households

Time is discrete, and a representative household has an additive utility function in consumption and labor supply:

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \omega \frac{L_t^{1+\nu}}{1+\nu} \right) \quad (4)$$

where β is the discount rate, C_t denotes consumption, L_t denotes labor supply, σ is the risk aversion, ω is the disutility from labor, and ν is the inverse of Frisch labor supply elasticity.

The household (1) purchases share θ_{jt} at price P_{jt} , (2) receives share repurchases s_{jt} and capital gains $P_{jt} - P_{j,t-1}$ from a fixed continuum of firms $j \in [0, 1]$, (3) purchases a risk-free

bond B_t with return r_t , and (4) supplies labor at wage rate w_t .⁹ The household also needs to pay income taxes τ_i on labor income and bond returns, and capital gains tax τ_{jt}^s and receives government lump-sum transfer T_t . The household's budget constraint is:

$$\begin{aligned} & C_t + \int P_{jt} \theta_{jt+1} dj + B_{t+1} \\ &= \int \left[P_{jt-1} + (1 - \tau_{jt}^s)(s_{jt} + P_{jt} - P_{jt-1}) \right] \theta_{jt} dj + (1 + (1 - \tau^i)r_t)B_t + (1 - \tau^i)w_t L_t + T_t \end{aligned} \quad (5)$$

Note that $s_t < 0$ means new equity issuances by firms. Also, the capital gains tax rate depends on firm size owned by the household. The details are specified below.

The household's intra-temporal condition in consumption and labor is:

$$(1 - \tau^i)w_t = \omega C_t^\sigma L_t^\nu$$

The risk free bond holding condition is:

$$1 = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (1 + (1 - \tau^i)r_t) \right]$$

The firm share θ_t holding condition is:

$$P_t = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (P_{t-1} + (1 - \tau_{jt}^s)(s_t + P_t - P_{t-1})) \right]$$

In a stationary equilibrium without aggregate shocks, aggregate consumption stays constant $C_{t+1} = C_t$. Hence, the combination of the two conditions above yields the following required return on the firm share

$$(1 - \tau^i)r = \frac{1}{P_t} (1 - \tau_{jt+1}^s) E_t [s_{jt+1} + P_{jt+1} - P_{jt}]. \quad (6)$$

In equilibrium, the household holds all shares of the firms $\theta_{jt} = 1$ and zero bonds $B_t = 0$.

⁹In Korea, the top marginal dividend tax rate is 38%, which is higher than the top capital gains tax rate of 24%, but firms still pay dividends along with share repurchases. Since our main focus is the effects of capital gains taxes on investment dynamics, we do not include dividend payments in our model. Incorporating dividends into our model will not qualitatively change our model predictions or results.

4.2 Firms

4.2.1 Technology and Capital Gains Taxes

There is a continuum of firms $j \in [0, 1]$ in the economy. A firm j produces output y_{jt} with Cobb-Douglas technology:

$$y_{jt} = z_{jt} k_{jt}^{\alpha_k} l_{jt}^{\alpha_l},$$

where y_{jt} , z_{jt} , k_{jt} and l_{jt} denote output, productivity, capital, and labor, respectively. α_k and α_l denote capital and labor elasticity of production. We assume that the productivity follows an AR(1) process, and innovations to productivity arrive infrequently as in [Midrigan \(2011\)](#) and [Bachmann and Bayer \(2014\)](#) with a Poisson probability p_z :

$$\log z_{jt} = \begin{cases} \rho_z \log z_{jt-1} + \varepsilon_{jt}, & \varepsilon_{jt} \sim N(0, \sigma_z) \quad \text{with probability } p_z \\ \log z_{jt-1} & \text{with probability } 1 - p_z \end{cases} \quad (7)$$

A firm can invest i_{jt} in capital for the next period's capital:

$$k_{jt+1} = (1 - \delta)k_{jt} + i_{jt}, \quad (8)$$

where δ is the physical capital depreciation rate. In the beginning of the period, it draws ψ_0 from a distribution $G(\psi_0)$ and has to pay a fixed cost proportional to the capital stock $\psi_0 k_{jt}$ for non-zero investment $i_{jt} \neq 0$. Also it has to pay a quadratic adjustment cost of capital $\frac{\psi}{2} \left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt}$. The firm faces a linear corporate tax rate τ_c on its profit and receives a fraction $\hat{\delta}$ of its capital stock for depreciation allowances. In sum, the firm's budget constraint is:

$$s_t + i_{jt} + \psi_0 \mathbb{1}_{i_{jt} \neq 0} + \frac{\psi_1}{2} \left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt} = (1 - \tau^c) (y_{jt} - w_t l_{jt}) + \tau^c \hat{\delta} k_{jt}. \quad (9)$$

4.2.2 Size-dependent Capital Gains Tax Rates

The capital gains tax rate faced by the household is firm-size specific. Holding a share in a small firm is associated with a low average tax rate τ_l^g , and in a large firm is associated with a high average rate τ_h^g . A firm is categorized as small if it jointly satisfies two criteria:

(1) total revenue below \bar{y} and (2) number of employees below \bar{l}_E .¹⁰ The tax schedule can be summarized as:

$$\tau_{jt+1}^s = \begin{cases} \tau_h^s & \text{if } l_{jt} > \bar{l}(z_{jt}, k_{jt}) \equiv \min\{\bar{l}_R(z_{jt}, k_{jt}), \bar{l}_E\} \\ \tau_l^s & \text{otherwise,} \end{cases} \quad (10)$$

where $\bar{l}_R(z_{jt}, k_{jt}) \equiv \left(\frac{\bar{y}}{z_{jt}k_{jt}^{\alpha_k}}\right)^{\frac{1}{\alpha_l}}$.

4.2.3 Optimization Problem

Let $V(z, k, \tau_g, \psi_0)$ be the value of a firm entering the period with productivity z , capital stock k , capital gains tax rate τ_g , and a draw of fixed cost ψ_0 and define it as the sum of net share repurchases and equity value:

$$V(z, k, \tau_g, \psi_0) = s + P$$

Using equation (6), the firm's dynamic problem can be written as the following:

$$V(z, k, \tau^s, \psi_0) = \max_{l, i, s} s + \frac{1}{1 + \frac{(1-\tau^i)r}{1-\tau^{g'}}} \mathbb{E}_t \left[V(z', k', \tau^{g'}, \psi'_0) \right], \quad (11)$$

subject to (9), and (10). From the equation above, we see that the capital gains tax rate does not distort a firm's intra-temporal decision; hence, we drop τ^s from the state variables: $V(z, k, \tau^s, \psi_0) = V(z, k, \psi_0)$.

Firm's problem (11) can be rewritten as the following:

$$V(z, k, \psi_0) = \max\{V_N(z, k), V_A(z, k) - \psi_0 k\},$$

in which the firm decides to pay the fixed cost or not. $V_N(z, k)$ denotes the value of a firm not paying the fixed cost for capital adjustment:

$$V_N(z, k) = \max_{l \in \{\bar{l}(z, k), l^*(z, k)\}} (1 - \tau^c) (zk^{\alpha_k} l^{\alpha_l} - wl) + \tau^c \delta k + \frac{1}{1 + \frac{(1-\tau^i)r}{1-\tau^{g'}(l)}} \mathbb{E}_t \left[V(z', (1 - \delta)k, \psi'_0) \right], \quad (12)$$

¹⁰Since we do not observe firm-specific prices, we use revenue and output interchangeably in this paper.

where $l^*(z, k)$ is the firm's unconstrained labor choice:

$$\begin{aligned} l^*(z, k) &\equiv \arg \max_l zk^{\alpha_k} l^{\alpha_l} - wl \\ &= \left(\frac{\alpha_l}{w} zk^{\alpha_k} \right)^{\frac{1}{1-\alpha_l}}. \end{aligned}$$

A firm always chooses $l^*(z, k)$ that maximizes the current profit flow if it is not above the size threshold $\bar{l}(z, k)$. Otherwise, it needs to decide between $l^*(z, k)$ and constrained labor $\bar{l}(z, k)$ that results in the low capital gains tax rate.

If the firm chooses to pay the fixed cost, its value function becomes:

$$\begin{aligned} V_A(z, k) = \max_{i, l \in \{\bar{l}(z, k), l^*(z, k)\}} & (1 - \tau^c) (zk^{\alpha_k} l^{\alpha_l} - wl) + \tau^c \delta k - i - \frac{\psi_1}{2} \left(\frac{i}{k} \right)^2 k \\ & + \frac{1}{1 + \frac{(1-\tau^i)r}{1-\tau^g(l)}} E_t \left[V(z', (1-\delta)k + i, \psi'_0) \right]. \end{aligned} \quad (13)$$

After paying the fixed cost, the firm can choose any value of investment subject to quadratic costs to maximize its discounted present value. It also chooses labor between $\bar{l}(z, k)$ and $l^*(z, k)$.

The firm would choose to make non-zero investment if and only if the benefit of making adjustments is higher than paying the fixed cost. There is a unique threshold $\hat{\psi}_0(z, k)$ that satisfies:

$$\hat{\psi}_0(z, k) = \frac{V_A(z, k) - V_N(z, k)}{k}.$$

If the fixed cost draw ψ_0 is smaller than $\hat{\psi}_0$, then the firm is willing to pay for capital adjustments. Note that this threshold is increasing in the gap between the current capital stock and desired capital level. If the current capital is close to the desired level, a firm would not change investment. This feature generates lumpy investment behavior in the model.

4.3 Comparative Statics

To illustrate how the capital gains taxes affect investment in the model, we first make the following simplifying assumptions:

1. Physical and depreciation-allowance capital depreciate fully in one period $\delta = \hat{\delta} = 1$.
2. Idiosyncratic productivity takes two states $\{\bar{z}, \underline{z}\}$, and transition probability is $\Pr(z = \bar{z}|z = \bar{z}) = \Pr(z = \underline{z}|z = \underline{z}) = \rho$.
3. We assume that if $z = \bar{z}$, the firm is categorized as a large firm and faces a high capital gains tax rate, and vice versa.
4. Firm always chooses flow profit maximization labor $l^*(z, k)$. Hence the firm's flow profit $\pi(z, k)$ is

$$\pi(z, k) \equiv (1 - \alpha_l) \left(\frac{\alpha_l}{w} \right)^{\frac{\alpha_l}{1-\alpha_l}} (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}} \quad (14)$$

5. Firm chooses investment before observing the current productivity. This is a simple way to capture the capital adjustment cost.

For a firm with productivity $z = \bar{z}$ and capital stock k in the last period, its maximization problem is

$$\begin{aligned} V(k, \bar{z}) = \max_i & \left\{ \pi(k, \bar{z}) - i + \left(1 + \frac{(1 - \tau_i)r}{1 - \tau_h^g} \right)^{-1} \mathbb{E} [\pi(i, z) | \bar{z}] \right\} \\ & + (1 - \rho) \left\{ \pi(k, \underline{z}) - i + \left(1 + \frac{(1 - \tau_i)r}{1 - \tau_l^g} \right)^{-1} \mathbb{E} [\pi(i, z) | \underline{z}] \right\}. \end{aligned} \quad (15)$$

Then the investment elasticity with respect to the net of capital gains tax rate $(1 - \tau_h^g)$ is

$$\begin{aligned} \epsilon_{i, 1-\tau_h^g} & \equiv \frac{\partial i}{\partial (1 - \tau_h^g)} \frac{1 - \tau_h^g}{i} \\ & = \underbrace{\left(1 - \frac{\alpha_k}{1 - \alpha_l} \right)^{-1}}_{\text{profit curvature effect}} \underbrace{\frac{(1 - \tau_i)r}{(1 - \tau_i)r + 1 - \tau_h^g}}_{\text{user cost of capital effect}} \underbrace{\frac{\frac{\rho}{R_h} \mathbb{E} [z^{1/(1-\alpha_l)} | \bar{z}]}{\frac{\rho}{R_h} \mathbb{E} [z^{1/(1-\alpha_l)} | \bar{z}] + \frac{1-\rho}{R_l} \mathbb{E} [z^{1/(1-\alpha_l)} | \underline{z}]}}_{\text{size threshold effect}}, \end{aligned} \quad (16)$$

where $R_h \equiv 1 + \frac{(1-\tau_i)r}{1-\tau_h^g}$ and $R_l \equiv 1 + \frac{(1-\tau_i)r}{1-\tau_l^g}$.

The equation 16 shows that the investment elasticity with respect to the net of tax rate is always positive and can be further decomposed into three parts. The first part is the *profit curvature effect*. A more concave profit function of capital yields a smaller response of investment, which could be due to decreasing returns-to-scale technology or

a downward-sloping demand curve.¹¹ The second term is *user cost of capital effect*. As the required return $(1 - \tau_i)r$ increases, a firm's investment policy would also be more responsive to a change in capital gains taxes. The last one is *size threshold effect*, which is increasing in ρ . Hence, if a large firm today is more likely to remain large in the next period, it would increase investment more from a tax cut. It turns out that the last effect is significant in our dynamic heterogeneous firm model and sharply disciplines parameters related to the productivity process. Not controlling for this effect would yield different results and have different implications for policy analysis.

4.4 Stationary Competitive Equilibrium

A stationary competitive equilibrium consists of (i) invariant joint distribution of idiosyncratic productivity and capital $F(z, k)$, (ii) firm policy functions $l(z, k)$ and $i(z, k)$, and (iii) household wage w and consumption C such that

1. $l(z, k)$ and $i(z, k)$ solve firm's maximization problem;

2. Labor market clears

$$L(w, C) = \int l(z, k) dF(z, k) \quad (17)$$

3. Aggregate Output

$$Y = \int y(z, k) dF(z, k); \quad (18)$$

4. Aggregate Investment

$$I = \int i(z, k) dF(z, k); \quad (19)$$

5. Aggregate Adjustment Cost

$$\Psi = \int \psi_0 \mathbb{1}_{i(z, k) \neq 0} k dG(\psi_0) dF(z, k) + \int \frac{\psi_1}{2} \left(\frac{i(z, k)}{k} \right)^2 k dF(z, k); \quad (20)$$

6. Government Budget Constraint

$$T = \tau^i w \int l(z, k) dF(z, k) + \tau^c \int (y(z, k) - wl(z, k) - \hat{\delta}k) dF(z, k) + \int \tau^s(z, k) s(z, k) dF(z, k); \quad (21)$$

¹¹Note that a model with equity issuance costs would generate an inactive region of firms not responding to changes in capital gains tax rates. Studying the interaction of financial constraints and capital gains taxes would be an interesting addition to this paper.

7. Aggregate Consumption

$$C = Y - I - \Psi; \tag{22}$$

5 Calibration and Simulation

To quantify the effects of reducing capital gains taxes, we calibrate parameters in two steps. First, we externally calibrate a subset of parameters by adopting commonly used values in the literature. Second, we calibrate the rest of the parameters by matching micro moments from our reduced-form analysis, in addition to important aggregate moments from our firm-level data from 2009 to 2017.

5.1 Externally Calibrated

The model period is one year. We choose the risk-free interest rate to be 4 percent, which implies from the household's inter-temporal condition that the discount rate is equal to 0.97. We set the constant relative risk aversion σ to 1, meaning that the household has log utility in consumption. We also set the Frisch elasticity of labor supply to be 1 as suggested by [Chang et al. \(2018\)](#) for a representative household model. Labor disutility parameter ω is chosen such that the aggregate labor supply is 1/3 in the steady state. In order to evaluate the firm-size reform in 2014, we set the income tax rate $\tau^i = 25$ percent, corporate tax rate $\tau^c = 34$ percent, and low (high) capital gains tax rates as 10 percent (24 percent), consistent with the tax rates in Korea. For capital depreciations, we set the physical rate and allowance rate to be the same value of 10 percent, implying that the aggregate investment rate is 10 percent. Lastly, we set the capital production elasticity α_k and labor production elasticity α_l to be 0.28 and 0.57, such that the capital-labor ratio is 0.5 and total returns-to-scale is 0.85.

5.2 Internally Calibrated

The rest of the parameters are jointly calibrated using a simulated method of moments to minimize the distance between empirical moments and simulated moments. We choose a uniform distribution $[0, \bar{\psi}_0]$ for the fixed-cost distribution. Hence, the internally calibrated parameters are (1) the upper bound of fixed-cost distribution $\bar{\psi}_0$, (2) the quadratic adjustment cost ψ_1 , (3) the persistence of productivity ρ_{z_t} , (4) the standard deviation of pro-

ductivity shock σ_z , (5) a Poisson probability of shock arrival p_z , (6) the revenue threshold \bar{y} , and (7) the employee threshold \bar{l}_E .

Table 4 reports the data and simulated moments. We select the following seven moments as informative about the parameters (1) to (5): a fraction of the absolute investment to capital ratio less than 5 percent (inaction rate) and larger than 20 percent (spike rate); standard deviation of the investment rate; standard deviation of $\log(\text{output})$; output autocorrelation of one, three, and five years; and the reduced-form estimates of the changes in capital stocks for affected firms relative to unaffected firms after the reform. For the size thresholds \bar{y} and \bar{l}_E , we match the percentiles of thresholds to compare our data with the model for policy evaluations.

All parameters are estimated jointly; hence, it is hard to give a one-to-one mapping between parameters and moments. However, intuitively, the investment rate moments discipline the adjustment costs, revenue moments discipline the AR(1) productivity process, and the difference-in-differences estimate of the capital elasticity pins down the Poisson probability through the size-threshold effect. We use short and long horizons of output autocorrelations to distinguish between two seemingly similar productivity processes.

Table 5 reports the estimated parameters. We find low estimates of fixed adjustment costs, equivalent to 0.25 percent of capital stock for adjustments, while the estimate of Cooper and Haltiwanger (2006) is 3.9 percent. The Poisson probability of new productivity shock is $p_z = 0.33$. This estimate is comparable to 0.41 in Bachmann and Bayer (2014) and much higher than 0.03 in Midrigan (2011).¹² The estimated quadratic cost is 0.15, comparable to 0.05 in Cooper and Haltiwanger (2006). Finally, the persistence of an AR(1) productivity process is 0.87 and the standard deviation of shocks is 0.10, comparable to the findings in the literature.

Lastly, although not targeted, the baseline model yields a high kurtosis for investment rate (7.5) and output growth rate (9.6), comparable to 7.4 and 10.3 in the data, respectively. This is because the productivity process with the Poisson shocks itself has a high kurtosis. In contrast, the Gaussian model yields only kurtosis of 3.7 for the investment rate and 4.7 for the output growth rate, close to the kurtosis of a normal distribution.

¹²Bachmann and Bayer (2014) assume a mixture of Gaussian productivity shocks in a real business cycle model with heterogeneous firms and lumpy investment decisions. Midrigan (2011) identifies the Poisson probability with cross-sectional firm price moments.

5.3 Inspecting the Mechanism of Poisson Shocks

To explain the role of the Poisson shock in our model, we use the following illustration. First, we recalibrate a model without the Poisson shock and report the model fits in Table 4 along with the baseline case. We refer to it as the Gaussian ($p_z = 1$) case. We find that the model could match all the micro moments well except for the difference-in-differences estimate of the capital stock response. The Gaussian case yields a much smaller response of the treated firms, 0.03, compared to 0.09 that we estimated in the data.

The smaller response in the Gaussian case is due to the size threshold effect in the model. We illustrate this point using a heuristic example in Figure 3. The two panels show the distribution of firm size in the next period, conditional on today's firm size being 0. The left and right panels show cases when the shock to productivity is Gaussian ($p_z = 1$) and Poisson ($p_z < 1$), respectively. \bar{l} is the size threshold for the capital gains tax rates. A firm faces the low tax rate when downsizing below \bar{l} and the high tax rate otherwise. We see that the distribution of the Gaussian shock is more dispersed while the Poisson shock has more mass concentrated in the mean (more "peakedness"). Therefore there is a larger shaded area below \bar{l} in the left panel, meaning a low probability of staying large. This corresponds to the low persistence parameter ρ in equation (16). Hence, the Poisson model has a stronger size-threshold effect and is able to match the large difference-in-differences estimate from our reduced-form analysis.

For a more quantitative explanation, we consider the following two economies: Gaussian economy and Poisson economy. In a Gaussian economy, a firm receives the following Gaussian shock and its next period size evolves as the following:

$$l' = l + \varepsilon_g, \quad \varepsilon_{jt} \sim N(0, \sigma_g) \quad (23)$$

Alternatively, in a Poisson economy, a firm receives a Gaussian shock with probability p_z :

$$l' = \begin{cases} l + \varepsilon_p, & \varepsilon_{jt} \sim N(0, \sigma_p) & \text{with probability } p_z \\ l & & \text{with probability } 1 - p_z, \end{cases} \quad (24)$$

We normalize the current firm size to $l = 0$ and restrict the variance of the two economies to be the same, which is similar to matching the same standard deviation of output in our calibration. Then we have

$$\sigma_p = \frac{\sigma_g}{\sqrt{p_z}}. \quad (25)$$

Note that the kurtosis of the Gaussian shock is 3, while the Poisson shock is $\frac{3}{p_z}$. In Figure 4, we plot the probability ratio $\Pr(\varepsilon_p < \bar{l})/\Pr(\varepsilon_g < \bar{l})$ for different values of p_z . We also plot for different values of labor threshold \bar{l} . We see that the probability ratio is a monotonically increasing function of p_z for the range of \bar{l} . Furthermore, for a given value of p_z , the probability ratio increases with \bar{l} . This is because the Poisson shock has “fatter tails” than the Gaussian shock. As the threshold \bar{l} gets far away from the mean, the effect of “fatter tails” starts dominating that of “peakedness.” In general, either “fatter tails” or “peakedness” could dominate. Nevertheless, the latter effect dominates in our simulation with an estimated Poisson probability $p_z = 0.33$. In the Poisson economy, the probability of a firm above the threshold today going below the threshold after 1, 3, and 5 years are 7.72%, 20.90%, and 31.75%, respectively. The corresponding probabilities in the Gaussian economy are 9.91%, 24.29%, and 35.27%, respectively. In terms of the ratio of the probability, the differences between the two economies are 28.37%, 16.22%, and 7.69% over 1-, 3-, and 5-year horizons. Therefore the size threshold effect on the capital response of treated firms is much larger in the Poisson economy, which is more consistent with our data, than in the Gaussian economy.

6 Transitional Dynamics and Welfare Implications

Now we present the results of transitional dynamics under alternative policies on firm size thresholds that determine the capital gains tax rates. The initial steady state is in 2014, as it was in Korea, where firms with fewer than 300 employees and less than 100 million dollars in revenues face the capital gains tax rate of 10 percent, and 24 percent otherwise. We focus on three different policy experiments of permanent tax reforms, which occur at period 2, and are unexpected for the household and the firms in the economy.

6.1 Firm Size Reform in 2014

We start with the case of the firm size reform. In 2014, the government removed the labor threshold and increased the revenue threshold from 100 million dollars to 150 million dollars. Since the actual reform affected only a small fraction of firms in the economy, we target the difference-in-differences estimate of the capital stock response in a partial

equilibrium for our baseline calibration. For the first experiment, we extend the scope of the reform to the whole economy and study the aggregate effects.

Figure 5 presents the transitional dynamics of wage, interest rate, consumption, capital, investment, output, labor, TFP, equity issuance, and share repurchase. In general equilibrium, aggregate investment jumps by 2.6 percent in the short run. An increase in the interest rate induces the representative household to save more by decreasing consumption and increasing labor supply for capital investment. Hence, the effect of the capital gains tax cut on investment is larger in the short run. Since capital is the accumulated investment net of depreciation, it increases gradually to the steady state. Finally, firms finance investment by cutting back on share repurchases and issuing new equity in the first few periods.

Table 8 summarizes the long-run percent changes of the aggregate variables. In the steady state, aggregate capital, labor, output, consumption, and wage increase by 1.61%, 0.21%, 0.60%, 0.40%, and 0.61% respectively, while TFP does not change much. The increase in the output comes mostly from the newly accumulated capital by the firms. The total labor supply goes up by much less than suggested by the increase in the wage, because of the wealth effect through consumption. Also, since only a small fraction of firms were affected by the 2014 reform, there is not much resource reallocation among firms and TFP does not change much.

The analysis above considers the case of full general equilibrium, where both wage and interest rate are flexible. Here, we also consider the case of small open economy, a suitable case for Korea. In this exercise, we keep the interest rate fixed and the consumption is determined by the inter-temporal budget constraint. Figure 5 shows the results labeled by SOE (Small Open Economy). Since the interest rate is constant, the consumption jumps instantly to and stays flat at the new level. Due to the wealth effect, the short-run labor supply does not increase as much as in the general equilibrium case. Also, we see that the short-run investment is more volatile in the case of SOE, since firms have stronger incentives to increase their investment with a fixed interest rate. The aggregate investment increases by 7.19 percent right after the tax cut, compared to 2.6 in the general equilibrium case. Table 9 summarizes the long-run percent changes of the aggregate variables. In the long run, the capital, output, and labor are slightly higher than their counterparts in the general equilibrium. This is due to the over-accumulation of capital from investment spikes right after the reform.

6.1.1 Partial Equilibrium vs. General Equilibrium

The analysis of the transitional dynamics above accounts for general equilibrium (GE) effects through the interest rate and wage. The partial equilibrium (PE) analysis reveals that ignoring aggregate prices would yield results with large differences.

For this exercise, we keep both the interest rate and wage fixed at the initial level. In the short run, Tables 6 and 7 show that aggregate investment and capital increase by 14.37 and 1.44 percent, respectively, in the partial equilibrium. These responses are much higher than the ones from both general equilibrium and small open economy cases. Although the interest rate is kept fixed for both PE and SOE cases, the initial increase in the wage dampens firms' investment responses. In the new steady-state, the PE analysis also overstates the increase in consumption, capital, output, and labor by 2.00 (2.09), 1.94 (1.88), 1.99 (1.93), and 2.56 (2.49) percentage points than the GE (SOE) case, respectively. Firms in the GE and SOE cases face more expensive labor inputs, so they do not invest as much as the firms in the PE case. Overall, we see that the results of alternative cases of partial equilibrium look dramatically different from the general equilibrium.

6.1.2 Welfare Changes

We now calculate the welfare changes of the firm-size reform in 2014. First, we define the consumption-equivalent welfare changes Δ_{SS} between two steady states (C^*, L^*) and (C^{**}, L^{**}) as the following:

$$\frac{((1 + \Delta_{SS})C^*)^{1-\sigma}}{1 - \sigma} - \omega \frac{L^{*1+\nu}}{1 + \nu} = \frac{C^{**1-\sigma}}{1 - \sigma} - \omega \frac{L^{**1+\nu}}{1 + \nu}. \quad (26)$$

However, the measure above does not account for the potential welfare loss along the transitional dynamics. In the 2014 reform, the representative household has to decrease consumption and increase labor supply in the short-run to accumulate higher capital stock in the long run, meaning that Δ_{SS} might overstate the actual welfare gain. Therefore, we also define the consumption-equivalent welfare changes along a transitional path $(C_t, L_t)_{t=1,2,\dots,\infty}$ as the following:

$$\frac{1}{1 - \beta} \left[\frac{((1 + \Delta_{TD})C^*)^{1-\sigma}}{1 - \sigma} - \omega \frac{L^{*1+\nu}}{1 + \nu} \right] = \sum_{t=1}^{\infty} \beta^{t-1} \left(\frac{C_t^{1-\sigma}}{1 - \sigma} - \omega \frac{L_t^{1+\nu}}{1 + \nu} \right) \quad (27)$$

The results are in Table 8 and Table 9, indicating that the steady state welfare gain is

0.30% in GE and 0.16% in SOE. In the last row of Table 8, we see that the transitional welfare gain in GE is 0.18% and is around 60% of the steady-state gain (0.30%). But, in Table 9, we see that the transitional welfare gain in SOE is similar to the steady-state gain due to the perfect consumption smoothing with the world interest rate and free capital flow.

How large are these welfare changes? To put our estimates of welfare gains into perspective, we compare our results with other findings. Lucas (1987) finds that welfare gains from eliminating business cycles from a representative agent economy with log utility is 0.008 percent. A recent study by Krusell et al. (2009) estimates a heterogeneous agent model and finds that the business cycle welfare costs range from 0.1% to 1%. Although the 2014 reform affected only a subset of firms in the economy, its welfare implication is comparable to eliminating business cycle risks in the economy.

6.2 Uniform and Zero Tax Rate

We conduct two relevant counterfactual analyses. The first case is, if the government removed both revenue and labor thresholds completely in 2014, what would have been the alternative outcome of the economy? The steady-state results are in the second column of Table 8. Aggregate capital, labor, output, consumption, and welfare would have increased by 6.89%, 1.10%, 2.81%, 1.92%, and 1.34%, respectively. TFP increases by 0.26% since firm-size distortions from different capital gains tax rates disappear, accounting for 9% of the increase in output. The transitional dynamics are presented in Figure 7. The dynamics exhibit a pattern similar to the post-2014 reform: in the short run, consumption drops and rises gradually to the new steady state. Investment and labor jump and gradually fall to the new levels. The transitional welfare gain of this reform is 0.84%. Again, as in Figure 8, the prediction would be rather different if general equilibrium effects were not considered.

In the last policy experiment, we set the capital gains tax rate to zero in the economy. Capital, labor, output, consumption, and welfare increase by 12.39%, 1.50%, 4.50%, 2.78%, and 1.99%, respectively. But TFP gain does not change much from the second policy experiment, since there is no redistribution effect from the uniform tax case to the zero tax case.

7 Relevance of Micro-Moments for Policy Implications

In this section, we explore whether successfully capturing the micro moments in the data is important for evaluating the aggregate effects of reducing capital gains taxes. In the baseline model, Poisson shocks, high productivity persistence, and capital adjustment costs are important for the model to match the investment rate moments, output moments, and the difference-in-differences estimate of the capital stock elasticity in the partial equilibrium. Here, we explore how quantitatively important they are for policymakers aiming to calculate the aggregate impacts of changing size thresholds that determine capital gains tax rates in the general equilibrium framework.

To illustrate the importance of matching micro moments, we compare three different cases. The first case is the baseline model with Poisson shocks. The second case is the gaussian model as calibrated in section 5. The gaussian model is able to match the investment and output moments, but not the capital stock response of the treated firms. The last one is the limited information case, in which we consider a hypothetical scenario that policymakers have observations only before the 2014 reform. Since there is no natural policy experiment in the limited information case, policymakers would not observe the capital stock response of firms affected by the reform, thereby underweighting the output persistence moments for calibration criteria to capture the size threshold effect. In terms of modeling, policymakers would assume a simple AR(1) process with Gaussian shocks for firm productivity. For calibration, they would choose to match only the following moments: inaction rate, spike rate, standard deviation of investment rate, and standard deviation of output.

The results for the targeted moments are listed in the last column of Table 4, and the calibrated parameters are listed in Table 5.¹³ We see that the limited information case implies very low autocorrelations of output in the long run. The 3-year and 5-year autocorrelations are only 0.71 and 0.54, compared with 0.93 and 0.88 in the data. Also, the capital response of treated firms is only one-tenth of the empirical estimate. Matching the high persistence of output is important, but not enough to generate the large capital response that we see in the data. The Gaussian case previously discussed, though successfully matching long-run autocorrelation of output, yields less than one-third of the capital stock response. Only the baseline case that features both Poisson shocks and high persistence of output could match the high elasticity. This comparison

¹³Clementi and Palazzo (2016) show that persistence of idiosyncratic productivity is weakly identified by using investment moments alone, so we exogenously choose $\rho_z = 0.8$, a value commonly used in the lumpy investment literature.

further demonstrates that the “peakedness effect” of Poisson shocks is essential to reduce the size-threshold effect.

But how quantitatively important is matching micro-moments for aggregate implications? In Figure 11, we plot the transitional dynamics of the aggregate variables for baseline, gaussian, and limited information cases in general equilibrium. We see that the gaussian model would under-predict the total capital, labor, consumption, and output by 9%, 8%, 10%, and 9% in the new steady state. We also compare the baseline with the limited information case. We see that not accounting for the persistence of output would under-predict the total capital, labor, consumption, and output by 42%, 32%, 38%, and 37%, respectively, in the steady state.

The reason that the limited information case predicts much smaller increases in aggregate variables than do the baseline and the gaussian cases is due to the low persistence of the productivity and its implication for firm-level capital accumulation. Table 10 shows the output, labor, and capital share of the firms above both revenue and labor thresholds in the pre-reform period. Although three models imply the same output and labor share, but the capital shares are 0.44 and 0.43 for the baseline and gaussian cases, respectively, much higher than the capital share of 0.26 in the limited information case. Since the productivity is less persistent, combined with costly capital adjustments, large firms in the limited information case tend to accumulate less capital. Although three cases are calibrated to match the same standard deviation of log output, the standard deviation of capital in the baseline and gaussian cases are 50% larger than the limited information case. Since the aggregate effect of the uniform tax rate depends on the share of capital distorted by the high capital gains tax rate, the limited information case shows smaller responses to the tax cut compared to the responses in the other cases.

Next, we compare three cases under small open economy. Figure 12 plots the transitional dynamics of aggregate variables for the baseline, gaussian, and limited information cases. In small open economy, the interest rate is fixed at the initial level, and the short-run dynamics display further differences among the cases considered. Now the baseline model predicts a much higher short-run increase in aggregate investment than do the gaussian and limited information models. Right after the policy implementation, aggregate investment in the baseline case increases by 31%, while aggregate investment in the gaussian and limited information cases increases by 22% and 11%, respectively. This is because only the baseline case is able to match the difference-in-differences estimate of treated firms’ capital elasticity by capturing the size-thresholds effect. Similarly, capital, output, and labor all increase more in the baseline case after the tax cut. Therefore,

our simulation shows that capturing micro-level moments are essential for accurately predicting both short-run and long-run investment dynamics in the policy analysis.

8 Conclusion

This paper quantifies the long-run aggregate effects of reducing capital gains taxes. We build a dynamic general equilibrium model with heterogeneous firms facing discrete capital gains tax rates based on firm size. We calibrate our model by targeting key micro moments and the difference-in-differences estimate of the capital elasticity based on the institutional setting in Korea. We find that the reform that reduced the capital gains tax rates from 24 percent to 10 percent for firms affected by the new regulations increased aggregate investment by 1.61 percent in the steady state, with the short run effects overstating the effects by 1 percentage points. Moreover, a counterfactual analysis where we set the uniformly low tax rate of 10 percent shows that aggregate investment rose by 6.89 percent in the long run. Furthermore, we find that general equilibrium effects through prices are substantial in our simulation. Our findings suggest that reducing capital gains tax rates would substantially increase investment in the short-run, and accounting for dynamic and general equilibrium responses is important for understanding the aggregate effects of capital gains taxes.

Our paper bridges the gap between reduced-form studies that evaluate tax policies with limited aggregate implications and structural papers that analyze the aggregate responses of tax reforms without fully capturing micro moments derived from clean identification strategies. By bridging this gap, this paper not only captures the short-run effects of reducing capital gains tax rates on investment in the partial equilibrium, but also consistently predicts the long-run aggregate responses that reflect both the general equilibrium price effects and dynamic adjustment frictions. Exploring potential mechanisms behind the aggregate responses, such as financial constraints, and incorporating other relevant features in our model, such as debt-financing, would be a valuable extension of our paper that may shed further light on the efficiency cost of capital taxation.

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Table 1: Descriptive Statistics

	Listed and Private Firms		Listed Firms		Private Firms	
	(1) Treated	(2) Control	(3) Treated	(4) Control	(5) Treated	(6) Control
Total Revenue (in million)	74.69 (45.16)	251.8 (176.5)	95.13 (44.34)	284.4 (189.3)	67.10 (43.06)	226.6 (161.5)
Labor (Average Employees used)	243.1 (174.5)	393.4 (295.1)	254.3 (135.5)	467.5 (300.8)	238.9 (186.9)	335.9 (277.3)
Total Asset (in million)	75.02 (64.65)	237.3 (189.4)	123.1 (68.29)	305.2 (201.2)	57.16 (53.15)	184.7 (161.1)
Total Capital (in million)	40.50 (41.94)	123.1 (109.1)	74.52 (46.68)	165.8 (113.0)	27.86 (31.83)	89.99 (93.43)
CAPEX (in million)	4.067 (6.086)	11.22 (13.83)	5.763 (7.647)	13.34 (14.67)	3.436 (5.257)	9.580 (12.92)
CAPEX / lagged PPE	0.219 (0.264)	0.202 (0.234)	0.186 (0.224)	0.180 (0.209)	0.231 (0.277)	0.219 (0.250)
Observations	2635	8037	714	3509	1921	4528

Notes: Sample years include 2009-2017. Labor is the average employees used in a given year. CAPEX is expenditures on physical capital assets, such as plants, property, and equipment (PPE). Treated and control firms are defined in Section 3.

Table 2: Results on Investment and Capital Stock

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.356** (0.068)	0.087** (0.041)	0.040** (0.013)	0.040** (0.012)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.140	16.323	0.084	0.150
Implied Elasticity wrt (1-tau)	1.93	0.47	2.54	1.46
R-squared	0.72	0.93	0.20	0.42
Observations (firm-years)	12496	12693	12700	4732
Clusters (firms)	1477	1477	1477	1477

Notes: This table reports the tax effects on investment based on specification (2). The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 ppt, as explained in Section 3. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Investment is defined as the expenditures on physical capital assets. Capital Stock is the total book value of tangible assets, such as plants, properties, and equipments. Net Investment is the annual changes in tangible assets. Investment rate is the investment to capital stock ratio. Basic controls are quartics in firm age and industry specific time trends. Additional controls are dummies for pre-reform (2014) operating profit quintile interacted with time dummies. The main outcomes are winsorized at the 99% level. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. The sample includes both publicly listed and private firms. All specifications include time and firm fixed effects (FEs). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table 3: Fixed Parameter Values

Parameter	Symbol	Value
Discount Rate	β	0.97
Risk Aversion	σ	1
Labor Disutility	ω	6.616
Frisch Inverse Elasticity	ν	1
Risk-free Interest Rate	r	0.04
Income Tax Rate	τ^i	0.250
Corporate Tax Rate	τ^c	0.340
High (Low) Capital Gains Tax Rate	$\tau_h^g (\tau_l^g)$	0.24 (0.10)
Depreciation Rate	δ	0.10
Depreciation Allowance Rate	$\hat{\delta}$	0.10
Capital Elasticity	α_k	0.28
Labor Elasticity	α_l	0.57

Notes: This table shows externally calibrated parameters.

Table 4: Targeted Moments

Moment	Data	Baseline	Gaussian	Limited
Inaction Rate	0.32	0.28	0.34	0.34
Spike Rate	0.25	0.23	0.27	0.27
Std. of Investment Rate	0.16	0.16	0.15	0.17
Std. of log Output	1.23	1.15	1.19	1.19
1-year Autocorrelation of Output	0.97	0.98	0.98	<u>0.90</u>
3-year Autocorrelation of Output	0.93	0.93	0.93	<u>0.71</u>
5-year Autocorrelation of Output	0.88	0.87	0.86	<u>0.54</u>
Treated Group Capital Response	0.09	0.09	0.03	<u>0.01</u>

Notes: This table shows targeted moments in our model. Sample years include 2009-2017. Inaction rate is fraction of observations with absolute investment rate less than 5%. Spike rate is fraction of observations with absolute investment rate greater than 20%. Output is firm revenue. Treated group capital response is 3 year average of the difference-in-differences estimate of the capital stock response. Baseline case is an economy with Poisson shocks to firm productivity process. Gaussian case is an economy with Gaussian shocks to firm productivity process. Limited case is when policymakers have only observations before 2014 reform. Underlined moments are not included for parameter calibration.

Table 5: Estimated Parameter Values

Parameter	Symbol	Baseline	Gaussian	Limited
Upper Bound of Fixed Cost	ψ_0	0.0025	0.0018	0.0030
Quaratic Adjustment Cost	ψ_1	0.15	0.29	0.65
Persistence of Productivity	ρ_z	0.87	0.95	0.80
Std. of Productivity	σ_z	0.10	0.07	0.22
Poisson Probability	p_z	0.33	1	1
Revenue Threshold	\bar{y}	90%ile	90%ile	90%ile
Labor Threshold	\bar{l}_E	90%ile	90%ile	90%ile

Notes: This table shows parameters chosen to match empirical moments in Table 4.

Table 6: Post 2014 Aggregate Investment Dynamics

	Short Run	Long Run
Partial Equilibrium	14.37	3.55
General Equilibrium	2.57	1.61
Small Open Economy	7.19	1.67

Notes: This table shows percent changes of post 2014 aggregate investment compared to the pre-2014 steady-state.

Table 7: Post 2014 Aggregate Capital Dynamics

	Short Run	Long Run
Partial Equilibrium	1.44	3.55
General Equilibrium	0.26	1.61
Small Open Economy	0.72	1.67

Notes: This table shows percent changes of post 2014 aggregate capital compared to the pre-2014 steady-state.

Table 8: Aggregate Effects of Size-dependent Capital Gains Taxes: General Equilibrium

	Post 2014	$\tau^s = 0.10$	$\tau^s = 0$
Capital	1.61	6.89	12.39
Labor	0.21	1.10	1.50
Output	0.60	2.81	4.50
Consumption	0.40	1.92	2.78
TFP	0.03	0.26	0.25
Equity Issuance	-1.17	16.33	27.31
Share Repurchase	-0.50	0.23	1.22
Wage	0.61	3.03	4.32
Welfare (Steady)	0.30	1.34	1.99
Welfare (Transitional)	0.18	0.83	1.11

Notes: This table shows percent changes of aggregate variables in the long-run compared to the pre-2014 steady state in general equilibrium. First column refers to the case of eliminating labor threshold \bar{l}_E and increasing revenue threshold \bar{y} from 100 million dollars to 150 million dollars. The second column refers to the case of setting a uniform tax of 10 percent. Third column refers to the case of eliminating capital gains taxes altogether.

Table 9: Aggregate Effects of Size-dependent Capital Gains Taxes: Small Open Economy

	Post 2014	$\tau^s = 0.10$	$\tau^s = 0$
Capital	1.67	7.21	12.97
Labor	0.28	1.46	2.14
Output	0.66	3.11	5.03
Consumption	0.31	1.47	2.00
TFP	0.03	0.26	0.25
Equity Issuance	-1.08	16.50	27.78
Share Repurchase	-0.55	0.52	1.75
Wage	0.59	2.96	4.19
Welfare (Steady)	0.16	0.71	0.88
Welfare (Transitional)	0.16	0.74	0.93

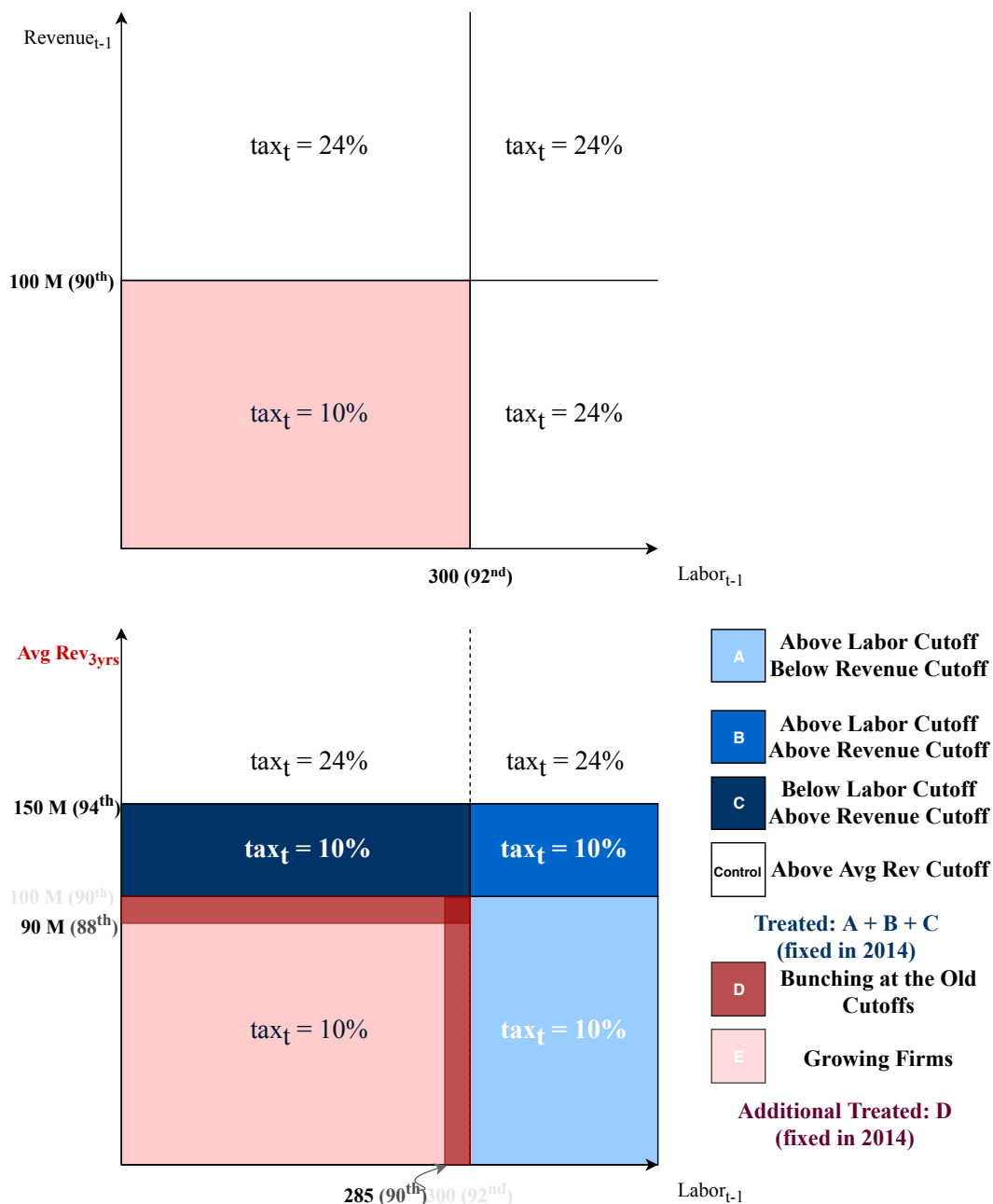
Notes: This table shows percent changes of aggregate variables in the long-run compared to the pre-2014 steady state in general equilibrium. First column refers to the case of eliminating labor threshold \bar{l}_E and increasing revenue threshold \bar{y} from 100 million dollars to 150 million dollars. The second column refers to the case of setting a uniform tax of 10 percent. Third column refers to the case of eliminating capital gains taxes altogether.

Table 10: Comparison of Capital Distribution

	Data	Baseline	Gaussian	Limited
Std. of log Output	1.23	1.15	1.19	1.19
Std. of log Labor	1.06	1.14	1.19	1.19
Std. of log Capital	1.29	1.08	1.09	0.72
Output Share	0.65	0.47	0.48	0.48
Labor Share	0.53	0.48	0.49	0.48
Capital Share	0.57	0.44	0.43	0.26

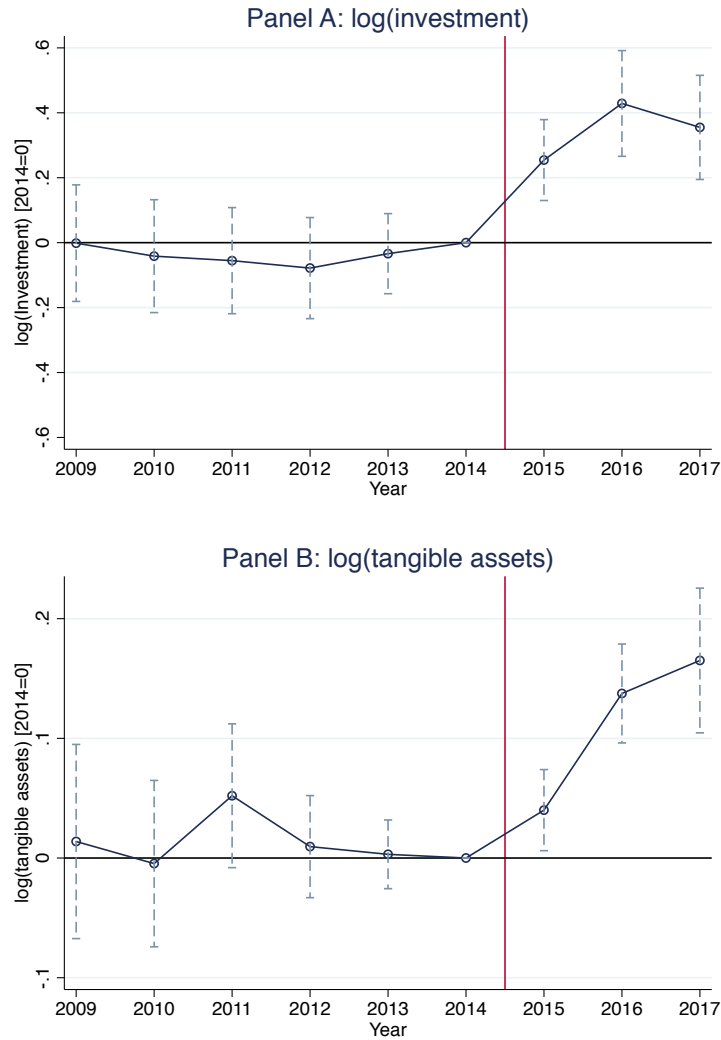
Notes: This table shows size moments for the cases of baseline, gaussian, and limited information. The first to third row show the standard deviation of log output, labor, and capital for all firms. The last three rows show the output, labor, and capital share of firms above Pre-2014 revenue and labor thresholds.

Figure 1: Policy Reform 2014 and Treated vs. Control Groups (Listed and Private Firms)



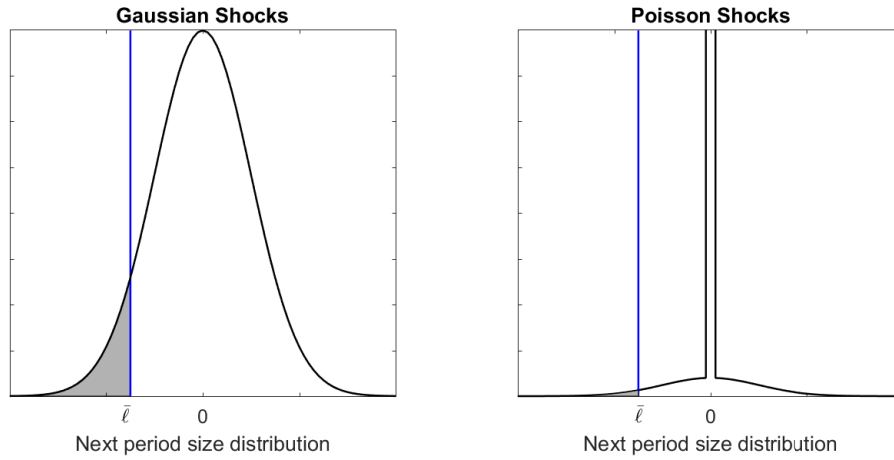
Notes: This figure illustrates how the reform in 2014 assigned firms into treated (tax cut) or control groups. The first figure on the top shows the initial rule on firm size prior to the reform, where firms in the pink area are jointly below labor and revenue threshold at time $t - 1$ and face a tax rate of 10%. The second figure shows how the reform affected firm size and the tax rates. I use firms in the blue areas (that experienced a tax cut by 14 percentage points) as the main treated group, and run a separate analysis using the second type of treated firms (that bunched in red areas) in Appendix B. I define the control group as firms that did not face any change in the tax rate or incentive to invest (in the white areas above the new revenue cutoff). Firms in the pink area were not directly impacted by the reform, but it is difficult to consider them as part of the control group because these firms were growing and may grow even more because the old thresholds are no longer binding.

Figure 2: Tax Effects on $\log(\text{investment})$ and $\log(\text{tangible assets})$



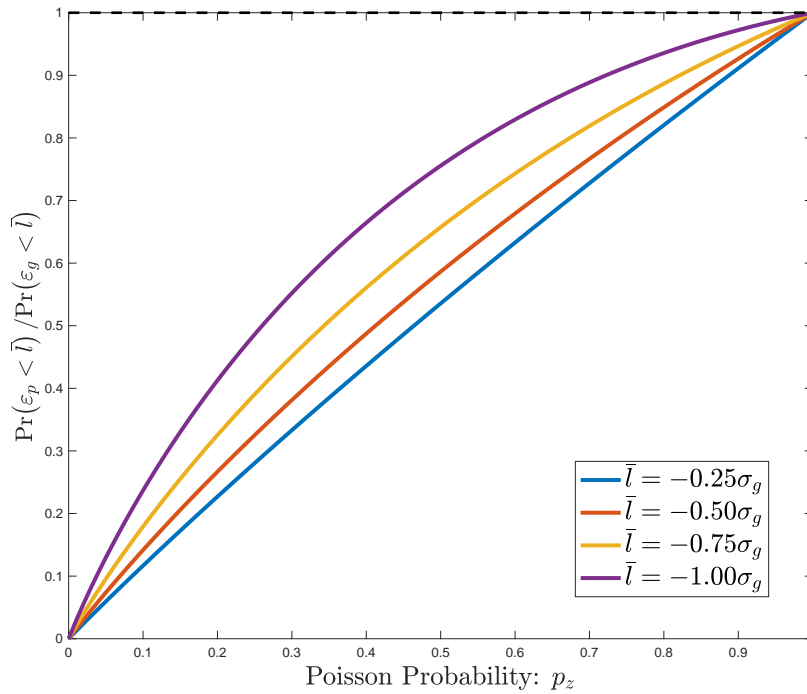
Notes: Panel A of this figure shows the coefficients on $Treated \times Time$ for firms' investment, defined as $\log(\text{expenditures on physical capital assets})$, in equation (1) using both publicly listed and private firms. The dashed lines indicate 95% confidence intervals for these coefficient estimates. The solid vertical line indicates the reform year. Panel B of this figure shows the coefficients on $Treated \times Time$ for firms' capital stock, defined as $\log(\text{tangible assets})$.

Figure 3: Size Threshold Effect



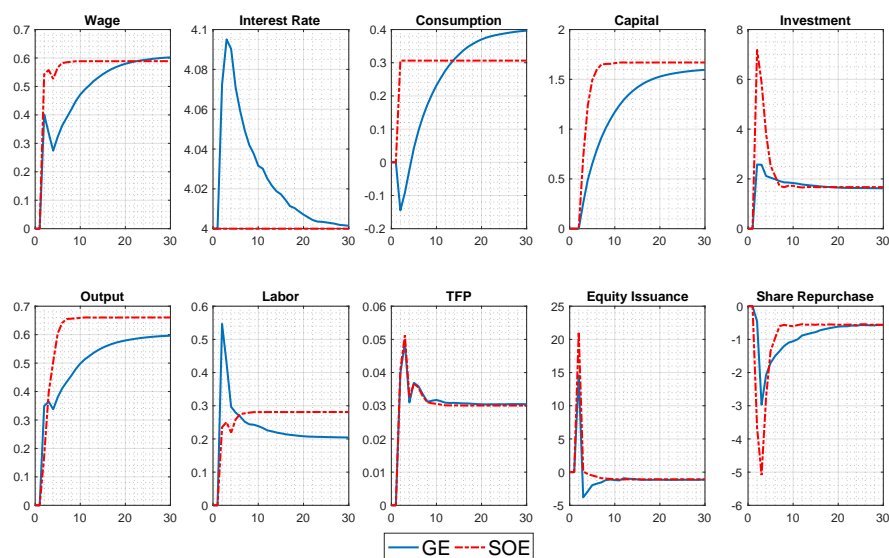
Notes: This figure illustrates size threshold effect. The left panel is the case of Gaussian shocks, and the right panel is the case of Poisson shocks.

Figure 4: Gaussian Shock vs Poisson Shock



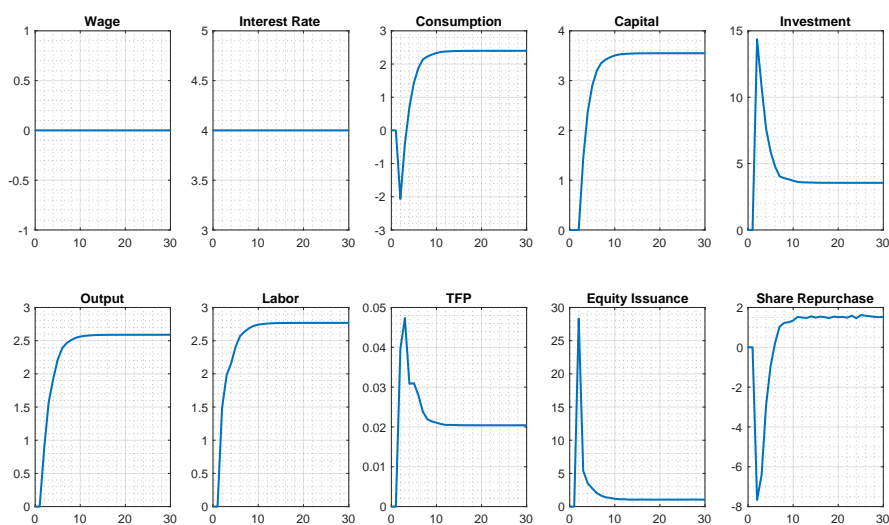
Notes: This figure illustrates the probability ratio of firm size below threshold \bar{l} . $\bar{l} \in \{-0.25\sigma_g, -0.50\sigma_g, -0.75\sigma_g, -1.00\sigma_g\}$ corresponds to lines from bottom to above.

Figure 5: Transitional Dynamics of Firm-size Reform in 2014



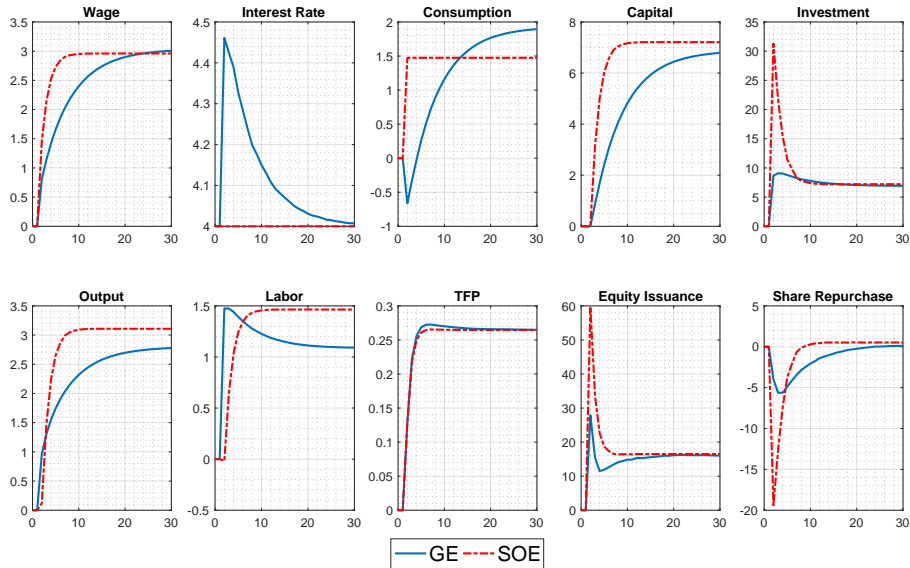
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform of eliminating labor threshold and increasing revenue threshold from 100 million to 150 million dollars. GE is the case of general equilibrium. SOE is the case of Small Open Economy.

Figure 6: Transitional Dynamics of Firm-size Reform in 2014: Partial Equilibrium



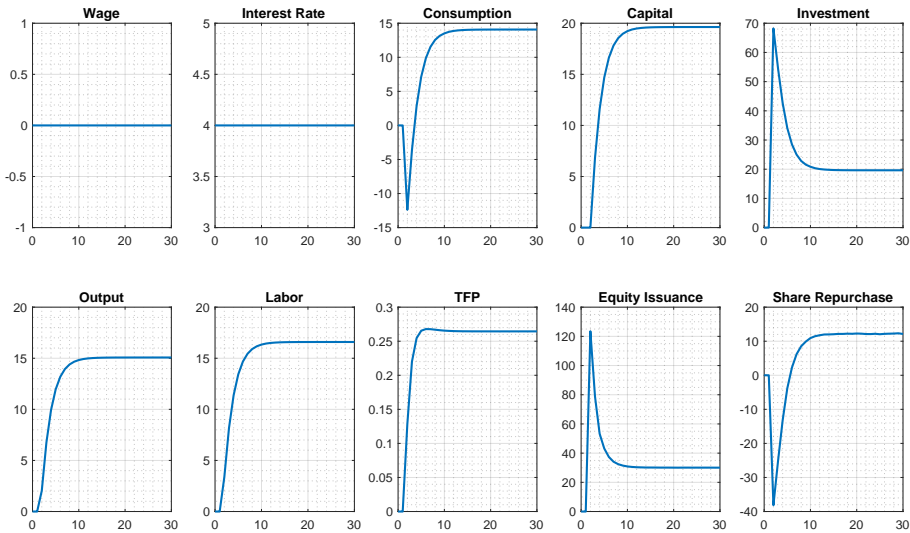
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform of eliminating labor threshold and increasing revenue threshold from 100 million to 150 million dollars. Both wage and interest rate are kept at initial level for Partial Equilibrium analysis.

Figure 7: Transitional Dynamics of Uniform Tax Rate



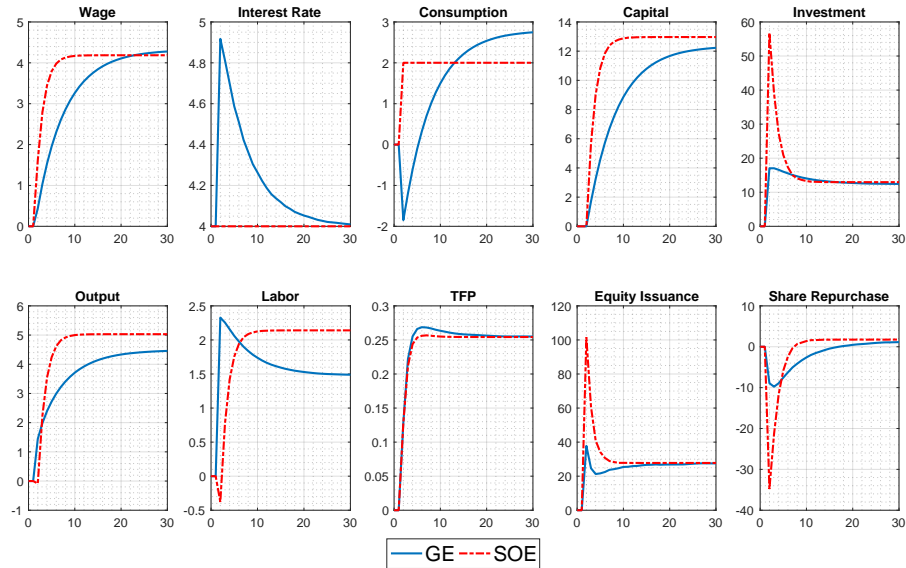
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting a uniform capital gains tax rate of 10%. GE is the case of general equilibrium. SOE is the case of Small Open Economy.

Figure 8: Transitional Dynamics of Uniform Tax Rate: Partial Equilibrium



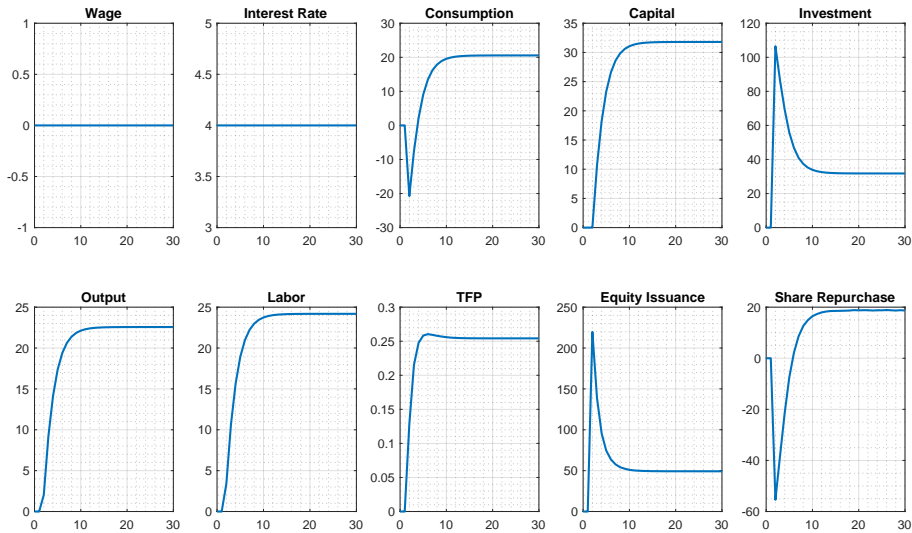
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting a uniform capital gains tax rate of 10%. Both wage and interest rate are kept at initial level for Partial Equilibrium analysis.

Figure 9: Transitional Dynamics of Zero Tax Rate



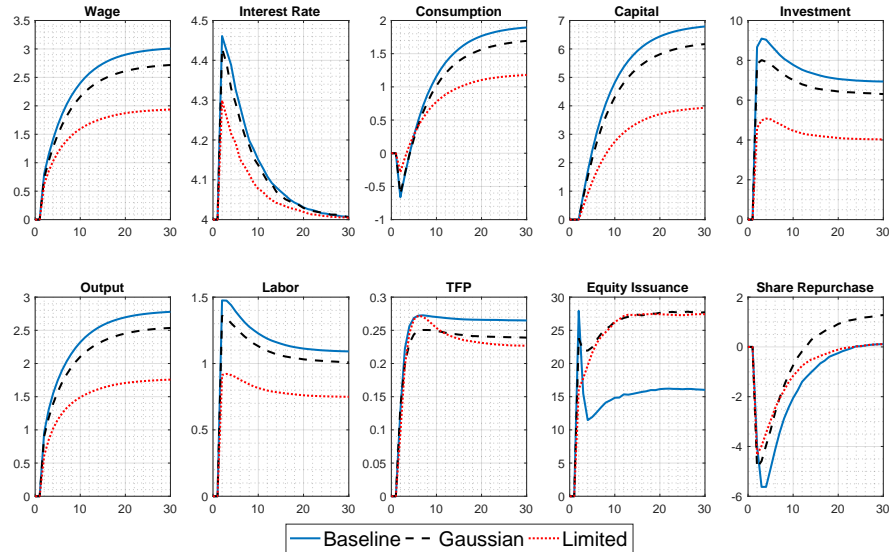
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting the capital gains tax rate to zero. GE is the case of general equilibrium. SOE is the case of Small Open Economy.

Figure 10: Transitional Dynamics of Zero Tax Rate: Partial Equilibrium



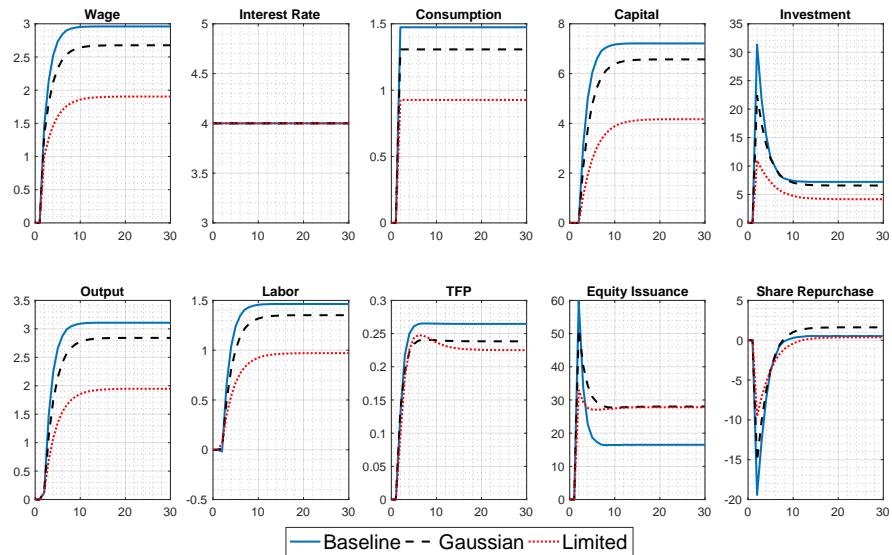
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting the capital gains tax rate to zero. Both wage and interest rate are kept at initial level for Partial Equilibrium analysis.

Figure 11: Comparison of Baseline, Gaussian, Limited Information Cases (GE)



Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting a uniform capital gains tax rate of 10% in general equilibrium, for baseline, gaussian, and limited information cases.

Figure 12: Comparison of Baseline, Gaussian, Limited Information Cases (SOE)



Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to setting a uniform capital gains tax rate of 10% in small open economy, for baseline, gaussian, and limited information cases.

Appendix Materials

A Institutional Details

In Appendix A, we provide further institutional details regarding corporate tax rates and firm size regulations in Korea. In Appendix A.1, we describe historical corporate income tax rates on profits and dividend tax rates. In Appendix A.2, we give more institutional details on the firm-size regulations and the policy reform in 2014. Note that most of the details in Appendix A are directly from Moon (2018), in which further details are available.

A.1 Corporate and Capital Tax Rates in Korea

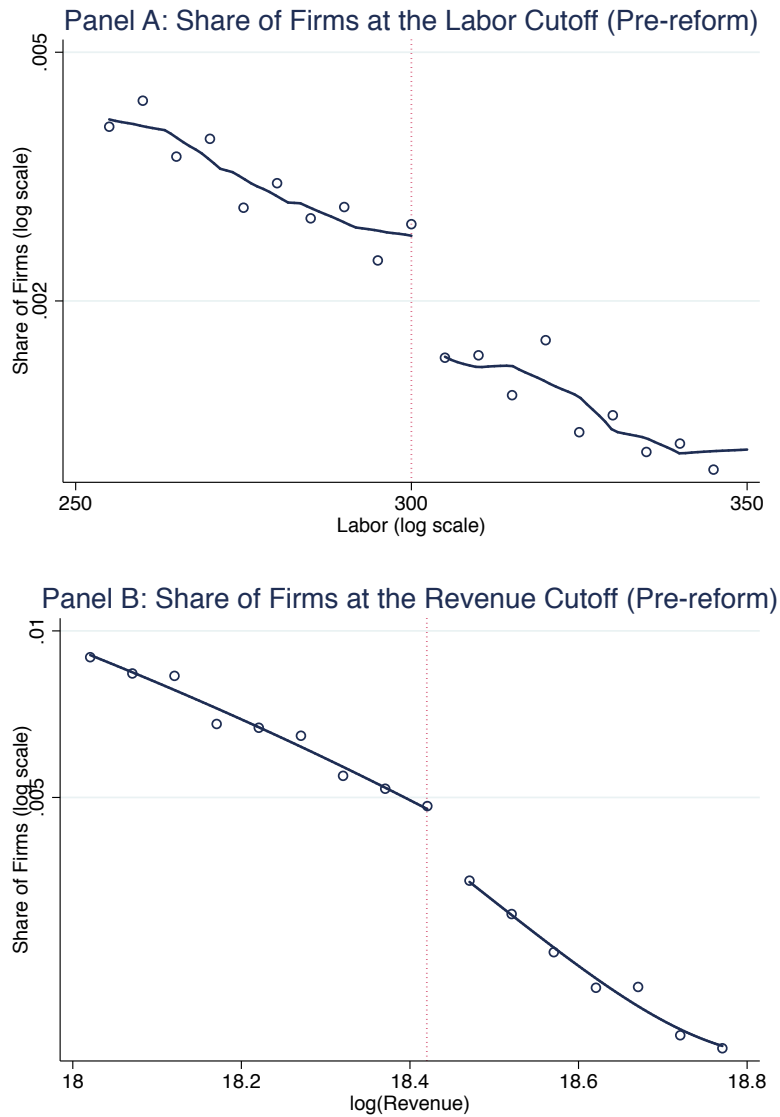
A.1.1 Corporate Income Tax Rates on Profits

In Korea, from 2005 to 2007, the corporate income tax rate is 13% for profits below \$100,000, and 25% for profits above. From 2008 to 2011, the profit threshold had increased to \$200,000, and the tax rates below and above the cutoff were reduced to 10% and 22%, respectively. From 2012, the government has added a third profit threshold of \$20 million, has reduced the tax rate in the middle category to 20%, and has kept the top corporate tax rate at 22%. Although there were changes in corporate income tax rates across time in Korea, the last change happened in 2011, which was 3 years before the main reform that we exploit for identification. More importantly, the profit threshold was even low for many firms in our sample, so unlikely had influenced their investment following the reform in 2014. We confirm that this issue does not affect our results using placebo tests (See Appendix B).

A.1.2 Dividend Tax Rates

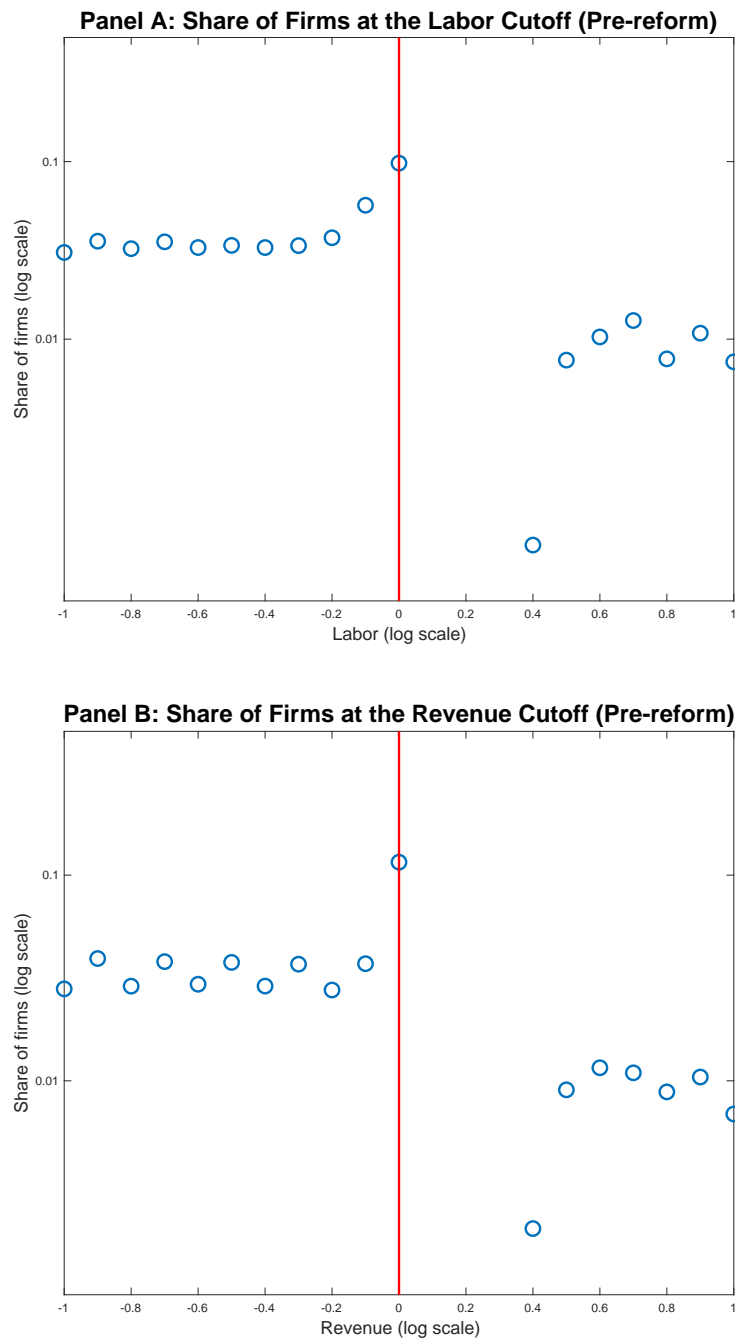
In Korea, dividends are taxed similarly as individual incomes. If an investor's dividend income in a given year is less than \$20,000, then the tax rate is 15.4%. However if dividend income is above \$20,000, then it becomes part of the investor's income, and the marginal tax rate can rise up to 38%, depending on his total income. From 2005 and 2010, the top dividend tax rate was 35% and increased to 38% in 2011.

Figure A.1.1: Firm density at Firm-size Cutoff (Data)



Notes: Panel A in this figure shows the firm density at the labor cutoff, conditional that the firms are jointly below the other thresholds (revenue, total capital, and assets). The cutoff is at the labor of 300, and the bin size is 5 average employees. The hollow dots indicate the share of firms at a given bin. The solid lines are the local polynomial smooth plots, fitted to below and above the cutoff separately. The standard McCrary test (2008) rejects the null that the coefficient at the jump is statistically not different from zero. Panel B shows the firm density at the revenue cutoff, conditional that the firms are jointly below the other thresholds (labor, total capital, and assets). The cutoff is at the revenue of 100 million dollars, and the bin size is 0.05 log revenues. The McCrary test (2008) rejects the null that the coefficient at the jump is statistically not different from zero.

Figure A.1.2: Firm density at Firm-size Cutoff (Model)



Notes: Panel A of this figure shows the firm density around the labor cutoff (normalized to be zero) from the model simulation prior to the reform. Panel B of this figure shows the firm density around the revenue cutoff (normalized to be zero) from the model simulation prior to the reform.

A.2 How to Account for Subsidiaries for Tax Purposes

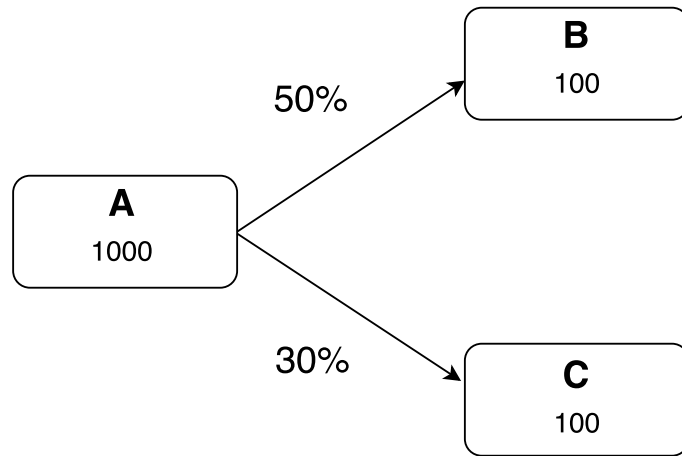
Table A.2: Computing Accounting Variables for Tax Purposes

Firm	Relationship	Labor	Ownership	Labor Size for Tax Purposes
Case 1				
A	Parent to B & C	1000	-	$1000 + (1.0) * 100 + (0.3) * 100 = 1130$
B	Subsidiary to A	100	50%	$100 + (1.0) * 1000 = 1100$
C	Subsidiary to A	100	30%	$100 + (0.3) * 1000 = 400$
Case 2				
X	Parent to Y	3000	-	$3000 + (1.0) * 2000 + (0.5) * 1000 = 5500$
Y	Parent to A	2000	50%	$2000 + (1.0) * 3000 + (1.0) * 1000 + (0.5) * 100 = 6050$
A	Parent to B	1000	50%	$1000 + (0.5) * 3000 + (1.0) * 2000 + (1.0) * 100 + (0.5) * 50 = 4625$
B	Parent to C	100	50%	$100 + (0.5) * 2000 + (1.0) * 1000 + (1.0) * 50 = 2150$
C	Subsidiary to B	50	50%	$50 + (0.5) * 1000 + (1.0) * 100 = 650$

Notes: This table shows how to compute values for a firm's accounting variables for tax purposes. In Case 1 example, I assume that firm A is the parent company with two subsidiaries, namely B and C. Assume that each of the subsidiary does not own any other subsidiary (if it does, then it will just become a part of the parent firm's subsidiary). The column, "Labor", denotes how many average employees each firm used in a given operating period of time. Given the rules described in Section 2.4, each firm's labor input for tax purposes is computed as shown in the last column. For example, to compute the parent company's labor size for tax purposes, we add a subsidiary's labor input multiplied by the ownership rate if the rate is less than 50% and add the entire labor input of firm y since A owns at least 50%. In Case 2 example, we compute the accounting values for parent firms subsidiaries in a similar way, except that if a parent firm owns a grandchild firm through its subsidiary, then the parent firm's ownership of that firm is equal to its subsidiary's ownership rate of that firm if the ownership rate is at least 50%. If the ownership rate is less than 50%, then the parent firm's ownership of the grandchild firm is computed by multiplying two ownership rates together. To compute the values for other accounting variables (i.e. revenues, total capitals, assets), we repeat the same exercise for each variable.

Figure A.2: Computing Accounting Values

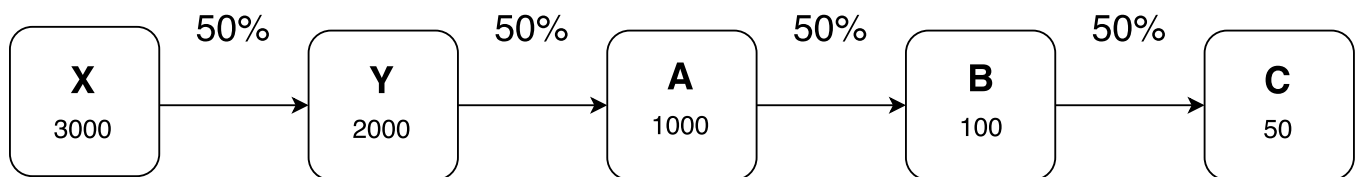
Case 1



Notes: This figure shows how to compute accounting values for firms in a case where firm A owns just two subsidiaries, B and C. Suppose that firm A owns 50% of firm B and 30% of firm C, and that neither B nor C owns any subsidiary. Also, suppose that in a given year, firm A, B, and C used 1000, 100, and 100 employees on average, respectively. The government computes the average employee used for each firm in the following way:

- (1) firm A: $1000 \times (100\% \text{ of firm A}) + 100 \times (100\% \text{ of firm B}) + 100 \times (30\% \text{ of firm C}) = 1130$
- (2) firm B: $1000 \times (100\% \text{ of firm A}) + 100 \times (100\% \text{ of firm B}) = 1100$
- (3) firm C: $1000 \times (30\% \text{ of firm A}) + 100 \times (100\% \text{ of firm C}) = 400$

Case 2



Notes: This figure shows how to compute accounting values for firms in a case where firm X owns 50% of Y, which owns 50% of A, which owns 50% of B, which owns 50% of C. Suppose that there's no other subsidiary involved in any of the firms. Also, suppose that in a given year, firm X, Y, A, B, and C used 3000, 2000, 1000, 100, and 50 employees on average, respectively. The government computes the average employee used for each firm in the following way:

- (1) firm X: $3000 + (1.0) \times 2000 + (0.5) \times 1000 = 5500$
- (2) firm Y: $2000 + (1.0) \times 3000 + (1.0) \times 1000 + (0.5) \times 100 = 6050$
- (3) firm A: $1000 + (0.5) \times 3000 + (1.0) \times 2000 + (1.0) \times 100 + (0.5) \times 50 = 4625$
- (4) firm B: $100 + (0.5) \times 2000 + (1.0) \times 1000 + (1.0) \times 50 = 2150$
- (5) firm C: $50 + (0.5) \times 1000 + (1.0) \times 100 = 650$

B Robustness Checks

In Appendix B, we provide a set of robustness tests for the main results in Section 3.

B.1 Without Controls

We repeat the main analysis in equation (1), without basic or additional controls and with only basic controls. Panel A of Figure B.1 shows the main results on log(investment) without any basic or additional controls, and Panel B of Figure B.1 shows the main results on log(tangible assets) without any basic or additional controls. The coefficient estimates after the year 2014 are smaller when we do not include any controls or when we include only basic controls, but the results are qualitatively similar to the ones from the main specification in equation (1).

B.2 With Different Levels of Winsorizing

We repeat the main analysis using the same specification as in equation (2), winsorizing (top-coding) main outcome variables at the 95% level, instead of at the 99% level. Table B.2 shows the main results based on this different level of winsorizing. The estimates on this table suggest that the main results are robust to and qualitatively similar when using different levels of winsorizing.

B.3 Using Balanced Panel

We repeat the main analysis using the same specification as in equation (2), using a balanced panel. Table B.3 shows the main results based on using the balanced panel. The main results are qualitatively similar whether the sample is balanced or not.

B.4 Including Firms in Other Sectors

We repeat the main analysis using the same specification as in equation (2), including firms in other sectors. Table B.4 shows the main results based on using firms in other sectors in addition to the firms in the main analysis sample. The main results are qualitatively similar when we include firms in other sectors.

B.5 Firms that Bunched at Old Cutoffs

We repeat the main analysis on investment using firms that were bunching at either of the old cutoffs prior to the reform. Since firms were bunching precisely to avoid higher capital

gains tax rates, removing the old cutoffs may increase their incentive to invest. Table B.5 shows results just using firms that were bunching as treated group and unaffected firms as control. As columns (1) and (3) show, their investment response is slightly higher than the average investment response from the overall affected firms that include both types of treated firms, although the difference is not statistically different from one another.

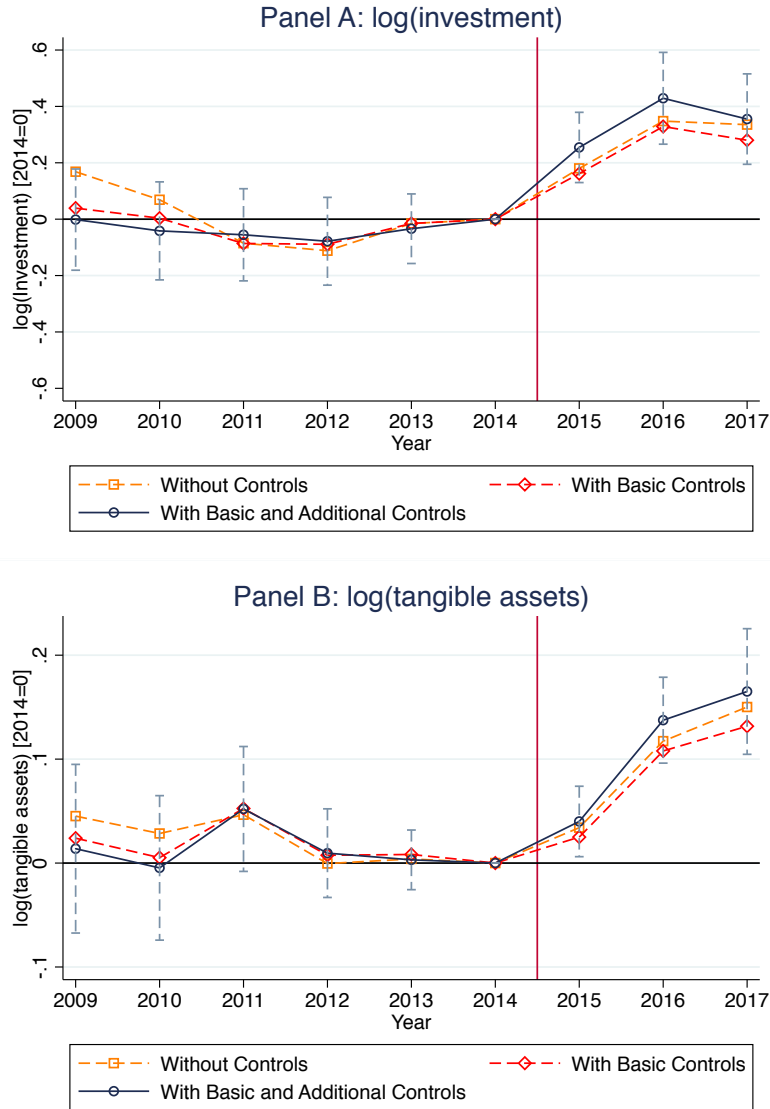
B.6 Placebo Test using earlier periods

Since other time-varying shocks, such as different policy reforms, may coincide or occur close to the reform in 2014, we conduct placebo tests using earlier time periods. For example, there was a corporate tax reform in 2012, which moderately changed the tax schedule for firms making under \$200,000. Even though this change was small enough so that it would not necessarily affect the overall results, we still use year 2012 as the placebo date and set *Post* equal to 1 if it is after 2012. Table B.6 shows the results based on the placebo test. The coefficients are not statistically different from zero even at the 90% confidence level, suggesting that there were no other changes that could have affected the main results around this period of time.

B.7 Placebo Test using random cutoffs

To ensure that the main results on investment are driven by the policy variation, which generated a set of firms whose investment incentives have changed due to changes in regulations on firm size, we conduct a placebo test using random cutoffs to define the treated group. For example, we set an arbitrarily much higher value of \$450 million (instead of \$150 million) for the new revenue threshold, so that many of the unaffected firms are defined now as treated firms. The placebo tests are qualitatively similar if we use other random cutoffs (much lower or higher threshold). Table B.7 shows the results based on the placebo test. The coefficients are not statistically different from zero even at the 90% confidence level, suggesting that the policy variation based on the reform in 2014 was the main driver of the investment responses for the affected firms.

Figure B.1: Tax Effects on Real Outcomes of Affected and Unaffected Firms



Notes: Panel A of this figure shows the coefficients on $Treated \times Time$ for firms' investment, defined as $\log(\text{expenditures on physical capital assets})$, in equation (1). The dashed lines indicate 95% confidence intervals for these coefficient estimates. The solid vertical line indicates the reform year. The orange dash line indicates the coefficients in equation (1) without any controls and the red dash line indicates those with only basic controls. Panel B of this figure shows the coefficients on $Treated \times Time$ for firms' $\log(\text{tangible assets})$.

Table B.2: Main Results with Different Level (95%) of Winsorizing

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.353*** (0.068)	0.087** (0.041)	0.037*** (0.011)	0.039*** (0.011)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.139	16.323	0.062	0.141
Implied Elasticity wrt (1-tau)	1.92	0.47	3.21	1.49
R-squared	0.72	0.93	0.23	0.43
Observations (firm-years)	12496	12693	12700	4732
Clusters (firms)	1477	1477	1477	1477

Notes: This table reports the tax effects on investment. The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 ppt, as explained in Section 3. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table B.3: Main Results by Balanced panel

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.362*** (0.073)	0.123*** (0.033)	0.036*** (0.014)	0.044*** (0.012)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.322	16.580	0.094	0.150
Implied Elasticity wrt (1-tau)	1.96	0.67	2.10	1.60
R-squared	0.71	0.94	0.19	0.43
Observations (firm-years)	10813	10890	10891	4263
Clusters (firms)	1223	1223	1223	1223

Notes: This table reports the tax effects on investment. The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 ppt, as explained in Section 3. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table B.4: Main Results by Including Firms in Other Sectors

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.349*** (0.065)	0.119*** (0.039)	0.038*** (0.013)	0.044*** (0.012)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.124	16.283	0.083	0.150
Implied Elasticity wrt (1-tau)	1.90	0.64	2.47	1.58
R-squared	0.72	0.92	0.20	0.42
Observations (firm-years)	15012	15250	15258	5255
Clusters (firms)	1814	1814	1814	1814

Notes: This table reports the tax effects on investment. The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 ppt, as explained in Section 3. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table B.5: Main Results by Treated Firms with Either Tax Cut and/or Bunching

	Bunching Firms	Tax Cut Firms	Bunching and Tax Cut Firms
	(1)	(2)	(3)
	ln(I)	ln(I)	ln(I)
Treated x Post	0.388*** (0.109)	0.356*** (0.068)	0.361*** (0.062)
Controls	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes
Pre-reform Treated Mean	14.376	14.140	14.188
Implied Elasticity wrt (1-tau)	2.11	1.93	1.96
R-squared	0.71	0.72	0.71
Observations (firm-years)	10024	12496	13461
Clusters (firms)	1172	1477	1591

Notes: This table reports the tax effects on the main corporate outcomes based on the difference-in-differences estimation, where I combine treated firms for those that face lower tax rates after the reform with firms that were bunching prior to 2014. The dummy for $Treated_i$ equals 1 if a firm i either had a tax reduction of 14 ppt or faced an incentive to invest, as explained in 3. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table B.6: Placebo Test using an Earlier Period

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.128 (0.097)	0.052 (0.048)	0.020 (0.018)	0.023 (0.017)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.126	16.250	0.100	0.146
Implied Elasticity wrt (1-tau)	0.70	0.28	1.06	0.86
R-squared	0.72	0.93	0.20	0.42
Observations (firm-years)	12247	12440	12447	4649
Clusters (firms)	1476	1476	1476	1476

Notes: This table reports the tax effects on the main corporate outcomes as a placebo test. The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 ppt, as explained in Section 3. The dummy for $post_t$ equals 1 if the time period is after the end of the placebo year (2012). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table B.7: Placebo Test using a Random Cutoff

	Investment	Capital Stock	Net Investment	Investment Rate
	(1)	(2)	(3)	(4)
	ln(I)	ln(K)	dK/K	I/K
Treated x Post	0.115 (0.085)	0.059 (0.044)	-0.003 (0.014)	0.012 (0.013)
Basic Control	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	Yes	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.892	17.060	0.093	0.146
Implied Elasticity wrt (1-tau)	0.63	0.32	-0.16	0.43
R-squared	0.72	0.93	0.20	0.42
Observations (firm-years)	12135	12324	12331	4624
Clusters (firms)	1440	1440	1440	1440

Notes: This table reports the tax effects on the main corporate outcomes as a placebo test. I use a random cutoff of \$450 million to define treated firms. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Variables are as defined in Table 2. Each time period is a year, and the sample period is from 2009 to 2017. The reform was announced in the middle of 2014 and implemented by the end of 2014. All specifications include time and firm fixed effects (FE). The standard errors are clustered at the firm level and are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.