Capital Gains Taxation and Investment Dynamics*

Sungki Hong† Terry S. Moon‡

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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 relevant micro moments as well as the difference-in-differences estimate of the capital elasticity based on the institutional setting and a policy reform 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 2 percent and 1.2 percent in the short-run and in the steady state, respectively. Additionally, in a counterfactual analysis where we set the uniformly low tax rate of 10 percent, the aggregate investment rose by 5.9 percent in the long-run. 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.

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†Federal Reserve Bank of St. Louis, Email: Sungki.Hong@stls.frb.org.

‡Vancouver School of Economics, University of British Columbia, 6000 Iona Drive, Vancouver, B.C., V6T 2E8. Email: tsmoon@mail.ubc.ca. Phone: +1 604 822 0762.

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 an investment model by Gourio and Miao (2010), 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 calibrate our model's key parameters using our difference-in-differences estimate of the capital stock elasticity with respect to capital gains tax rates. 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, jointly 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 current and past two years. Due to 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 40 log points and capital stock by 9 log points within four years after the reform. The estimates suggest that affected firms increased investment by roughly 2.5 billion dollars, which is 3 percent of total investment in the economy after the reform. We show that our results are internally consistent by showing 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' revenue, 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 pre-reform thresholds that determined 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 a 3 percent of total investment in the economy.

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

[1]There 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.

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 matches the data better than does our benchmark model.

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 1.7, 1.8, 2.6, and 1.9 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 0.25, 0.40, 1.18, and 0.14 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 0.07 percent, labor supply increases by 0.35 percent, and investment increases by 1.95 percent.

Moreover, we conduct a related counterfactual policy analysis by imposing a uniform capital gains tax rate of 10 percent and thereby eliminating the tax difference based on firm size. 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 1.58, 2.43, 5.89, and 0.96 percentage points.

We show that matching micro moments in the data is crucial for our model and for policy analysis. In the 2014 reform, a model without Poisson shocks would over-predict the increases in aggregate consumption, capital, output, and labor by 1.42, 1.40, 1.42, and 1.80 percent points, 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. Our paper provides 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 empirical strategy, data, and reduced-form estimates used 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. 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.[2] In 2014,

[2] In 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.

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 changes. 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 on firm size. For the main sectors (see Section 3) used in our analysis, a firm has to jointly satisfy the following criteria by December of year t to be classified as small in March of year $t + 1$: total revenue below 100 million dollars and average employee below 300.[3] The term, "average employee", is defined as the sum of daily workers employed over the entire operating days, divided by the sum of operating days, in each year. Firms have to report the number of employees and operating days to the government every quarter. For tax purposes, a parent firm's accounting variables incorporate the subsidiary's accounting variables by multiplying their values by the ownership rate. If the parent firm has at least 50 percent ownership, then the subsidiary's accounting variables are directly added to those of the parent firm. More details with examples are included in Appendix A.2.

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 current and past two years.[4] The primary intention of the reform was to simplify the rules on firm size. This reform was discussed by government officials in early 2014, its approval was announced in August, 2014, and it was implemented by the end of 2014; therefore, this policy change came as a shock to affected firms. Moreover, investors did not fully know which firms were actually affected by this reform until firm size was publicly announced through annual audit reports on March of 2015. This is evidenced by stock price responses for affected firms, relative to unaffected firms (Moon 2019). We describe how we use this reform for identification in Section 3.

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

[3]Full details on how small firms were defined prior to the reform in 2014 are described in Moon (2019).

[4]Although the reform eliminated the labor threshold for all sectors as a requirement to remain small, and further changed the revenue threshold into the average over the current and past two years, it increased the average revenue threshold to 150 million dollars only for certain industries within the manufacturing sector. We provide more details on how the reform differentially affected different sectors, and the sectoral and industrial compositions of firms in Appendix A.2.

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.[5]

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 current and past two 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 rate.[6] 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 may 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.[7] 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,

[5]Panel A of Figure A.2 in Appendix A.2 illustrates firm density around the labor cutoff, conditional that the firms are below the other thresholds. Panel B of Figure A.2 illustrates firm density around the revenue cutoff, conditional that the firms are below the other thresholds. On both graphs, the McCrary (2008) test rejects the null hypothesis that the jump is statistically not different from zero at the 5 percent significance level. These graphs provide suggestive evidence that firms want to avoid higher tax rates by trying to stay below each of the cutoffs, although some firms are right above the cutoff, either because of adjustment costs or inability to control firm size precisely.

[6]The new revenue threshold did not increase to 150 million dollars for certain industries within the manufacturing sector and for 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 (2019).

[7]We chose firms 5 percent below the labor cutoff and 10 percent below the revenue cutoff as part of the additional, but separate, treated group. The reason is that the growth rates of labor and revenue below each threshold were 5 percent and 10 percent on average prior to the reform, respectively.

given that there was no change in their incentive to invest.[8] 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 the reform.[9] We run a separate analysis for the second type of treated (bunching) firms in Appendix B. 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:

$$y_{it} = \sum_{\tau=2009}^{2018} \theta_\tau \mathbb{1}[t = \tau] \times Treated_i + \alpha_i + \alpha_t + X_{it}\beta + \epsilon_{it} \tag{1}$$

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. 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:

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

where $Post_t$ is a dummy equal to 1 if it is after the reform year of 2014, and all the other variables are as defined in equation (1). We report the estimates from this equation (1), as well as the ones

[8] Firms 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.

[9] I exclude the top five percent of firms based on their size because these big conglomerates (i.e., Samsung) are too big to be part of the control group.

from the equation (2) in Section 3.5.

We 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.

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, affected and unaffected firms showed parallel trends for key outcomes prior to the reform. Second, stock price responses show that the reform was unexpected (Moon 2019), and there was no evidence of sorting at the new cutoff for the first four 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 2018, 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 88 percent of all publicly listed companies and 84 percent of all private firms.[10] Furthermore, firms in these sectors account for about 82 percent of total revenue in the entire sample. Moreover, for private firms, expenditures on physical capital investment are more frequently observed in these sectors than in other sectors, such as retail. We run a separate analysis including firms in other sectors and

[10] Top five sectors in my analysis sample are (1) Manufacturing, (2) Construction, (3) Production and Information Services, (4) Retail, and (5) Science and Technology Services, which account for about 96 percent and 91 percent of the entire sample of publicly listed and private firms, respectively.

find qualitatively similar results (see Appendix B).

We acquired the accounting data set for private firms 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, average employment, and total revenue. 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 employee, physical capital (tangible) assets, expenditures on physical capital assets, profits, and total capital.

The key outcome variables are physical capital assets and investment. We define physical capital assets as the book value of tangible assets (i.e., plants, properties, and equipment) as they appear in firms' balance sheets. We define investment as the log of expenditures on physical capital assets. We winsorize the main outcome variables at the first and ninety-ninth percent levels, and do robustness checks by winsorizing the main outcomes at the fifth and ninety-fifth percent levels in Appendix B.

3.4 Descriptive Statistics

We summarized the main variables, such as revenue, asset, average employee, 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 tangible 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 $\tau \in (2009, ..., 2018)$, for log(investment) as in equation (1). The graph shows the parallel trend on investment between the affected and unaffected firms, 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 $\tau \in (2009, ..., 2018)$, for log(tangible assets) as in the equation (1).The graph shows the parallel trend on investment between the affected and unaffected firms, 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 (bottom- and top-code) the main outcomes at the first and ninety-ninth percentile. Column (1) shows the coefficient is 0.403 for log(investment), with the 95% confidence interval of (0.285,0.521), implying that firms that experienced a reduction in capital gains tax rates from 24 percent to 10 percent increased investment by 36 log points, compared to unaffected firms. Column (2) shows the coefficient is 0.095 for log(tangible assets), with the 95% confidence interval of (0.019,0.171), 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:

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

The estimated elasticity is 0.51, 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 fifth and ninety-fifth percent levels. 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 2011, 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 in which 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:

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

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 $P_{jt} - P_{jt-1}$ 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.[11] The household also needs to pay income taxes τ_i on labor income and bond returns, and capital gains tax τ^g_{jt} and receives government lump-sum transfer T_t. The household's budget constraint is:

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

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:

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

The firm share θ_t holding condition is:

$$P_t = \beta \mathrm{E}_t \left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(P_{t-1} + (1-\tau^g_t)(s_t + P_t - P_{t-1})\right) \right]$$

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

$$(1-\tau^i)r = \frac{1}{P_t}(1-\tau^g_{jt+1})\mathrm{E}_t\left[s_{jt+1} + P_{jt+1} - P_{jt}\right]. \quad (6)$$

[11]In 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.

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

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:

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

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

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

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:

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

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 $\bar{l}_E$.[12] The tax schedule can be summarized as:

$$\tau^g_{jt+1} = \begin{cases} \tau^g_h & \text{if } l_{jt} > \bar{l}(z_{jt}, k_{jt}) \equiv \min\{\bar{l}_R(z_{jt}, k_{jt}), \bar{l}_E\} \\ \tau^g_l & \text{otherwise,} \end{cases} \tag{10}$$

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:

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

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^g from the state variables: $V(z, k, \tau^g, \psi_0) = V(z, k, \psi_0)$.

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:

$$V_N(z, k) = \max_{l \in \{\bar{l}(z,k), l^*(z,k)\}} (1 - \tau^c)\left(z k^{\alpha_k} l^{\alpha_l} - wl\right) + \tau^c \hat{\delta} k + \frac{1}{1 + \frac{(1-\tau^i)r}{1-\tau^{g'}(l)}} \mathrm{E}_t \left[V\left(z', (1-\delta)k, \psi_0'\right) \right], \tag{12}$$

[12] Since 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:

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

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:

$$V_A(z,k) = \max_{i,l \in \{\bar{l}(z,k), l^*(z,k)\}} (1-\tau^c)\left(zk^{\alpha_k} l^{\alpha_l} - wl\right) + \tau^c \hat{\delta} k - i - \frac{\psi_1}{2}\left(\frac{i}{k}\right)^2 k$$
$$+ \frac{1}{1 + \frac{(1-\tau^i)r}{1-\tau^{g'}(l)}} \mathrm{E}_t\left[V\left(z', (1-\delta)k + i, \psi_0'\right)\right]. \tag{13}$$

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

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

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

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

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

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

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.[13]

[13]Note 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.

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 persistent 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 and the risk-free interest rate. 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
$$L(w,C) = \int l(z,k)dF(z,k) \tag{17}$$

3. Aggregate Output
$$Y = \int y(z,k)dF(z,k); \tag{18}$$

4. Aggregate Investment
$$I = \int i(z,k)dF(z,k); \tag{19}$$

5. Aggregate Adjustment Cost
$$\Psi = \int \psi_0 \mathbb{1}_{i(z,k)\neq 0} k dG(\psi_0)dF(z,k) + \int \frac{\psi_1}{2}\left(\frac{i(z,k)}{k}\right)^2 kdF(z,k); \tag{20}$$

6. Government Budget Constraint
$$T = \tau^i w \int l(z,k)dF(z,k) + \tau^c \int \left(y(z,k) - wl(z,k) - \hat{\delta}k\right) dF(z,k) + \int \tau^g(z,k)s(z,k)dF(z,k); \tag{21}$$

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 2018.

5.1 Externally Calibrated

The model period is one year. 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. And as in Garicano, Lelarge and Van Reenen (2016), we allow for measurement errors and restrict the standard deviation σ_ϵ to be the same for both output and labor, which helps the model match the firm density around the size thresholds. 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, (4) the standard deviation of productivity shock σ_z, (5) a Poisson probability of shock arrival p_z, (6) the risk-free interest rate, (7) the standard deviation of measurement error σ_ϵ, (8) the revenue threshold $\bar{y}$, and (9) the employee threshold $\bar{l}_E$.

The top panel of Table 4 reports the data and simulated moments. We select the following fourteen moments as informative about the parameters (1) to (7): 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; kurtosis of the investment rate; standard deviation of log(output); output autocorrelation of one, three, and five years; standard deviation of output and labor growth rate; kurtosis of output and labor growth rate; 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.

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

The bottom panel of Table 4 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 estimated quadratic cost is 0.14, comparable to 0.05 in Cooper and Haltiwanger (2006). The persistence of an AR(1) productivity process is 0.75 and the standard deviation of shocks is 0.16, comparable to the findings in the literature. The Poisson probability of new productivity shock is $p_z = 0.30$. This estimate is comparable to 0.41 in Bachmann and Bayer (2014) and much higher than 0.03 in Midrigan (2011).[14] The risk-free rate is 3.41%, which is close to 4% widely used in the macroeconomics literature. Finally, the standard deviation of the measurement error is roughly a half of the standard deviation of the productivity shock.

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 fit 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 kurtosis of investment rate, output growth rate, and labor growth rate, and difference-in-differences estimate of the capital stock response. The Gaussian model yields a much higher estimate of the risk-free interest rate 9.20% compared to 3.41% in the baseline case.

[14] Bachmann 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.

The differences are due to the size persistent 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 persistent effect and requires a small user cost of capital effect through the risk-free rate to match the empirical moment.

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:

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

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

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

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

$$\sigma_p = \frac{\sigma_g}{\sqrt{p_z}}. \tag{25}$$

Note that the kurtosis of the Gaussian shock is 3, while the Poisson shock is $\frac{3}{p_z}$. In Figure 3, 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 persistent effect on the capital response of treated firms is much larger in the Poisson economy.

Lastly, the baseline model yields a high kurtosis for investment rate (10.48), output growth rate (5.42), and labor growth rate (5.63) more comparable to the data than the Gaussian model with the kurtosis for investment rate (3.65), output growth rate (3.44), and labor growth rate (4.62), respectively. This is in part due to the fact that the productivity process with Poisson shocks has a high kurtosis.

6 Transitional Dynamics and Welfare Implications

In this section, we present the results of transitional dynamics under alternative policies on firm size regulations 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 average employee and less than 100 million dollars in revenue faced the capital gains tax rate of 10 percent, and 24 percent otherwise. We focus on two 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 4 presents the transitional dynamics of wage, interest rate, consumption, capital, investment, output, labor, TFP. In general equilibrium, aggregate investment jumps by 1.95 percent on average over the four years after the reform. 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 5 also summarizes the long-run percent changes of the aggregate variables. In the steady state, aggregate capital, labor, output, consumption, and wage increase by 1.18%, 0.14%, 0.40%, 0.25%, and 0.39% 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.

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, Figure 5 shows that aggregate investment and capital increase by 8.63 and 1.54 percent, respectively, in the partial equilibrium. These responses are much higher than the ones from general equilibrium case. In the new steady-state, the PE analysis also overstates the increase in consumption, capital, output, and labor by 1.42, 1.40, 1.42, and 1.80 percentage points than the GE case, respectively. Firms in the GE case 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 in the partial equilibrium case look different from those in the general equilibrium.

6.1.2 Welfare Changes

We now calculate the welfare changes of the firm-size reform in 2014. We use a measure that accounts 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 only focusing on the steady state difference might overstate the actual welfare gain. Therefore, we define the consumption-equivalent welfare changes along a transitional path $(C_t, L_t)_{t=1,2,...,\infty}$ as the following:

$$\frac{1}{1-\beta}\left[\frac{((1+\Delta_{TD})C^{*})^{1-\sigma}}{1-\sigma}-\omega\frac{L^{*1+\nu}}{1+\nu}\right]=\sum_{t=1}^{\infty}\beta^{t-1}\left(\frac{C_t^{1-\sigma}}{1-\sigma}-\omega\frac{L_t^{1+\nu}}{1+\nu}\right) \tag{26}$$

The results are in Table 5, indicating that the steady state welfare gain is 0.09% in GE. 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 Tax Rate

We conduct one relevant counterfactual analysis, in which the government sets the uniformly low tax rate of 10 percent by removing both revenue and labor thresholds. The steady-state results are in the third column of Table 5. Aggregate capital, labor, output, consumption, and welfare would have increased by 5.89%, 0.96%, 2.43%, 1.58%, and 0.68%, respectively. TFP increases by 0.21% 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 6. 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.

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 two 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 results for the targeted moments and calibrated parameters are listed in Table 4. Although the Gaussian successfully matches long-run autocorrelation of output, it still needs a high risk-free interest rate to match the capital stock response of the treated firms because the size persistent effect is small. The baseline case that features both Poisson shocks and high persistence of output could match the high elasticity with a reasonable risk-free interest rate. It also does a better job at matching kurtosis of investment rate, output growth rate, and labor growth rate.

But how quantitatively important is matching micro-moments for aggregate implications? In Figure 7, we plot the transitional dynamics of the aggregate variables for baseline, and Gaussian cases in general equilibrium. We see that the Gaussian model would over-predict the total capital by 1% in the new steady state, almost doubling the result in the baselilne case.

8 Conclusion

This paper quantifies the aggregate effects of reducing capital gains taxes in the long-run. 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 relevant 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 2 percent and 1.2 percent in the short-run and in the steady state, respectively. Moreover, a counterfactual analysis where we set the uniformly low tax rate of 10 percent shows that aggregate investment rose by 5.9 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 frictions, and incorporating other relevant features in our model, such as debt-financing, will be an interesting 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 millon)	73.43	202.3	93.61	288.3	66.31	159.1
	(48.17)	(186.4)	(48.96)	(192.9)	(45.82)	(167.2)
Labor (Average Employee)	237.4	308.2	255.2	456.5	231.1	233.8
	(183.1)	(278.0)	(142.3)	(276.8)	(195.1)	(247.1)
Total Asset (in million)	74.44	193.4	124.2	313.7	56.86	133.1
	(65.76)	(195.3)	(72.06)	(206.6)	(53.26)	(158.1)
Total Capital (in million)	39.90	100.2	75.45	171.8	27.34	64.22
	(42.68)	(111.5)	(47.86)	(117.2)	(32.44)	(89.02)
CAPEX (in million)	3.970	8.694	6.079	13.13	3.225	6.468
	(6.218)	(12.35)	(8.417)	(14.08)	(5.021)	(10.72)
CAPEX / lagged PPE	0.219	0.196	0.197	0.179	0.227	0.204
	(0.285)	(0.256)	(0.244)	(0.214)	(0.297)	(0.274)
Observations	3196	12071	834	4031	2362	8040

Notes: Sample years include 2009 to 2018. Labor is the average employee 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	0.403***	0.095**	0.039***	0.021**
	(0.060)	(0.039)	(0.013)	(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	14.048	16.114	0.083	0.206
Implied Elasticity wrt (1-tau)	2.19	0.51	2.57	0.56
R-squared	0.77	0.82	0.75	0.82
Observations (firm-years)	18015	18564	17190	18593
Clusters (firms)	2778	2778	2778	2778

Notes: This table reports the tax effects on investment and capital based on specification (2). The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 percentage points, 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 log of 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, scaled by lagged tangible asset. Investment rate is the investment to capital stock ratio. Basic controls are quartics in firm age and industry dummies interacted with time dummies. Additional controls are dummies for pre-reform (2014) operating profit quintile interacted with time dummies. The main outcomes are winsorized at the 1% and 99% levels. Each time period is a year, and the sample period is from 2009 to 2018. 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
Risk Aversion	σ	1
Labor Disutility	ω	6.5
Frisch Inverse Elasticity	ν	1
Income Tax Rate	τ^i	0.250
Corporate Tax Rate	τ^c	0.340
High (Low) Capital Gains Tax Rate	τ_h^g (τ_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 (fixed) parameters. The parameter for labor disutility is chosen such that the aggregate labor supply is 1/3 at the steady state. The Frisch inverse elasticity is derived from Chang et al. (2018). Income tax, corporate tax, and capital gains tax rates are based on the institutional setting in Korea.

Table 4: Targeted Moments

Moment	Data	Baseline	Gaussian
Average Investment Rate	0.15	0.12	0.11
Inaction Rate	0.38	0.32	0.32
Spike Rate	0.26	0.32	0.34
Std. of Investment Rate	0.31	0.32	0.17
Kurtosis of Investment Rate	9.78	10.48	3.65
Std. of log Output	1.33	1.25	1.05
1-year Autocorrelation of Output	0.95	0.98	0.98
3-year Autocorrelation of Output	0.88	0.89	0.89
5-year Autocorrelation of Output	0.82	0.78	0.78
Std. of Output Growth Rate	0.47	0.28	0.23
Std. of Labor Growth Rate	0.33	0.28	0.25
Kurtosis of Output Growth Rate	20.98	5.42	3.44
Kurtosis of Labor Growth Rate	24.88	5.63	4.62
Treated Group Capital Response	0.095	0.09	0.07

Parameter	Symbol	Baseline	Gaussian
Upper Bound of Fixed Cost	$\bar{\psi}_0$	0.25%	0.17%
Quaratic Adjustment Cost	ψ_1	0.14	0.30
Persistence of Productivity	ρ_z	0.75	0.92
Std. of Productivity	σ_z	0.16	0.08
Poisson Probability	p_z	0.30	1
Risk-free Interest Rate	r	3.41%	9.20%
Std. of Output Measurement Error	σ_ϵ	0.08	0.04
Revenue Threshold	$\bar{y}$	90%ile	90%ile
Labor Threshold	$\bar{l}_E$	90%ile	90%ile

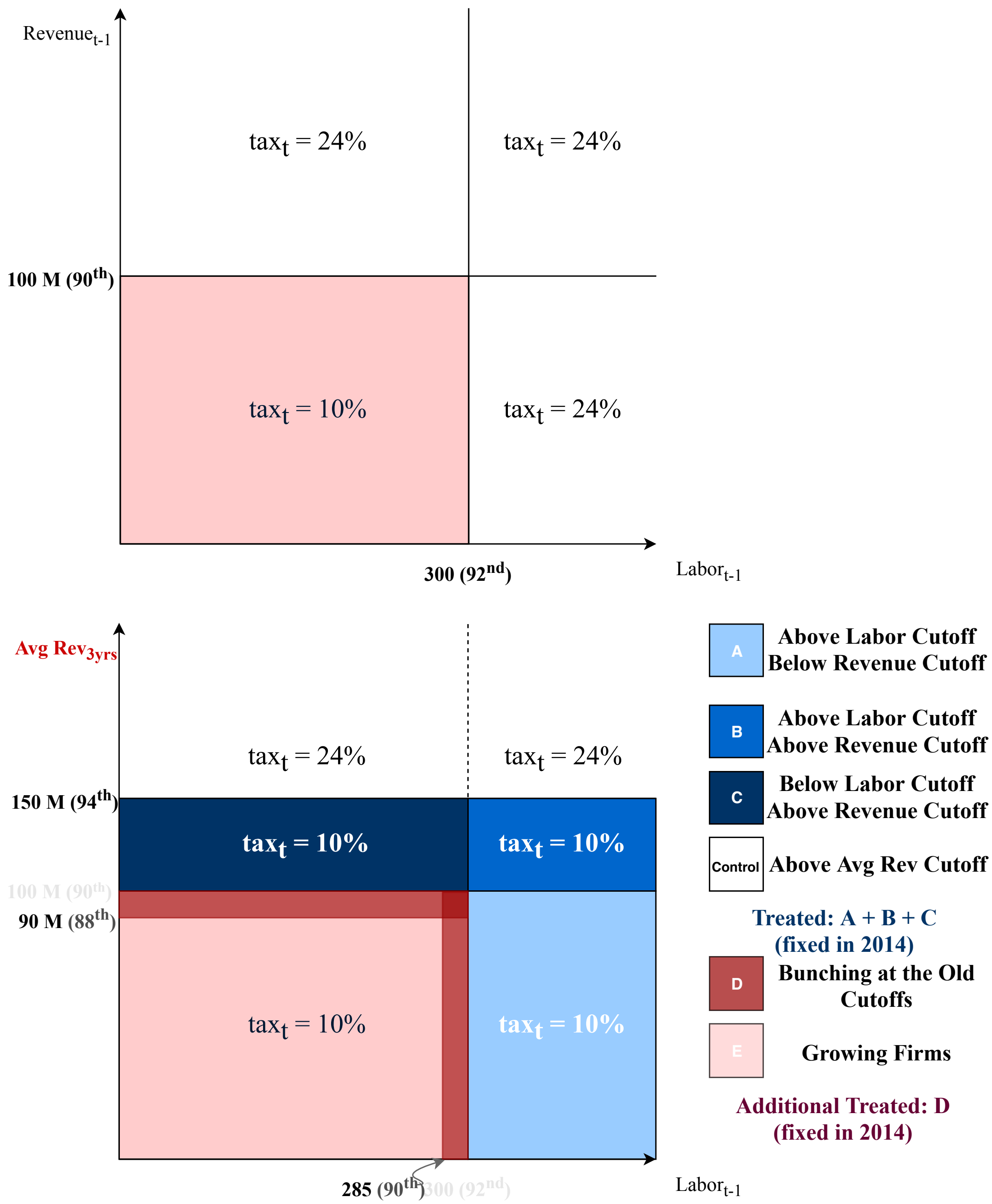
Notes: The top panel shows targeted moments in our model. Sample years include 2009-2018. Inaction rate is a fraction of observations with absolute investment rate less than 5%. Spike rate is a fraction of observations with absolute investment rate greater than 20%. Output is firm's revenue. The treated group's capital response is 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. The bottom panel shows parameters chosen to match empirical moments in the top panel.

Table 5: Aggregate Effects of Size-dependent Capital Gains Taxes (General Equilibrium)

	Post 2014		$\tau^g = 0.10$
	Short Run	Long Run	Long Run
Investment	1.95	1.18	5.89
Capital	0.29	1.18	5.89
Labor	0.35	0.14	0.96
Output	0.32	0.40	2.43
Consumption	-0.07	0.25	1.58
TFP	0.03	-0.01	0.21
Wage	0.28	0.39	2.56
Welfare	0.09		0.68

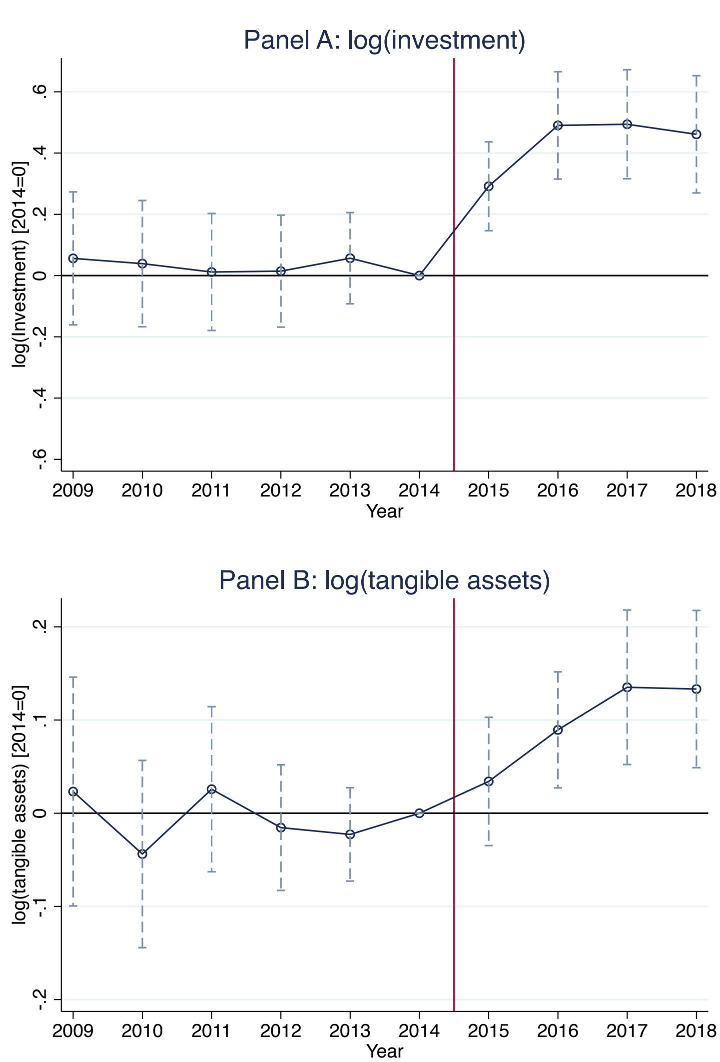
Notes: This table shows percent changes of aggregate variables compared to the pre-2014 steady state in general equilibrium. The welfare calculation accounts for the transitional dynamics. First two columns refer to the case of eliminating the labor threshold $\bar{l}_E$ and increasing the revenue threshold $\bar{y}$ from 100 million dollars to 150 million dollars in the short- and long-run, respectively. The short-run values are the average percentage changes over the four years after the reform. The third column refers to the case of setting a uniform tax of 10 precent in the long run.

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 the treated 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 percent. 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 removed after the reform.

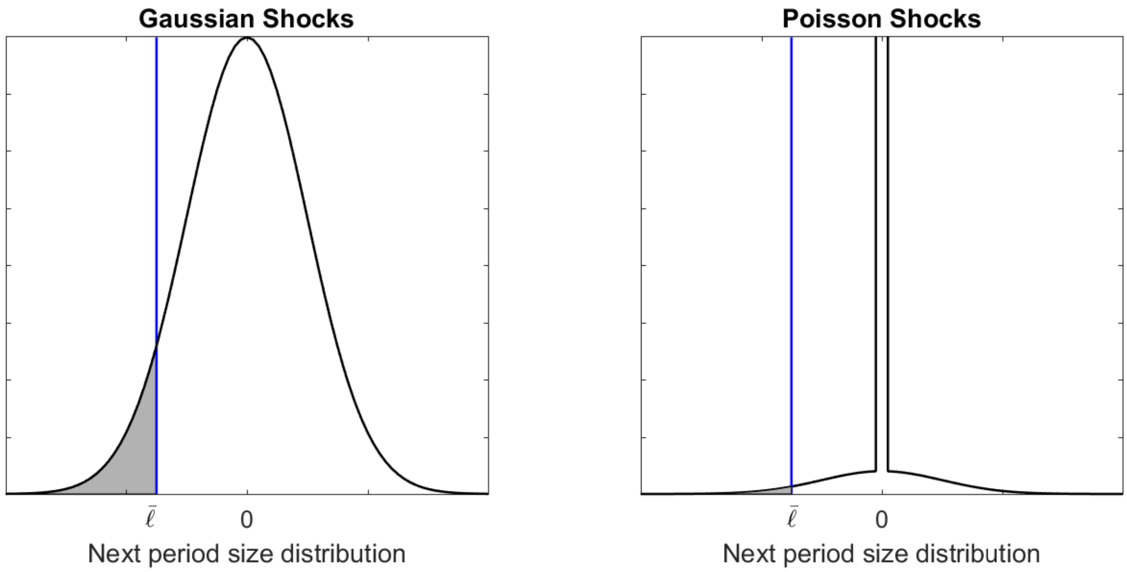
Figure 2: Tax Effects on *log*(investment) and *log*(tangible assets)



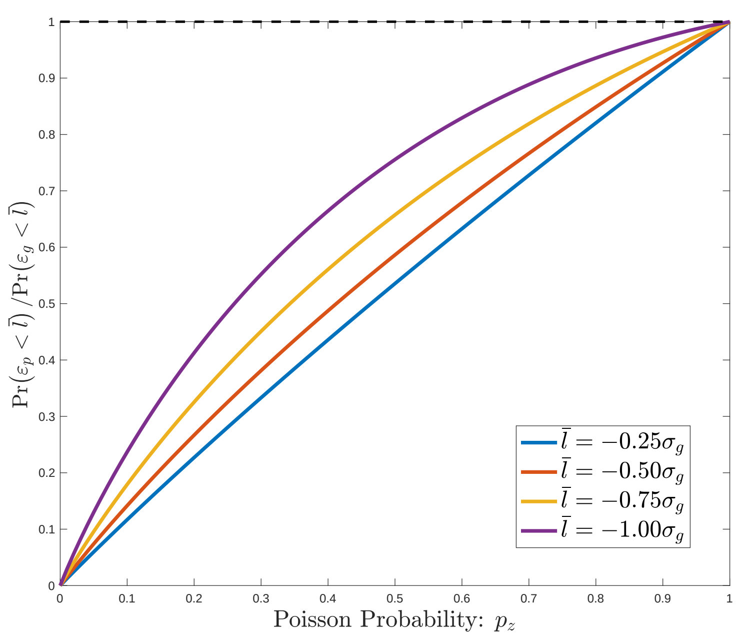
Notes: Panel A of this figure shows the coefficients on $Treated \times Time$ for firms' investment, defined as log(expenditures on physical capital assets), in equation (1) using both publicly listed and private firms. The dashed lines indicate 95% confidence intervals for these coefficient estimates.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

Figure 3: Size Persistent Effect

Panel A.

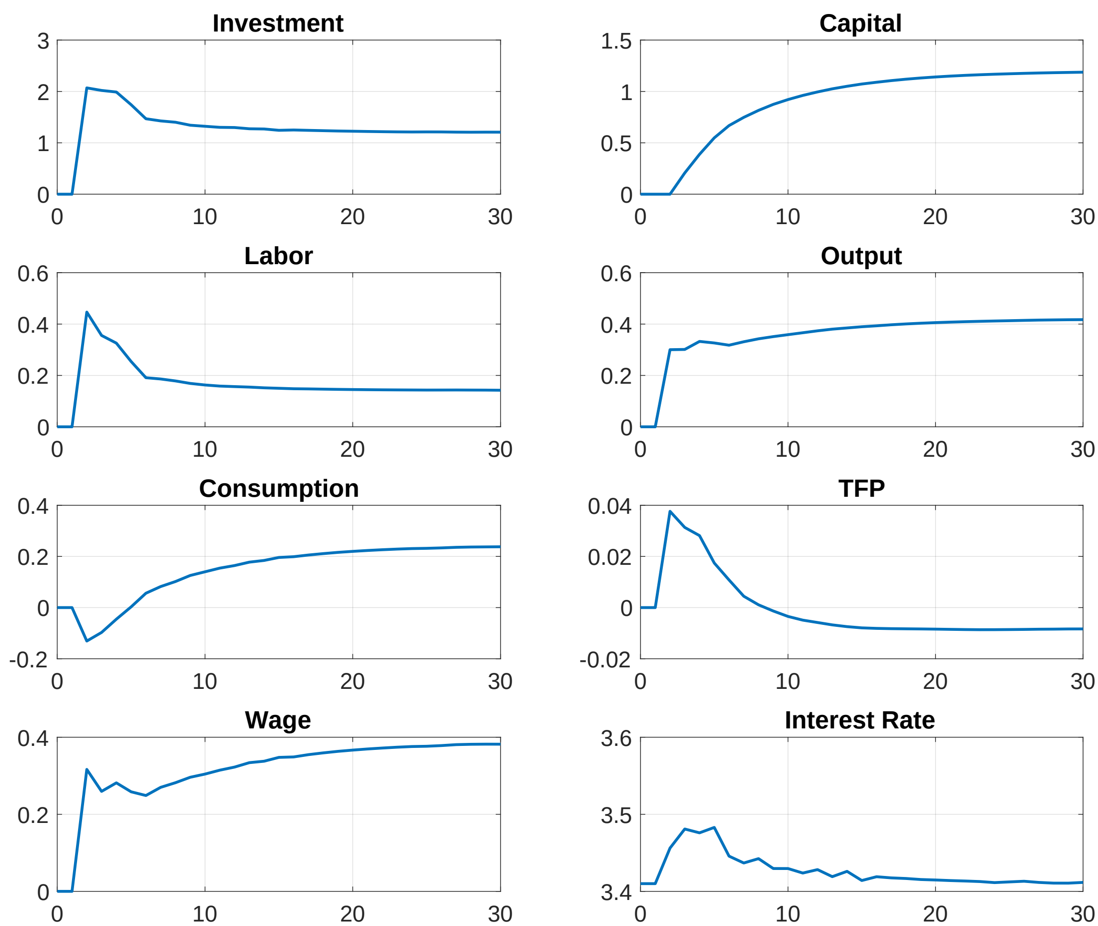


Panel B.



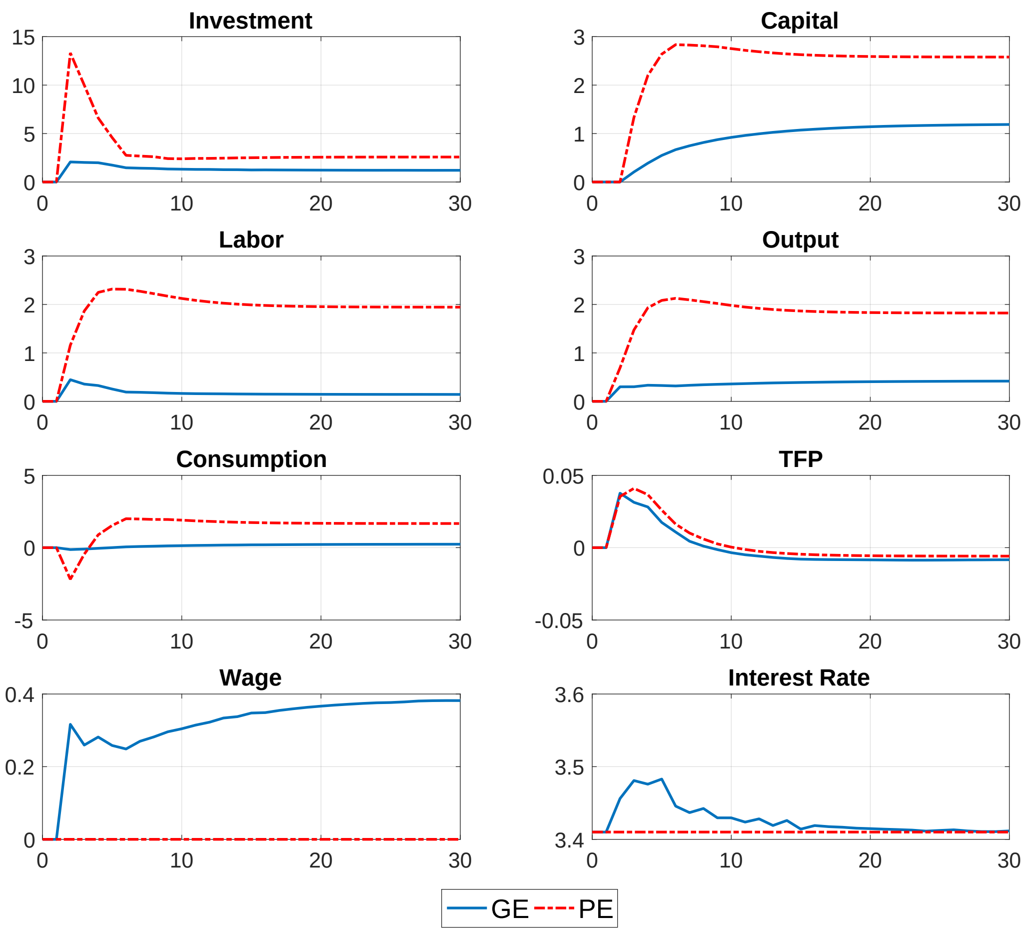
Notes: Panel A illustrates size-persistent effectS. The left panel on the top is the case of Gaussian shocks, and the right panel on the top is the case of Poisson shocks. Panel B illustrates the probability ratio of firm size below threshold $\bar{l}$ under Poisson shocks and Gaussian shocks. $\bar{l} \in \{-0.25\sigma_g, -0.50\sigma_g, -0.75\sigma_g, -1.00\sigma_g\}$ corresponds to lines from bottom to above.

Figure 4: Transitional Dynamics of Firm-size Reform in 2014 (General Equilibrium)



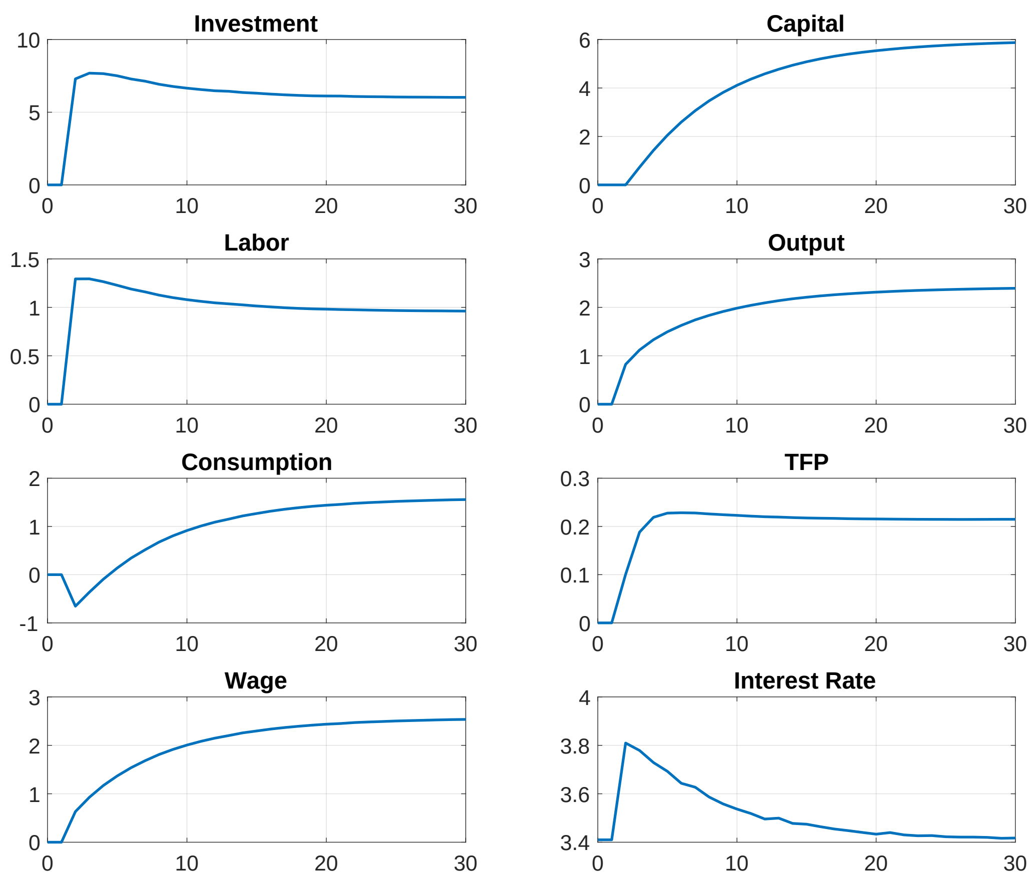
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform which eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars.

Figure 5: Transitional Dynamics of Firm-size Reform in 2014 (Partial Equilibrium)



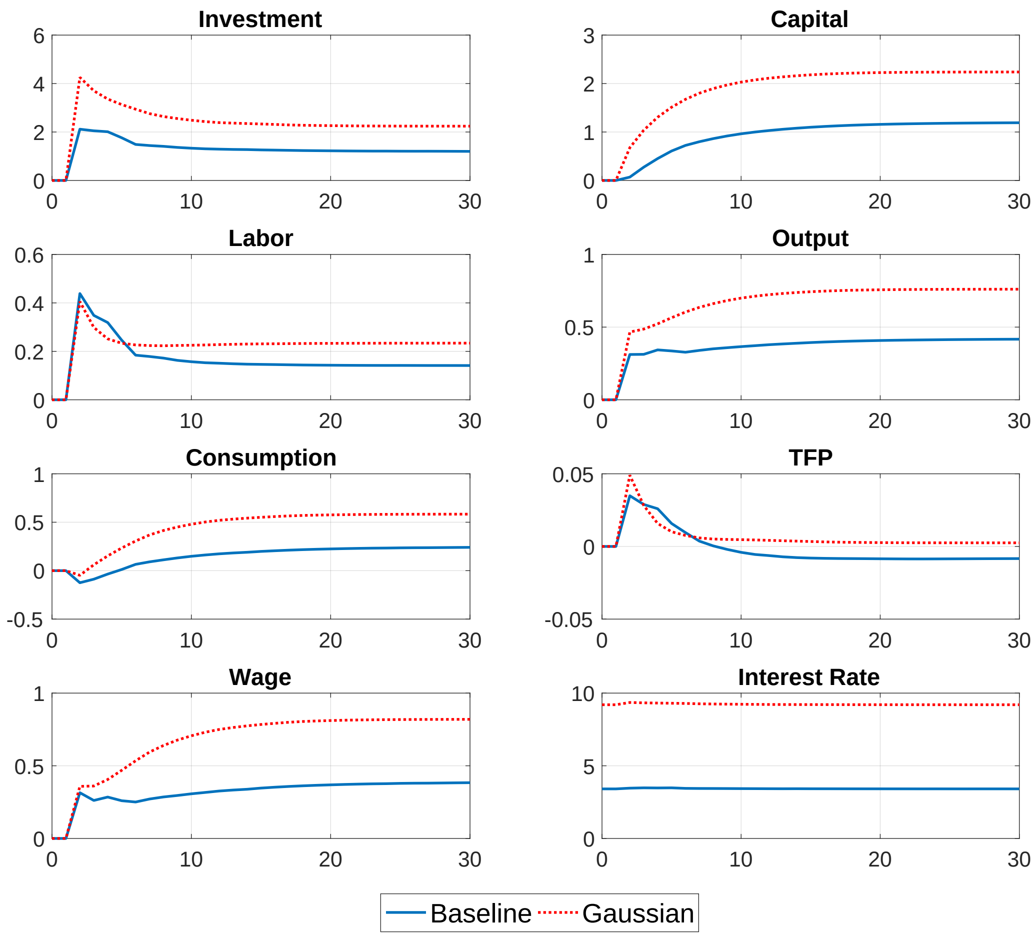
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform which eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars. Both wage and interest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

Figure 6: Transitional Dynamics of Setting Uniform Tax Rate (General 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%.

Figure 7: Comparison of Baseline and Gaussian Cases (General 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 which eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars in general equilibrium, for baseline and gaussian cases.

For Online Publication

This appendix supplements our paper "Capital Gains Taxation and Investment Dynamics" with the following sections:

- Section A provides institutional details.
- Section B shows the results from robustness tests.

A Institutional Details

In Appendix A, we provide further institutional details regarding corporate income 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 (2019), where further details are available.

A.1 Corporate and Dividend Tax System in Korea

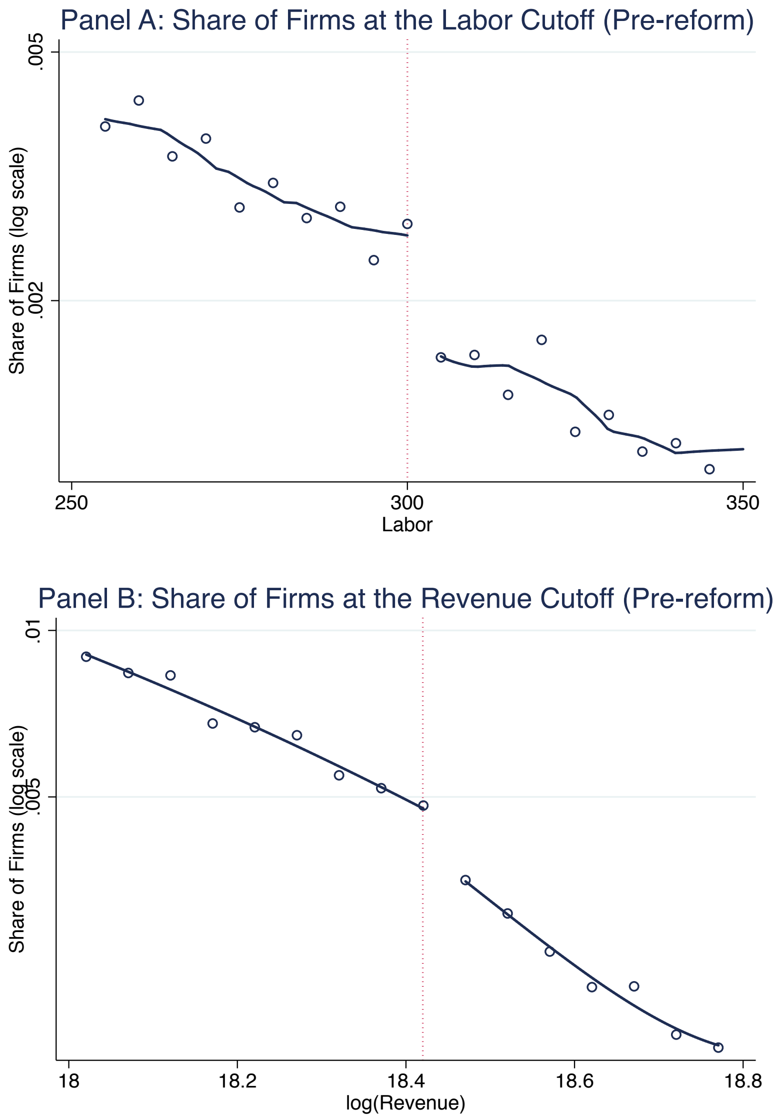
A.1.1 Corporate Income Tax Rates on Profits

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 at the end of 2011, which was 3 years before the main reform that I exploit for identification. More importantly, the profit threshold was even low for many firms in my sample, so unlikely had influenced their investment following the reform in 2014. We confirm that this issue does not affect my results using a placebo test (See Appendix B).

A.1.2 Dividend Tax Rates

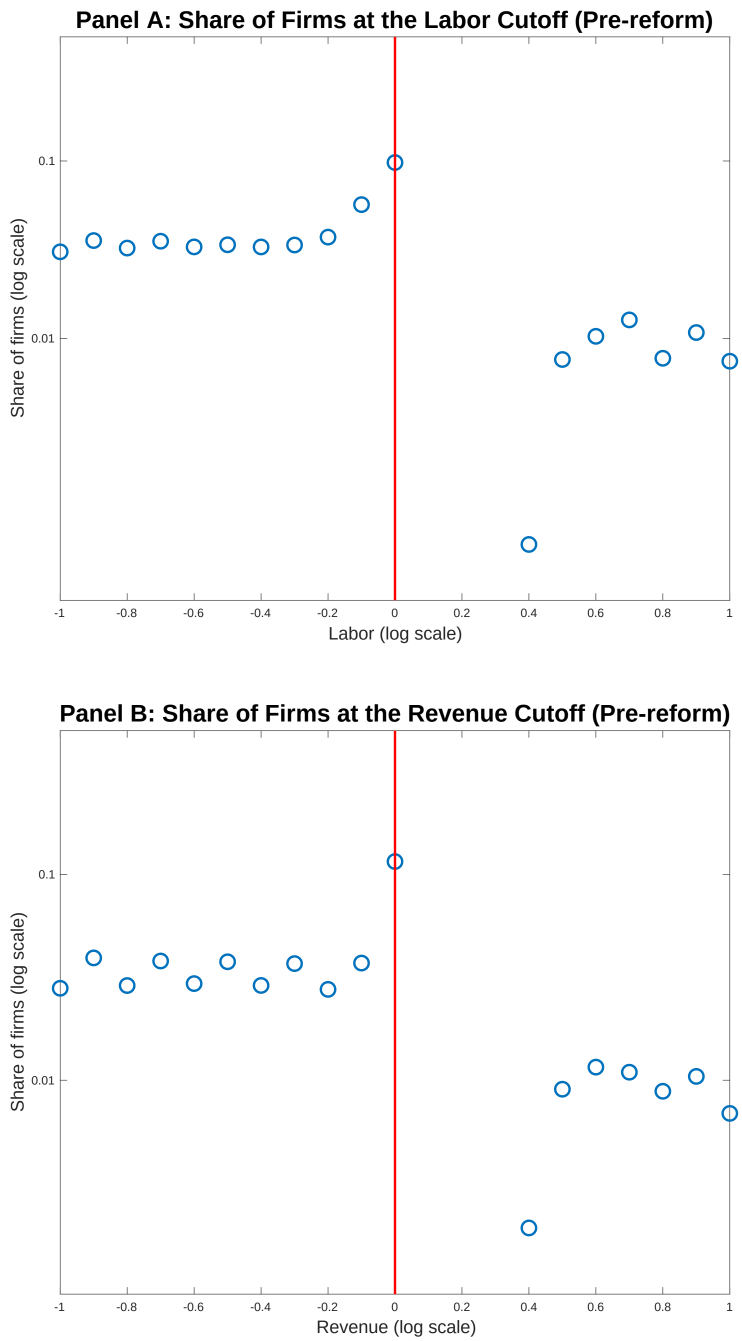
In Korea, dividends are taxed similarly as individual incomes. If an investor's dividend income in a given year is less than $20,000, then the tax rate is 15.4%. However if dividend income is above $20,000, then it becomes part of the investor's income, and the marginal tax rate can rise up to 38%, depending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

Figure A.1: 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 asset). The cutoff is at the labor of 300, and the bin size is 5 average employee. The hallow 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 McCrary (2008) test 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 asset). The cutoff is at the revenue of 100 million dollars, and the bin size is 5 log points in revenues. The McCrary (2008) test rejects the null that the coefficient at the jump is statistically not different from zero.

Figure A.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

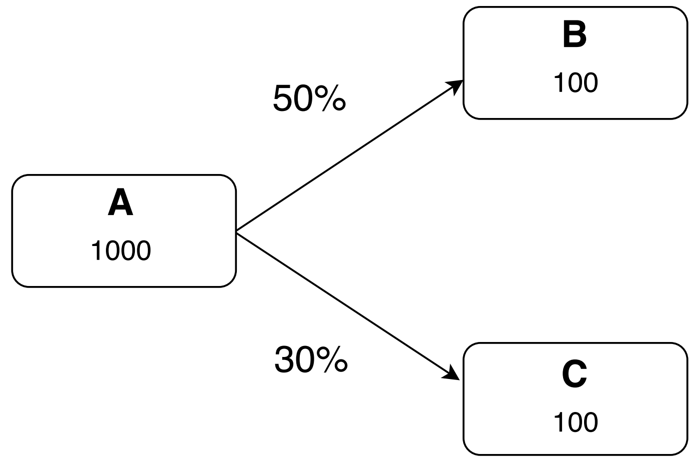
Table A.1: Computing Accounting Variables for Tax Purposes

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, 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 the average employee in a given year. Given the rules described in Section 2, each firm's labor size 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 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, 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 capital, assets), we repeat the same exercise for each variable.

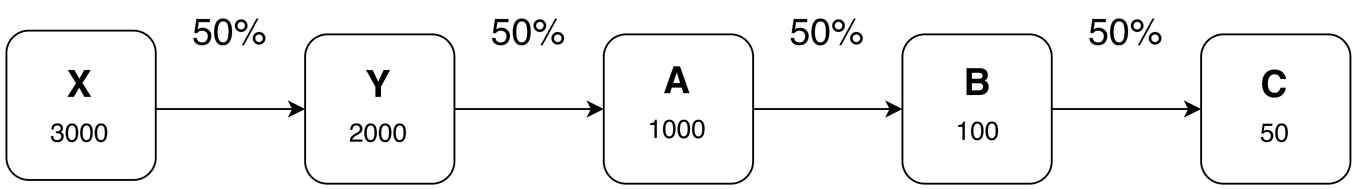
Figure A.3: Computing Accounting Values

Case 1



Notes: This figure shows how to compute accounting values for firms in a case where firm A owns 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×(100% of firm A)+100×(100% of firm B)+100×(30% of firm C)=1130
(2) firm B: 1000×(100% of firm A)+100×(100% of firm B)=1100
(3) firm C: 1000×(30% of firm A)+100×(100% 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: $2000 + (1.0) * 3000 + (1.0) * 1000 + (0.5) * 100 = 6050$
(3) firm A: $1000 + (0.5) * 3000 + (1.0) * 2000 + (1.0) * 100 + (0.5) * 50 = 4625$
(4) firm B: $100 + (0.5) * 2000 + (1.0) * 1000 + (1.0) * 50 = 2150$
(5) firm C: $50 + (0.5) * 1000 + (1.0) * 100 = 650$

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. Column (1) of Table B.1 shows the main result without any basic or additional controls, and Column (2) of Table B.1 shows the result with only basic controls. The coefficient estimates 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 (bottom- and top-coding) the main outcome variable at the 5% and 95% levels, instead of at the 1% and 99% levels. Column (3) of Table B.1 shows the result based on these different levels of winsorizing. The coefficient estimate for log(investment) is smaller, but qualitatively similar.

B.3 Using Balanced Panel

To address a changing composition over time, we repeat the main analysis based on the same specification as in equation (2), using a balanced panel. Column (4) of Table B.1 shows the result based on using the balanced panel. The coefficient estimate for log(investment) is larger in the balanced sample, but qualitatively similar to the estimate based on the unbalanced panel.

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. Column (5) of Table B.1 shows the main results based on using firms in other sectors in addition to the firms in the main analysis sample. The main result is qualitatively similar when we include firms in other sectors.

B.5 Placebo Tests

Since other time-varying shocks, such as different policy reforms, may coincide or occur close to the reform in 2014, we conduct a placebo test using an earlier time period. For example, there was a corporate tax reform at the end of 2011, which moderately changed the corporate income 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, I still use the year 2011 as the placebo date and set *Post* equal to 1 if it is after 2011. Column (1) of Table B.2 shows the result based on this placebo test. The coefficient estimate s not statistically different from zero even at the 90% confidence level, suggesting that the main result is unlikely driven by other policy changes.

To ensure that the mains result on investment is driven by the policy variation, which generated a set of firms whose investment incentives changed due to changes in regulations on firm size, we conduct a placebo test using a random cutoff to define the treated group. For example, we set arbitrarily much higher value of $10 million (instead of $150 million) for the new revenue threshold, so that many of the unaffected firms are defined now as treated firms. One caveat with this exercise is that the random threshold has to be either sufficiently low or high enough so that the randomly defined treatment group will not contain the actual treated firms. Column (2) of Table B.2 shows the result based on the placebo test. The coefficient estimate is 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.

B.6 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.3 shows the result just using firms that were bunching as treated and unaffected firms as control. Columns (1) shows that their investment response is lower than the one from the firms with a tax cut, consistent with the idea that firms that were bunching did so because they did not have investment opportunities to justify crossing the thresholds.

Table B.1: Tax Effects on Investment Across Different Robustness Tests

	Control Variables		Sample Selection		
	(1) Without Controls	(2) Basic Controls	(3) Winsor	(4) Balanced	(5) Other Sectors
Treated x Post	0.334***	0.346***	0.368***	0.332***	0.382***
	(0.058)	(0.061)	(0.056)	(0.070)	(0.056)
Basic Control	No	Yes	Yes	Yes	Yes
Profit Quintile x Time FE	No	No	Yes	Yes	Yes
Time and Firm FE	Yes	Yes	Yes	Yes	Yes
Pre-reform Treated Mean	14.048	14.048	14.111	14.318	13.997
Implied Elasticity wrt (1-tau)	1.81	1.88	2.00	1.80	2.08
R-squared	0.72	0.75	0.77	0.78	0.78
Observations (firm-years)	18026	18015	18015	10866	21257
Clusters (firms)	2778	2778	2778	1124	3389

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 percentage points, as explained in Section 4. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Investment is defined as log of expenditures on physical capital assets. Column (1) does not include any basic or additional control variables. Column (2) includes only basic controls. In Column (3), the main outcome is winsorized at the fifth and the ninety-fifth levels. Column (4) uses the balanced panel. Column (5) includes firms in other sectors. Each time period is a year, and the sample period is from 2009 to 2018. 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.2: Placebo Tests

	Using 2011 as Reform Year	Using Random Cutoff
	(1)	(2)
	log(CAPEX)	log(CAPEX)
Treated x Post	-0.059	-0.204
	(0.083)	(0.224)
Time and Firm FE	Yes	Yes
Pre-reform Treated Mean	13.962	12.547
Implied Elasticity wrt (1-tau)	-0.32	-1.11
R-squared	0.71	0.70
Observations (firm-years)	18026	67019
Clusters (firms)	2778	8948

Notes: This table reports the tax effects on investment using placebo tests. The dummy for $Treated_i$ equals 1 if a firm i had a tax reduction of 14 percentage points, as explained in Section 4. In Column (1), the dummy for $post_t$ equals 1 if the time period is after the placebo year of 2011. In Column (2), I use a random cutoff of $10 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). Investment is defined as log of expenditures on physical capital assets. The main outcome is winsorized at the 1% and 99% levels. Each time period is a year, and the sample period is from 2009 to 2018. 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 Firms Bunching at Old Cutoffs

	Bunching Firms	Tax Cut Firms
	(1)	(2)
	ln(CAPEX)	ln(CAPEX)
Treated x Post	0.323***	0.403***
	(0.105)	(0.060)
Controls	Yes	Yes
Time and Firm FE	Yes	Yes
Pre-reform Treated Mean	14.322	14.048
Implied Elasticity wrt (1-tau)	1.75	2.19
R-squared	0.77	0.75
Observations (firm-years)	14945	18015
Clusters (firms)	2367	2778

Notes: This table reports the tax effects on investment based on the difference-in-differences estimation, where I define treated firms in Column (1) as those that were bunching at the old cutoffs prior to 2014. The dummy for $post_t$ equals 1 if the time period is after the end of the reform year (2014). Investment is defined as log of expenditures on physical capital assets. The main outcome is winsorized at the 1% and 99% levels. Each time period is a year, and the sample period is from 2009 to 2018. All specifications include time and firm 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.