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Capital Gains Taxation and Investment Dynamics*

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Abstract

This paper quantifies the long-run effects of reducing capital gains taxes on aggregate investment. We develop a dynamic general equilibrium model with heterogeneous firms, which face discrete capital gains tax rates based on firm size. We calibrate our model by targeting micro moments and a difference-in-differences estimate of the capital stock response based on the institutional setting and policy reform in Korea. We find that the reform that reduced the capital gains tax rates for a subset of firms substantially increased investment in the short run, and capturing general equilibrium price responses is important to quantify the long-run aggregate outcomes.

JEL Codes: E22, E62, G11, H25, O16.
Keywords: Capital, Fiscal Policy, Investment Decisions, Business Taxes and Subsidies, Saving and Capital Investment.

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1 Introduction

A central question in the study of fiscal policies is the degree to which tax incentives affect aggregate investment to stimulate growth and job creation in the economy. While there is growing empirical evidence on how much investment responds to corporate tax incentives (Desai and Goolsbee (2004); House and Shapiro (2008); Zwick and Mahon (2017); Ohrn (2018)), a recurring topic that features prominently in policy debates is the extent to which a reduction in capital gains tax rates would stimulate 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. The effects of capital gains taxes on firm-level outcomes is even harder to assess, because the tax rates vary at the investor-level, but not at the firm-level, in most settings. Furthermore, quantifying the aggregate effects of capital gains taxes is challenging in 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. We micro-found its main features with our institutional setting, where capital gains tax rates vary across firms, and also with policy reform that reduced the tax rates for a subset of firms. We calibrate the key parameters of our model using our difference-in-differences estimate of the capital stock elasticity with respect to capital gains tax rates. That is, the parameter values are chosen so that the model in the short run reproduces the investment response observed after the reform in the data. We use our calibrated model to predict the long-run effects of reducing capital gains taxes on aggregate investment.

The reduced-form elasticities are estimated using the data from Korea, where capital gains tax rates varied 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 large firm faces a rate of 24 percent. In 2014, the government unexpectedly changed the firm size thresholds for capital gains tax brackets 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 significant number of firms above the old thresholds, 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 firms that did not, we find that the affected firms increased investment by 40 log points and capital stock by 10 log points within four years after the reform. The estimates suggest that affected firms increased investment by roughly 2.4 billion dollars, which is 2 percent of total investment in the economy after the reform. We show that our results are internally consistent by showing parallel pre-trends on the key outcomes and a set of robustness checks and placebo tests.

To quantify the aggregate effects in the long run, which capture general equilibrium price responses, 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 two 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 in Korea. Second, 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.

We structurally estimate the capital adjustment costs and an idiosyncratic productivity process using a simulated method of moments (SMM). We target the distribution of the investment-to-capital ratio, revenue, the number of employees across firms, and the difference-in-differences estimate of the capital stock elasticity. Although not targeted, our model generates a set of firms bunching below the pre-reform thresholds that determined the tax rates, consistent with the data.

One primary feature that distinguishes our approach is that we identify key model parameters from 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 conduct 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 2 percent of total investment in the economy.

A key finding from our model is that the effect of reducing capital gains taxes for firms around the thresholds depends on the persistence of firm size. In each period, firms expand or shrink in size, creating firm-size dynamics around each threshold. We deviate from the usual 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 gives the conditional distribution of next period's productivity have more peakedness around the mean with heavier tails. The "peakedness effect" increases the probability of a treated firm becoming a large firm again, while the "heavy tail effect" does the opposite. Our simulation shows that the former effect dominates the latter. Consequently, our model with Poisson shocks matches the panel

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

dimension of the data better than does our benchmark model.

Using the calibrated model, we assess the aggregate effects of the 2014 reform, which reduced the capital gains tax rates for a subset of firms, on the overall economy. In the partial equilibrium setting, the reform had a large impact on the economy, increasing aggregate consumption, output, capital, and labor by 1.8, 2.0, 3.1, and 2.0 percent, respectively, in the long run.

In the general equilibrium framework, which reflects the interest rate and wage responses, we find that the overall effects were much more dampened, with aggregate consumption, output, capital, and labor increasing by 0.3, 0.6, 1.7, and 0.2 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 0.1 percent, labor supply increases by 0.4 percent, and investment increases by 2.6 percent. The consumption equivalent welfare change that accounts for the transitional dynamics is 0.13 percent, comparable to the welfare gains of eliminating business cycles as in Lucas (1987) and Krusell et al. (2009).

Moreover, we conduct a relevant 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.[2] We find that, in the general equilibrium setting, eliminating distortions created by the size-dependent capital gains tax system would increase aggregate consumption, output, capital, and labor by 1.8, 2.7, 6.8, and 1.0 percentage points, respectively, in the long run.

We show that matching micro moments in the data is crucial for our model and for policy analysis. A model that does not match the reduced-form estimates in our setting would over-predict the increases in aggregate consumption, output, capital, and labor by 0.8, 0.8, 2.1, and 0.2 percentage points, respectively. Therefore, disciplining the model with the difference-in-differences estimate of the capital stock response is crucial for quantifying 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 overstate (or understate) 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

[2] 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.

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 payout taxation affects aggregate investment. Our paper provides supporting evidence for a class of the "traditional-view" models, which predict that lowering payout tax rates would increase investment by reducing the marginal cost of investment (Feldstein 1970; Poterba and Summers 1983).

More broadly, 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. Bridging this gap has tangible benefits: the micro elasticities discipline the model, and the model can answer questions that the reduced-form analysis cannot ask, such as quantifying that the long-run effects of a policy change on aggregate outcomes that account for general equilibrium responses.

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. Section 7 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 reclassified as small due to the changes in 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 tax rate of 10 percent.[3] In 2014, the government changed the regulations on firm size, which generated time-series variation in the tax rates within a given firm affected by the rule 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.

[3]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.

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.[4] The term, "average employee", is defined as the sum of daily workers employed over all 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.[5] 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 in March 2015. This is evidenced by the stock price responses of the 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 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.[6]

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

[5] 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. Moon (2019) describes how the reform differentially affected different sectors and the industrial compositions of firms in more details.

[6] Panel A of Figure A.2 in Appendix A.2 shows firm density around the labor cutoff, conditional that the firms are below the other thresholds. Panel B shows firm density around the revenue cutoff, conditional that the firms are below the other thresholds. In each graph, the McCrary (2008) test rejects the null hypothesis that the jump is statistically not different from zero at the 5 percent significance level, providing suggestive evidence that firms preferred lower taxes by staying below the cutoffs, although some firms were right above the cutoff potentially due to adjustment frictions.

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 reduction in their tax rate.[7] We define these firms that got a reduction in the 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.[8] Similarly, firms that were close to the old revenue cutoff, but 10 percent below it, fall into the second type of treated firms because they were bunching precisely to avoid higher tax rates; so, removing this cutoff may provide an incentive to increase investment.

On the other hand, firms whose size was unaffected by the reform serve as the control group, given that there was no change in their incentive to invest.[9] Therefore, our main analysis sample consists of the first type of treated firms that experienced a reduction in the 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.[10] 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.

[7]The new revenue threshold did not increase to 150 million dollars for certain industries within the manufacturing sector or 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).

[8]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.

[9]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.

[10]We exclude the top 1 percent of firms based on their size because these big conglomerates (i.e., Samsung) are too big to be part of the control group.

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

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

where α_i and α_t are firm and year fixed effects, $Treated_i$ is a dummy equal to 1 if the firm experienced a reduction in the 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 the treated and control groups. Furthermore, industry composition is different between the 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 zero.

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

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

where $Post_t$ is a dummy equal to 1 if it is after the reform year of 2014, and all the other variables are as defined in equation (1). We report the estimates from equation (1) as well as 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 after the reform. 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 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 the data company, 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 before changing 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.[11] 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 find qualitatively similar results (see Appendix B).

We acquired the accounting data set for private firms from the data company, 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.

[11] The top five sectors in the 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.

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 summarize the main variables, such as revenue, assets, average employee, and capital expenditure in Table 1. There are economically and statistically significant differences in these variables between the treated and control firms. An important thing to note is that the 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 the 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 in 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 in 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 the 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 a 95 percent 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 40 log points, compared to unaffected firms. Column (2) shows the coefficient is 0.095 for log(tangible assets), with a 95 percent confidence interval of (0.019,0.171), implying that firms that experienced a drop in the 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 1 percent increase in the net of tax rate would increase physical capital stocks by a 0.5 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 percentiles. 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 dynamic general equilibrium model with heterogeneous firms based on a framework by Gourio and Miao (2010). In our model, there are quadratic costs of capital adjustments and payout taxes, both of which affect firm investment decisions. We extend the model by incorporating the institutional feature in which firms face discrete average capital gains tax rates based on their firm size. Next, to isolate the tax effects from the size-dependent policy, especially around the size thresholds, we assume a idiosyncratic 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 the 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 is consumption, L_t is the labor supply, σ is risk aversion, ω is the disutility from labor, and ν is the inverse of Frisch labor supply elasticity.

The household (i) purchases share θ_{jt} at price P_{jt}, (ii) receives net share repurchases s_{jt} and capital gains $P_{jt} - P_{jt-1}$ from a fixed continuum of firms $j \in [0, 1]$, (iii) purchases a risk-free bond B_t with return r_t, and (iv) supplies labor at wage rate w_t.[12] The household also needs to pay income taxes τ_i on labor income and bond returns, and capital gains tax τ_{jt}^g on accrued gains as in Auerbach (2002) and Gourio and Miao (2010).[13] Lastly, the household receives a government

[12] In Korea, the top marginal dividend tax rate is 38 percent, which is higher than the top capital gains tax rate of 24 percent, but firms still do both dividend payouts and share repurchases. Since our main focus is estimating the effects of capital gains taxes on firms' investment, we do not include dividend payments in our model. Moreover, realized capital gains from stock sales have often exceeded dividends in the aggregate both in the U.S. (Smith, Zidar and Zwick 2019) and in Korea. Therefore, we focus on stock sales and repurchases as the primary way in which firms payout their investors.

[13] In Korea, capital gains are taxed based on realizations. We assume in our model that capital gains are based on accrual, as in Auerbach (2002), since we do not have household data to model households' financial decisions.

lump-sum transfer T_t. The household's budget constraint is

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

Note that $s_t < 0$ means new equity issuances by firms. Also, the capital gains tax rate depends on the size of the firm 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

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

The firm share θ_{jt} holding condition is

$$P_{jt} = \beta \mathrm{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(P_{jt} + (1-\tau^g_{jt+1})(s_{jt+1} + P_{jt+1} - P_{jt})\right)\right].$$

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:

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

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:

$$y_{jt} = z_{jt}\left(k_{jt}^\alpha l_{jt}^{1-\alpha}\right)^\mu,$$

where y_{jt}, z_{jt}, k_{jt}, and l_{jt} denote output, productivity, capital, and labor, respectively. α and μ denote the capital share and returns-to-scale of the production function. As in Midrigan (2011) and Bachmann and Bayer (2014), we assume that innovations to idiosyncratic productivity arrive infrequently with a Poisson probability p_z:

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

Conditional on the arrival, productivity follows an AR(1) process with normally distributed shocks. The heavy tails and peakedness properties of the Poisson process allow the model to match various statistics in the data including higher-order micro moments. It turns out that, to isolate tax effects under a size-dependent policy in a heterogeneous firm dynamics setting, capturing only lower-order statistics is not sufficient. Our calibration below shows that a model with usual Gaussian shocks misses higher-order moment targets and outputs abnormal estimates of key parameters that determine the effect of capital gains taxation. The details and the mechanism will be discussed below in section 5.

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

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

where δ is the physical capital depreciation rate. The firm has to pay a quadratic adjustment cost of capital $\frac{\psi}{2}\left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt}$.[14] The cost helps to reproduce more-realistic capital responses upon productivity shocks and tax changes. For incomes, the firm faces a linear corporate tax rate τ_c on its profit and receives a fraction δ of its capital stock for depreciation allowances. The firm uses share repurchases to pay back the shareholders and, if income is less than the sum of investment and adjustment costs, raises capital by issuing external equity.[15] In sum, the firm's budget constraint is

$$s_t + i_{jt} + \frac{\psi}{2}\left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt} = (1-\tau^c)\left(y_{jt} - w_t l_{jt}\right) + \tau^c \delta k_{jt}. \tag{9}$$

[14] In our sample, the share of firms with zero investment is less than 1 percent, in part because our unit of observation is at the firm-level, rather than at the plant-level. Therefore, we do not feature a fixed cost of investment in our model. However, as a robustness test, we have an extension of our model that includes fixed adjustment costs, along with the calibration results, in Appendix C.

[15] Firms can also raise funds through borrowing. We assume that the only source of financing is new equity to keep our model parsimonious, but we include an extension of our model that accounts for debt-financing in Appendix C.

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: (i) total revenue below $\bar{y}$ and (ii) number of employees below $\bar{l}_E$.[16] The tax schedule can be summarized as

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

where $\bar{l}_R(z_{jt}, k_{jt}) \equiv \left(\frac{\bar{y}}{z_{jt} k_{jt}^{\mu\alpha}}\right)^{\frac{1}{\mu(1-\alpha)}}$. [17]

4.2.3 Optimization Problem

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

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

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

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

subject to (9) and (10). From equation (11), we see that the current capital gains tax rate does not distort a firm's intra-temporal decision, because we assume accrued gains; hence, we drop τ^g from the state variables: $V(z, k, \tau^g) = V(z, k)$. In contrast, the capital gains tax rate in the next period affects the firm's decision today through the discount rate.

A firm's problem (11) can be rewritten as

$$V(z, k) = \max\{V_{UC}(z, k), V_C(z, k)\},$$

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

[17] In Appendix C, we incorporate measurement errors in revenue and labor into the baseline model. This is a reduced-form way to capture potential output and labor adjustment costs.

where $V_{UC}(z,k)$ denotes the value of a firm that chooses the unconstrained labor choice:

$$l^*(z,k) = \left(\frac{\mu(1-\alpha)}{w} z k^{\mu\alpha}\right)^{\frac{1}{1-\mu(1-\alpha)}} \equiv \arg\max_l z\left(k^\alpha l^{1-\alpha}\right)^\mu - wl$$

and $V_C(z,k)$ denotes the value of a firm that chooses the constrained labor choice $\bar{l}(z,k)$ as specified above.[18]

4.3 Comparative Statics

In the reduced-form analysis, the difference-in-differences estimate captures the treated firms' capital investment decisions in the 2014 policy reform. To qualitatively illustrate the relationship between the key parameters in our model and the empirical estimate, we make the following simplifying assumptions:

1. Physical capital depreciates fully in one period $\delta = 1$.

2. The only input for output production is capital $\alpha = 1$.

3. Instead of a size-dependent capital gains tax system, we assume that the tax rate depends on the productivity level:
$$\tau^{g'} = \begin{cases} \tau_h^g & \text{if } z > \bar{z} \\ \tau_l^g & \text{otherwise.} \end{cases}$$
And without loss of generality, we assume other taxes are zero.

4. A firm chooses investment before observing current productivity. This is a simple way to capture the capital adjustment cost.

Then the maximization problem becomes

$$\max_k -k + \int \left(1 + \frac{r}{1-\tau^g(z)}\right)^{-1} z k^\mu dF(z).$$

After obtaining the solution to the problem above, we could conduct the following comparative statics analysis. The treated firms in 2014 are reclassified from large to small and experience tax

[18] If a firm is indifferent between two choices, we assume that the firm chooses the constrained labor choice. This assumption is for simplicity and does not affect the results.

reductions. Their capital elasticity with respect to the net of the high capital gains tax rate (1-τ_h^g) can be written as

$$\epsilon_{k,1-\tau^g} \equiv \frac{\partial k}{\partial(1-\tau_h^g)} \frac{1-\tau_h^g}{k} \propto \underbrace{(1-\mu)^{-1}}_{\text{profit curvature}} \times \underbrace{r}_{\text{user cost of capital}} \times \underbrace{[1-\Pr(z \leq \bar{z})]}_{\text{size persistence}}. \tag{12}$$

The equation (12) shows that capital elasticity with respect to the net of the 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, which could be due to decreasing returns-to-scale technology or a downward-sloping demand curve.[19] The second term is a *user cost of capital effect*. As the required return r increases, a firm's capital policy would also be more responsive to a change in capital gains taxes. These two effects jointly determine the capital responses if all firms are uniformly affected by the tax rate changes.

The last one is a *size persistence effect*. In our institutional setting as in the 2014 policy reform, if a treated firm today is more likely to remain large in the next period, it would increase capital more from the tax cut for large firms. It turns out that accounting for this effect is crucial in our dynamic heterogeneous firm model to isolate tax effects. When calibrating the model to match the difference-in-differences moment, different size persistence would lead to different estimates of the user cost of capital.[20] In our calibration, we find that not correctly controlling for size persistence would lead to a high user cost of capital and hence overstate the aggregate effects of the 2014 policy reform.

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 the following hold:

1. $l(z,k)$ and $i(z,k)$ solve the firm's maximization problem.
2. Labor market clears:

$$L(w,C) = \int l(z,k)dF(z,k). \tag{13}$$

[19] 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.

[20] In the calibration, we externally fix the returns-to-scale parameter μ since the lack of information on product prices and material inputs does not allow us to perform production function estimations. In Appendix C, we conduct a sensitivity analysis of the main results based on a different choice of μ.

3. Aggregate output is

$$Y = \int y(z,k)dF(z,k). \tag{14}$$

4. Aggregate investment is

$$I = \int i(z,k)dF(z,k). \tag{15}$$

5. The aggregate adjustment cost is

$$\Psi = \int \frac{\psi}{2}\left(\frac{i(z,k)}{k}\right)^2 kdF(z,k). \tag{16}$$

6. The government budget constraint is

$$T = \tau^i w \int l(z,k)dF(z,k) + \tau^c \int \left(y(z,k) - wl(z,k) - \delta k\right) dF(z,k) + \int \tau^g(z,k)s(z,k)dF(z,k). \tag{17}$$

7. Aggregate consumption is

$$C = Y - I - \Psi. \tag{18}$$

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 in the data from 2009 to 2018, including our reduced-form analysis for the treated firms in the 2014 policy reform.

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.[21] We also set the Frisch elasticity of labor supply to 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 τ^i to 25 percent, corporate tax rate τ^c to 34 percent, and low (high) capital gains tax rates to 10 percent (24 percent), consistent with the

[21] We choose a value closer to the lower bound of estimates in the literature to be conservative about the general equilibrium effects.

tax rates in Korea. For capital depreciations, we set the physical rate and allowance rate also to 10 percent, implying that the aggregate investment rate is 10 percent. Lastly, because our data set lacks required information for production function estimation, we set the capital production elasticity α to $1/3$ and the returns-to-scale parameter μ to 0.85 as in Midrigan and Xu (2014)[22]. Table 3 lists all the externally calibrated parameters.

5.2 Internally Calibrated

The rest of the parameters are jointly calibrated using a simulated method of moments to minimize the distance between empirical and simulated moments. The internally calibrated parameters are (i) the quadratic adjustment cost ψ, (ii) the persistence of productivity ρ_z, (iii) the standard deviation of the productivity shock σ_z, (iv) a Poisson probability of shock arrival p_z, (v) the risk-free interest rate r, (vi) the revenue threshold $\bar{y}$, and (vii) the employee threshold $\bar{l}_E$. The top panel of Table 4 reports the data and simulated moments.

We pin down the quadratic adjustment cost parameter ψ by matching the average investment rate, the standard deviation of the investment rate, and the fraction of the absolute investment rate larger than 20 percent (spike rate). These moments are selected to capture the dispersion of investment rates. The estimated quadratic cost is 0.14, comparable to 0.05 in Cooper and Haltiwanger (2006).

As mentioned in the comparative statics analysis, it is important for the model to capture firm-size dynamics, so we calibrate the parameters of the productivity process to match a set of salient features in the data. The targeted moments include short and long horizons of output autocorrelations to distinguish the persistences between two seemingly similar productivity processes. The standard deviation of log output, the output growth rate, and the labor growth rate pin down the standard deviation of the productivity shocks. And the kurtosis of the investment rate, the output growth rate and the labor growth rate pin down the Poisson probability.

The estimation result shows that the Poisson probability of new productivity shock is $p_z = 0.29$. This estimate is comparable to the 0.41 result in Bachmann and Bayer (2014) and much higher than the 0.03 result in Midrigan (2011).[23] Conditional on the Poisson arrival, the productivity follows an AR(1) process with persistence of 0.74 and a standard deviation of 0.17. The persistence of AR(1) is low, but the adjusted persistence level with Poisson probability is $p_z\rho_z+(1-p_z) = 0.92$. Similarly,

[22] Since μ is an important parameter for the capital response elasticity, we consider an alternative value for robustness checks in the appendix.

[23] 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 adjusted standard deviation is $\sqrt{p_z}\sigma_z = 0.15$. The inclusion of Poisson probability enables the model to capture not only the lower-order statistics but also the kurtosis of the investment rate, output growth rate, and labor growth rate[24].

After controlling for firm-size dynamics, we use the post-reform reduced-form estimates of the changes in capital stocks for affected firms after the reform to pin down the risk-free interest rate r[25]. The estimate of r is 3.87%, close to the 4% widely used in the macroeconomics literature. Figure 3 also compares the model simulation to the empirical estimates by year. The red dotted line plots the difference-in-differences estimate in the data, the black dashed vertical lines indicate the 95% confidence intervals around the point estimates, and the blue solid line plots the model simulation. Though only a four-year average is targeted in the calibration, the model coupled with adjustment costs does a good job of replicating the dynamics of the capital responses after the 2014 reform.

Lastly, to capture the magnitude of potential misallocations caused by the size-dependent policy, we not only target the dispersion of output for the productivity process above, but also the empirical percentiles for the size thresholds $\bar{y}$ and $\bar{l}_E$.

5.3 Inspecting the Mechanism of Poisson Shocks

To explain the role of Poisson shocks in our model, we recalibrate a model without the Poisson shocks and report the model fit in Table 4 along with the baseline case. We refer to it as the Gaussian ($p_z = 1$) case. The results show that the Gaussian model could match the lower-order statistics of firm investment and sizes, but generates low values of kurtosis for the investment rate and output growth rate. Also, the Gaussian needs a high risk-free interest rate of 17.45%, compared to 3.87% in the baseline case, to match the treated group's capital response.

These results are due to the differences in distribution properties. We illustrate this by using a heuristic example in Figure 4. The two panels show the distribution of firm size in the next period, conditional on today's firm productivity 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. Even when both distributions have the same standard deviations, the Poisson shocks generate heavier tails, helping match the high kurtosis moments in the data.

And the difference in the risk-free interest rate estimates is due to the size-persistence effect.

[24] In the Appendix C, we find that a calibrated model with lumpy investment actually decreases the kurtosis of investment rate. The non-convex cost could amplify capital investments conditional on adjustment or make firms more cautious about capital adjustments. The latter dominates in our calibration.

[25] The simulation is performed in partial equilibrium. This assumption is suitable since the general equilibrium effects would be differenced out in the differences-in-difference framework.

As discussed in the comparative statics above, $\bar{z}$ is the productivity threshold for the capital gains tax rates. A firm faces the low tax rate when falling below $\bar{z}$ and the high tax rate otherwise. The Poisson shocks have more mass concentrated around the mean, yielding a larger "peakedness" effect. Therefore, there is a larger shaded area below $\bar{z}$ in the left panel, meaning a low probability of staying large. This corresponds to a large value of $\Pr(z \leq \bar{z})$ in equation (12), implying a low size-persistence effect. Hence, the Gaussian model requires a much higher user cost of capital effect through the risk-free rate to match the empirical moment. Note that matching the short- and long-horizon autocorrelations of output as in the Gaussian model is not sufficient, since the size persistence effect is also determined by the shape of the distribution. In the following section, we show how the differences in the micro moments translate into the differences in the aggregate implications.

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 the economy before the 2014 Policy Reform was implemented in Korea, where firms with average employment less than 300 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, both are unexpected for the household and the firms in the economy.

6.1 Firm-Size Reform in 2014

We start with the case of 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 to study the aggregate effects of the reform on the whole economy.

Figure 5 presents the transitional dynamics of the wage, the interest rate, consumption, capital, investment, output, labor, and total factor productivity (TFP). In general equilibrium, aggregate investment jumps by 2.64 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 the 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.

It is also interesting to study the potential misallocations caused by the size-dependent policy. For this purpose, we use the TFP mesure, defined as the ratio of aggregate output and aggreagte input:

$$TFP = \frac{Y}{K^{\mu\alpha} L^{\mu(1-\alpha)}}.$$

The 2014 policy reform have increased TFP by allowing the firms initially bunching below the old thresholds to grow by capital investment and labor hiring, but simultaneously could have decreased it by incentivizing firms above the new thresholds to cut back on their capital and labor expenditures. The transitional dynamics of TFP shows that the former effect dominates in the short run, while the latter effect dominates in the long run.

Table 5 also summarizes the long-run percent changes of the aggregate variables. In the steady state, aggregate capital, labor, output, consumption, and the wage increase by 1.74%, 0.15%, 0.56%, 0.32%, and 0.47% respectively, while TFP decreases by 0.02%. The increase in output comes mostly from firms' newly accumulated capital. 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 Relevance of Micro Moments for Policy Implications

We find that the baseline model with Poisson shocks does a better job of matching the micro moments than the Gaussian model, but how important is it 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. In Figure 6, we plot the transitional dynamics of the aggregate variables for the baseline and the Gaussian cases in general equilibrium based on the reform. We see that the Gaussian model would over-predict total capital by 2 percentage points in the new steady state, almost doubling the result in the baseline case. This is because the Gaussian model has a much higher risk-free interest rate.

6.1.2 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 7 shows that aggregate investment and capital increase by 10.77 and 1.89 percent, respectively, in the PE case. These responses are much higher than the ones from GE case. The same is true in the new steady-state in the PE case, where consumption, output, capital, and labor are 1.8, 2.0, 3.1, and 2.0 percentage points higher than in 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 PE case look different from those in the GE case.[26]

6.1.3 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. After the 2014 reform, the representative household has to decrease its consumption and increase its 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 $(C_t, L_t)_{t=1,2,\ldots,\infty}$ as

$$\frac{1}{1-\beta}\left[\frac{((1+\Delta_{TD})C^{*})^{1-\sigma}}{1-\sigma} - \omega\frac{L^{*1+\nu}}{1+\nu}\right] = \sum_{t=1}^{\infty}\beta^{t-1}\left(\frac{C_t^{1-\sigma}}{1-\sigma} - \omega\frac{L_t^{1+\nu}}{1+\nu}\right). \tag{19}$$

The results are in Table 5 and indicate that the steady-state welfare gain is 0.13% 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 a 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 increase

[26] In Appendix C, we also look at aggregate effects in the case of a small open economy, which is suitable for South Korea.

by 6.84%, 1.00%, 2.69%, 1.76%, and 0.75%, respectively. TFP increases by 0.22% since firm-size distortions from different capital gains tax rates disappear, accounting for 8% of the increase in output. The transitional dynamics are presented in Figure 8. The dynamics exhibit a pattern similar to those after the 2014 reform: in the short run, consumption drops and then rises gradually to the new steady state. Investment and labor jump and then gradually fall to the new levels.

7 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 the firms affected by the new regulations increased aggregate investment by 2.6 percent and 1.7 percent in the short run and in the steady state, respectively. Moreover, a counterfactual analysis where we set a uniformly low tax rate of 10 percent shows that aggregate investment rose by 6.8 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. Exploring potential mechanisms behind the aggregate responses, such as financial frictions, will be an interesting extension of our paper that may shed further light on the efficiency costs of payout 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	0.08	0.13	0.06	0.13
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 log of 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. The 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 the 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	6.50
Frisch Inverse Elasticity	ν	1
Income Tax Rate	τ^i	0.25
Corporate Tax Rate	τ^c	0.34
High (Low) Capital Gains Tax Rate	τ_h^g (τ_l^g)	0.24 (0.10)
Depreciation Rate	δ	0.10
Capital Share	α	1/3
Returns to Scale	μ	0.85

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	0.13	0.11
Spike Rate	0.26	0.30	0.28
Std. of Investment Rate	0.31	0.25	0.15
Kurtosis of Investment Rate	9.78	12.00	4.13
Std. of Log Output	1.33	1.28	0.78
1-year Autocorrelation of Output	0.95	0.98	0.97
3-year Autocorrelation of Output	0.88	0.89	0.87
5-year Autocorrelation of Output	0.82	0.78	0.75
Std. of Output Growth Rate	0.47	0.26	0.18
Std. of Labor Growth Rate	0.33	0.27	0.21
Kurtosis of Output Growth Rate	7.18	6.71	4.95
Kurtosis of Labor Growth Rate	7.96	6.97	8.54
Treated Group Capital Response	0.10	0.11	0.12

Parameter	Symbol	Baseline	Gaussian
Quaratic Adjustment Cost	ψ	0.14	0.26
Persistence of Productivity	ρ_z	0.74	0.92
Std. of Productivity	σ_z	0.17	0.06
Poisson Probability	p_z	0.29	1
Risk-free Interest Rate (%)	r	3.87	17.45
Revenue Threshold (Percentile)	$\bar{y}$	90	90
Labor Threshold (Percentile)	$\bar{l}_E$	90	90

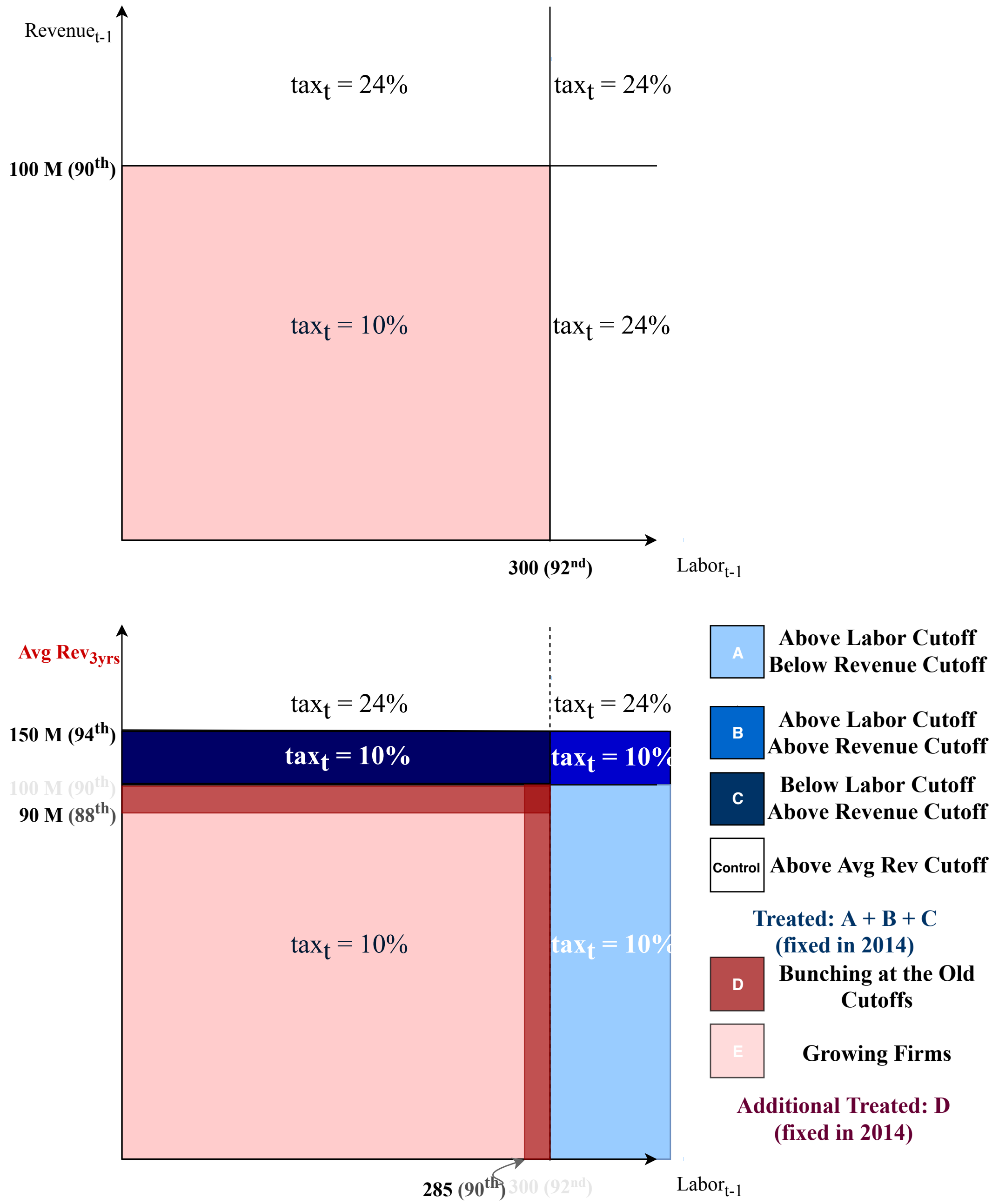
Notes: The top panel shows targeted moments in our model. Sample years include 2009-2018. The spike rate is the fraction of observations with an absolute investment rate greater than 20%. Output is firms' revenue. The treated group's capital response is the difference-in-differences estimate of the capital stock response. The baseline case is an economy with Poisson shocks to the firm productivity process. The Gaussian case is an economy with Gaussian shocks to firm productivity process. The bottom panel shows parameters chosen to match the 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	2.64	1.74	6.84
Capital	0.39	1.74	6.84
Labor	0.41	0.15	1.00
Output	0.39	0.56	2.69
Consumption	-0.11	0.32	1.76
TFP	0.03	-0.02	0.22
Wage	0.30	0.47	2.78
Welfare	0.13		0.75

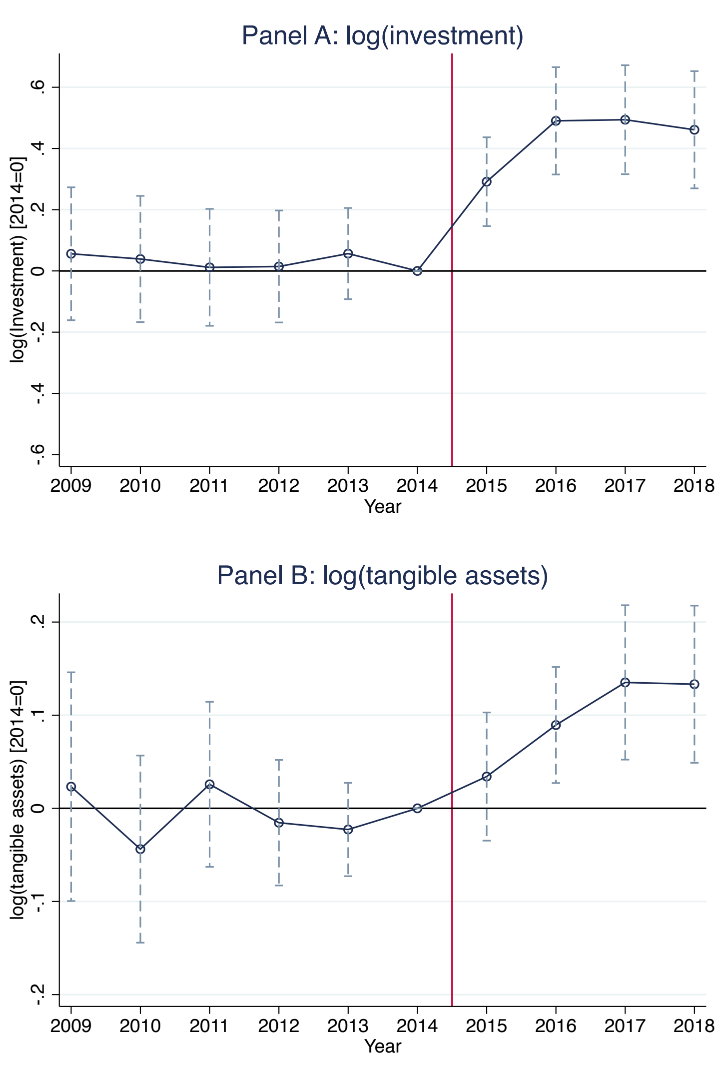
Notes: This table shows percent changes of aggregate variables compared to the pre-2014 steady state in general equilibrium. The welfare calculation accounts for the transitional dynamics. The first two columns refer to the case of eliminating the labor threshold $\bar{l}_E$ and increasing the revenue 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 rate of 10 percent in the long run.

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



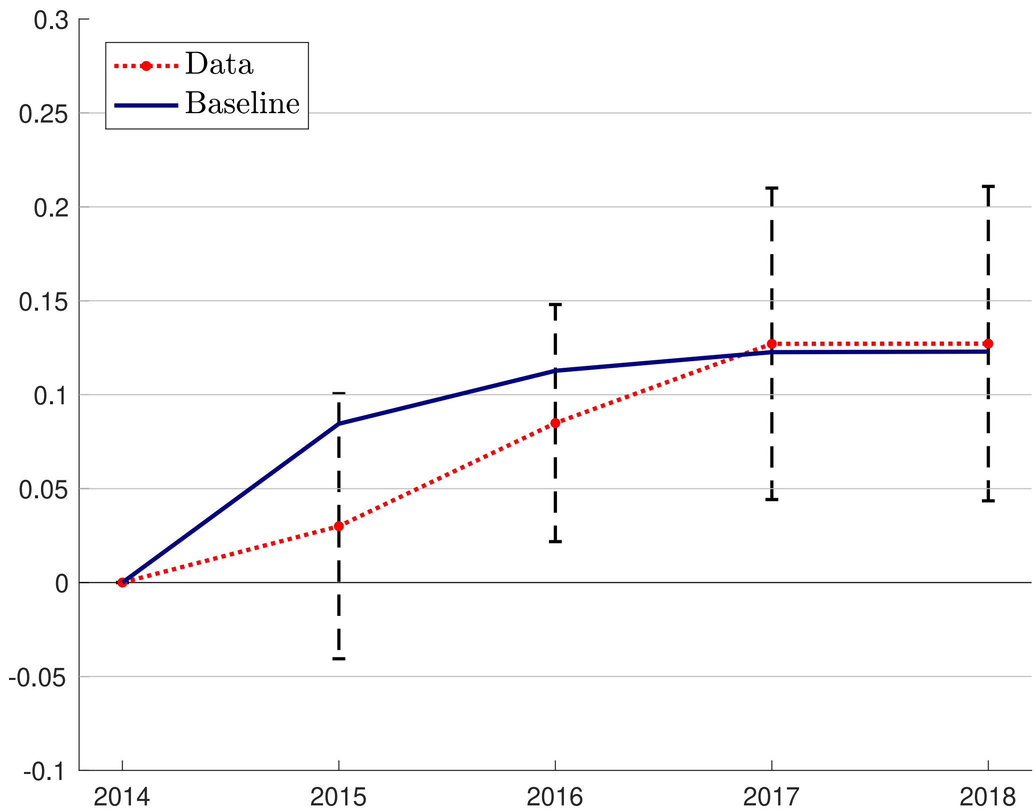
Notes: This figure illustrates how the reform in 2014 assigned firms into the treated or control groups. The top figure shows the initial rule on firm size prior to the reform, where firms in the pink area are jointly below labor and revenue thresholds at time $t-1$ and face a tax rate of 10 percent. The bottom figure shows how the reform affected firm size and the tax rates. I use firms in the blue areas (that experienced a tax cut of 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. We define the control group as firms that did not face any change in the tax rate or an 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 have grown even more after the old thresholds were removed by the reform.

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



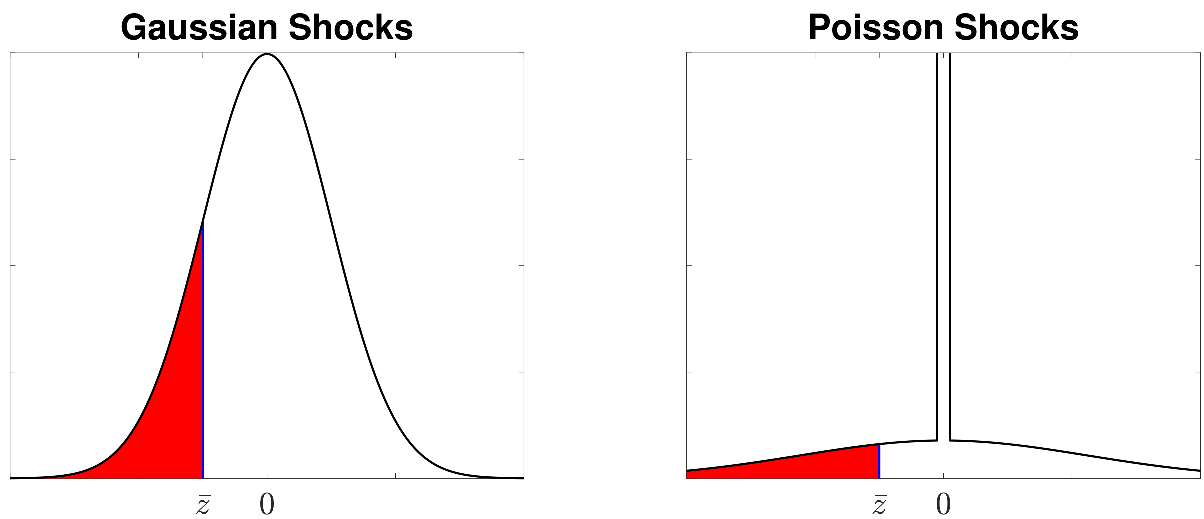
Notes: Panel A of this figure shows the coefficients on *Treated* × *Time* for firms' investment, defined as log(expenditures on physical capital assets), in equation (1) using both publicly listed and private firms. The dashed lines indicate 95% confidence intervals for these coefficient estimates.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

Figure 3: Difference-in-differences Estimates on Capital Stock: Data vs. Model



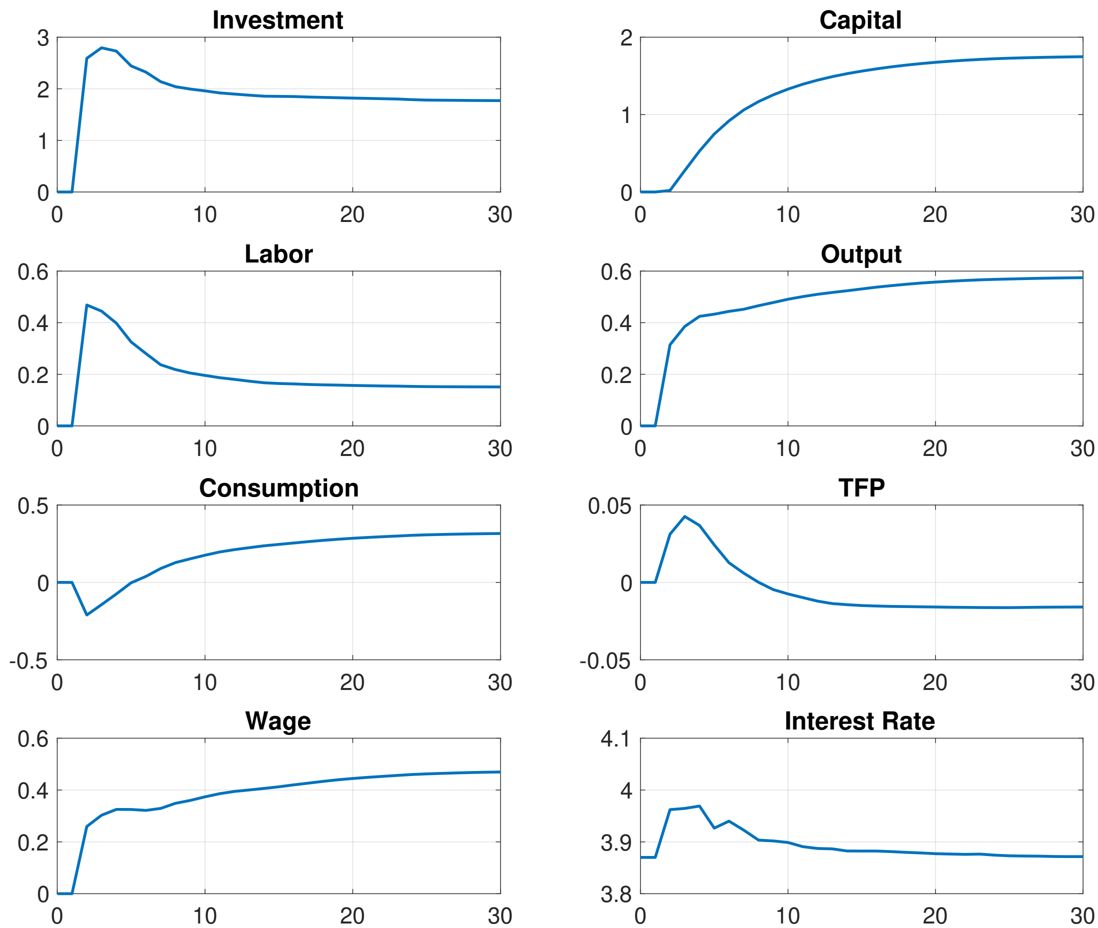
Notes: The figure plots the treated firms' capital stock responses, relative to those of the control firms, for each year after the reform. The red dash line indicates the the coefficients in equation (1) after year 2014, with their 95% confidence intervals in dash vertical lines. The solid blue line indicates our model simulation.

Figure 4: Size Persistence Effect



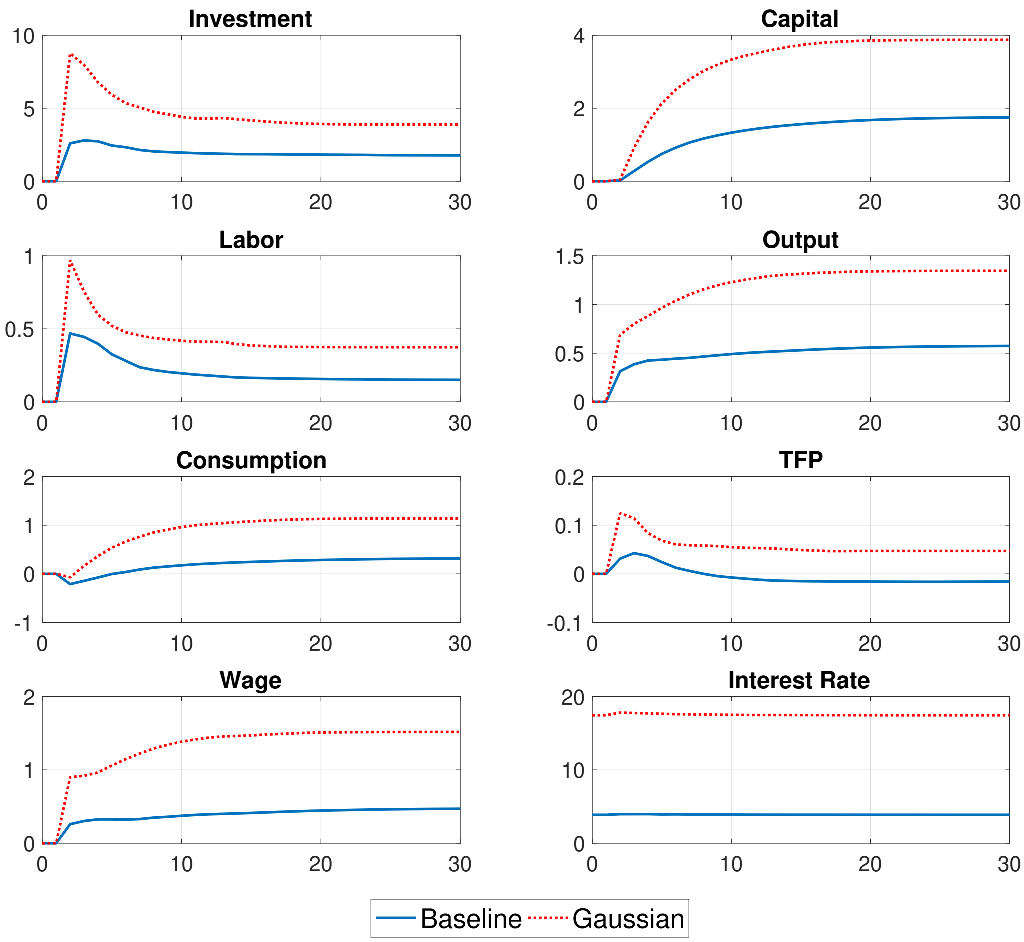
Notes: The figure illustrates the size-persistence effects, separately under the Gaussian shock and under the Poisson shock. Both have the same standard deviations. The shaded areas indicate the probability that a firm falls below the productivity threshold $\bar{z}$: $\Pr(z \leq \bar{z})$.

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



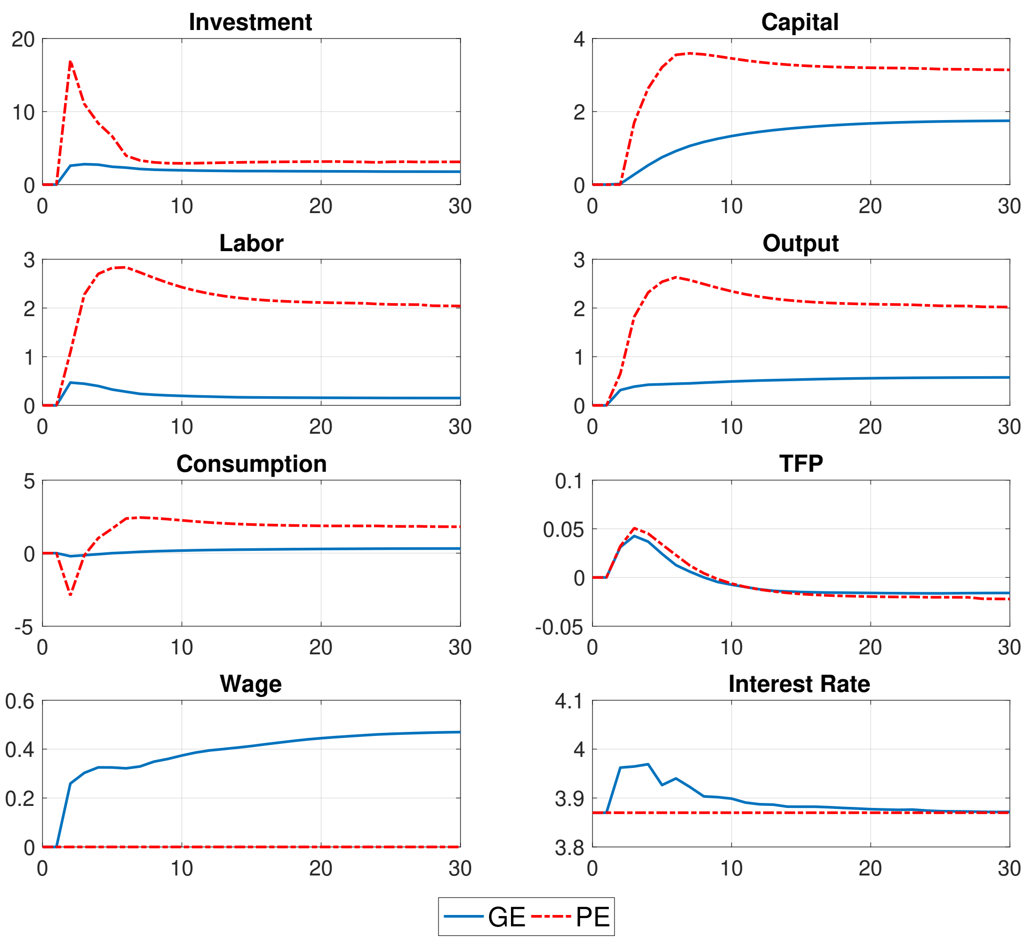
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform that eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars.

Figure 6: Comparison of Baseline and Gaussian Cases (General Equilibrium)



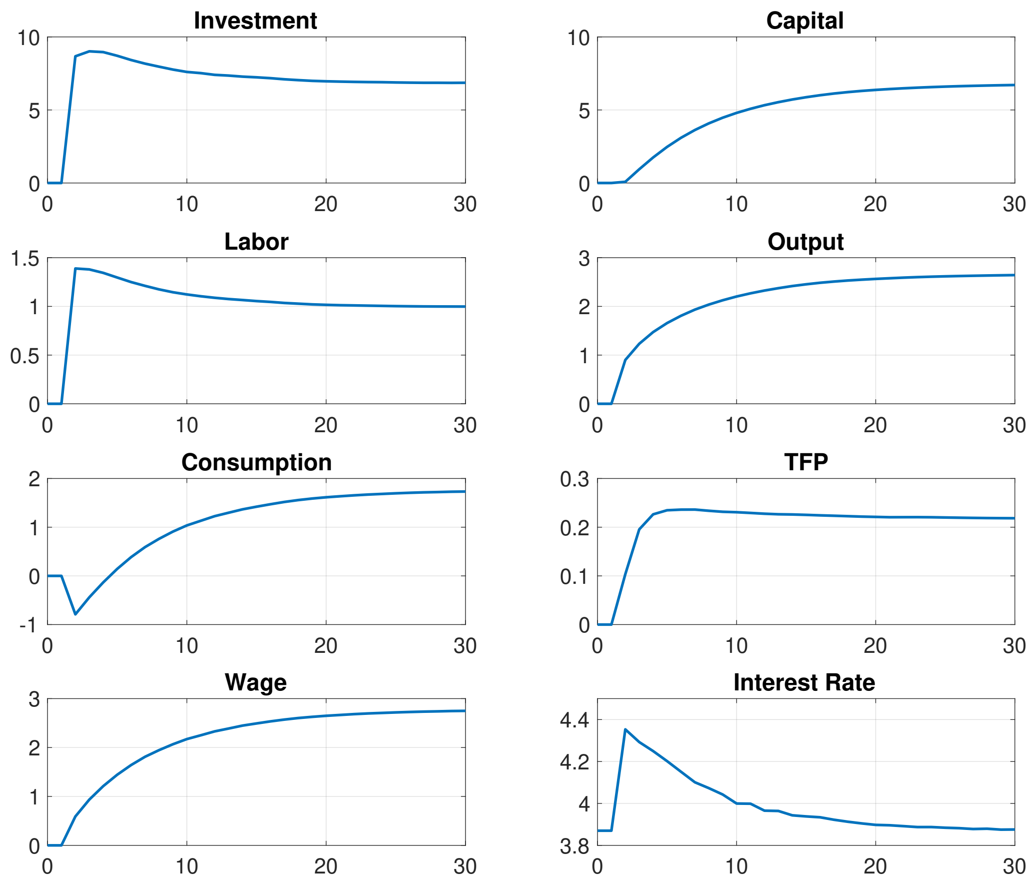
Notes: The economy is at the initial steady state before period 2. The figure plots the transitional dynamics of aggregate variables in response to the firm-size reform that eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars in general equilibrium,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

Figure 7: 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 that eliminated the labor threshold and increased the revenue threshold from 100 million to 150 million dollars. Both the wage and interest rate are kept at their initial levels for the partial equilibrium analysis.

Figure 8: 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%.

For Online Publication

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

- Section A provides additional institutional details.
- Section B shows the results from robustness tests.
- Section C shows the results from model extensions and sensitivity analyses.

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

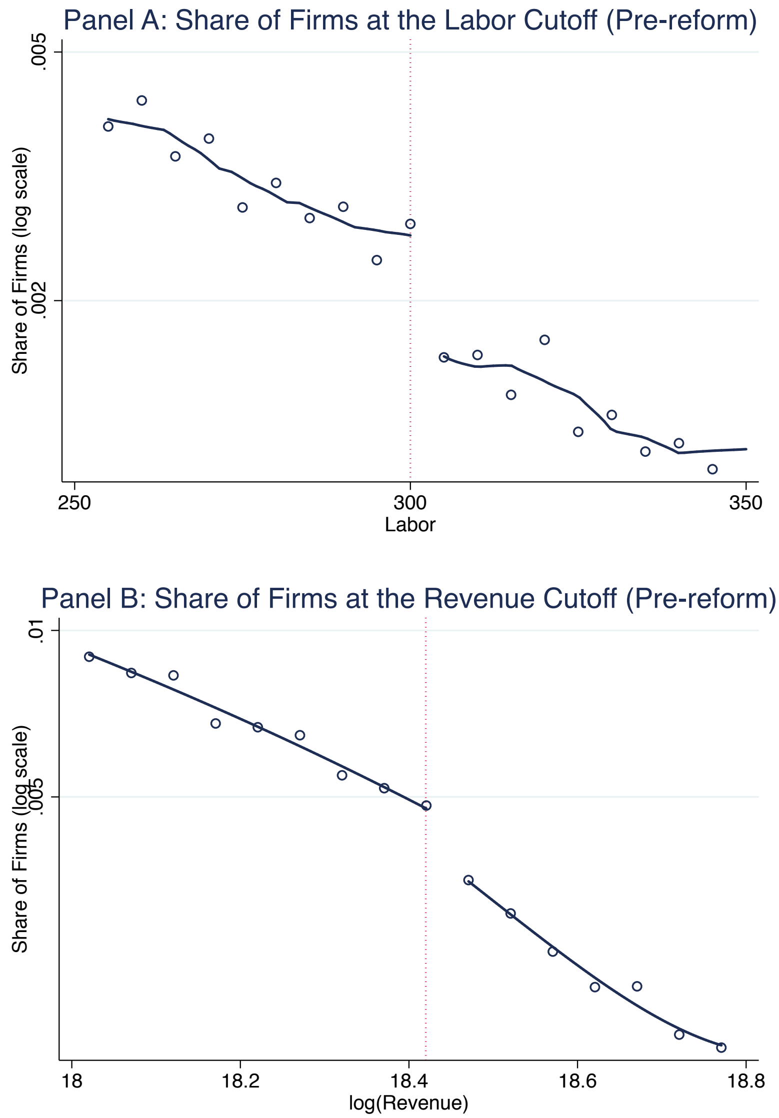
A.1.1 Corporate Income Tax Rates on Profits

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

A.1.2 Dividend Tax Rates

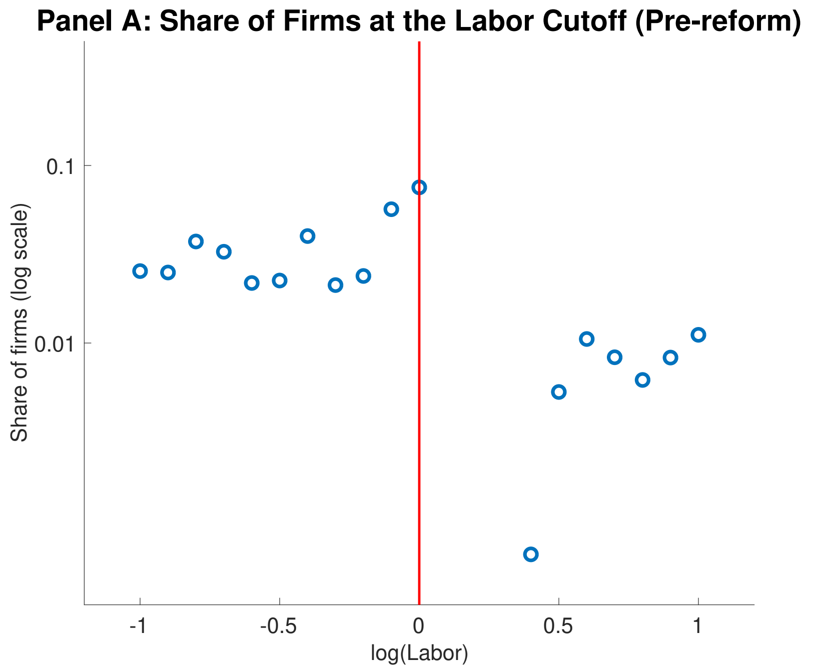
In Korea, dividends are taxed similarly as individual incomes. If an investor's dividend income in a given year is less than $20,000, then the tax rate is 15.4%. However if dividend income is above $20,000, then it becomes part of the investor's income, and the marginal tax rate can rise up to 38%, depending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

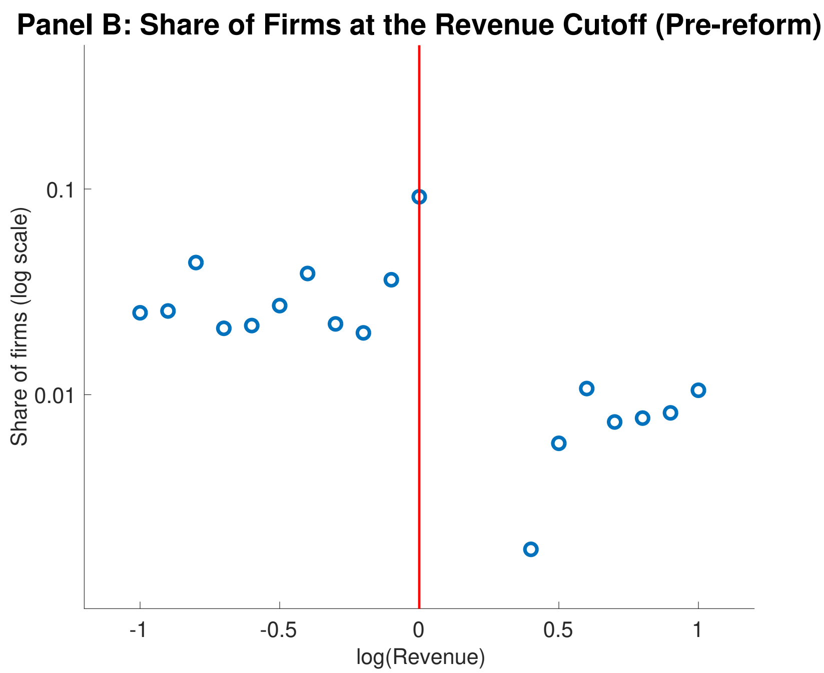
Figure A.1: Firm density at Firm-size Cutoff (Data)



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.

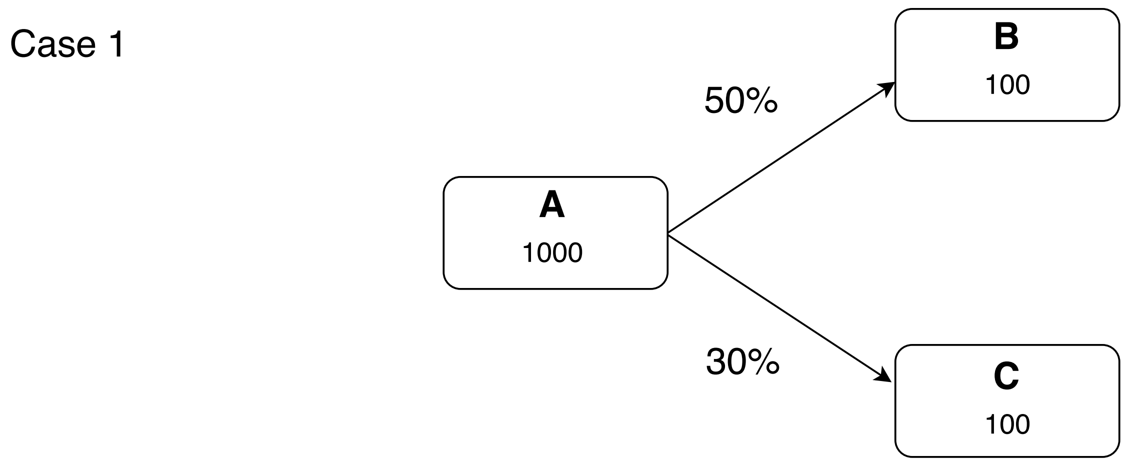
A.2 How to Account for Subsidiaries for Tax Purposes

Table A.1: Computing Accounting Variables for Tax Purposes

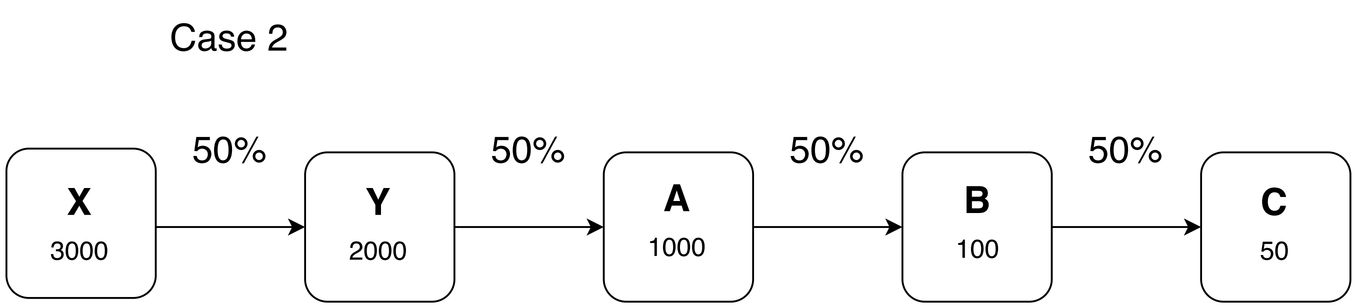
Firm	Relationship	Labor	Ownership	Labor Size for Tax Purposes
Case 1				
A	Parent to B & C	1000	-	$1000 + (1.0) * 100 + (0.3) * 100 = 1130$
B	Subsidiary to A	100	50%	$100 + (1.0) * 1000 = 1100$
C	Subsidiary to A	100	30%	$100 + (0.3) * 1000 = 400$
Case 2				
X	Parent to Y	3000	-	$3000 + (1.0) * 2000 +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



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



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 results 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 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 to 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 main results on investment are 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 an arbitrarily much lower 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	0.03	0.06	0.08	0.09	0.09
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	0.02	0.01
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), we 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	0.09	0.08
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 we 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.

C Model Extensions and Sensitivity Analysis

In Appendix C, we introduce several extensions to the baseline model and check the sensitivity of the main results in the paper. The results are summarized in Table C.1.

C.1 Small Open Economy

The main analysis considers the case of full general equilibrium, where both the wage and interest rates are flexible. Here, we also consider the case of a small open economy, a suitable case for Korea. In this exercise, we keep the interest rate fixed and impose a zero initial debt condition for the model solution. Then consumption jumps instantly to the new steady state value and is determined by the inter-temporal budget constraint:

$$C^{*} = \frac{r}{1+r}\sum_{t=0}^{\infty}\frac{1}{(1+r)^{t}}\left(Y_t - I_t - \Psi_t\right).$$

The small open economy case only slightly over-predicts the aggregate responses.

C.2 Alternative Returns-to-scale

In the main analysis, we consider the case of total returns to scale of the firm of 0.85. For our sensitivity analysis, we recalibrate our model with the returns-to-scale parameter equal to 0.50. We see that the baseline results are relatively robust to this extreme choice of value.

C.3 Measurement Error

The model features firm bunching below the thresholds but could not reproduce firm masses right above the thresholds as in the data. Hence we assume that there are measurement errors ϵ in firms' revenue and labor:

$$\tilde{y} = y\exp(\epsilon),$$
$$\tilde{l} = l\exp(\epsilon).$$

The measurement error accounts for (1) potential measurement errors, (2) output adjustment costs, and (3) labor adjustment costs. The inclusion of measurement errors only slightly decreases the baseline results.

C.4 Lumpy Investment

The baseline model assumes that firms only need to pay the quadratic adjustment cost of capital. Many researchers argue that non-convex costs also plays an important role for aggregate investment dynamics. To account for this, we introduce a fixed cost of capital adjustment into the model as in Khan and Thomas (2008). A firm draws ξ from a uniform distribution $U[0, \bar{\xi}]$ and has to pay a fixed cost proportional to the capital stock ξk_{jt} for non-zero investment $i_{jt} \neq 0$. The firm's budget constraint is

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

We calibrate the model to match not only the moments specified in the main body of the paper, but also an additional moment of inaction rate, defined as a fraction of the observations with an absolute investment rate less than 5%. We find that including non-convex costs slightly dampens the aggregate effects.

C.5 Debt Financing

We allow debt financing to raise external capital. Firms now can use both equity and debt to finance investments:

$$s_t + i_{jt} + \frac{\psi}{2}\left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt} + (1 + (1-\tau_c) r_t) b_{it} = (1-\tau^c)\left(y_{jt} - w_t l_{jt}\right) + \tau^c \delta k_{jt} + b_{it+1},$$

such that

$$b_{it+1} \leq \zeta k_{it}.$$

For simplicity, we assume that the borrowing constraint binds each period: $b_{it+1} = \zeta k_{it}$. We set $\zeta = 0.2$, which is in line with the estimate by Ramey and Shapiro (2001) and Hennessy and Whited (2005). Since firms can use a mixture of equity and debt for financing, the effects of capital gains taxes on aggregate outcomes are dampened in our results.

C.6 Costly External Financing

There is no extra cost to the firms issuing equity to finance their investments in the main analysis. Here we assume that there is a flotation cost of equity issued $\gamma > 0$:

$$(1 + \gamma \mathbb{1}_{s_t < 0}) s_t.$$

We set the value to be 3% of the equity issued, which is in line with the estimates by Gomes (2001) and Hennessy and Whited (2007). The external financing cost discourages firms from raising capital after the 2014 reform, hence slightly dampening the aggregate effects.

Table: C.1: Aggregate Effects of Post 2014 Reform with Model Extensions

	Baseline	SOE	$\mu = 0.5$	ME	LI	Debt	Equity
K	1.74	1.77	1.30	1.26	1.17	0.94	1.20
L	0.15	0.21	0.17	0.12	0.11	0.11	0.09
Y	0.56	0.60	0.30	0.41	0.39	0.31	0.37
C	0.33	0.25	0.20	0.24	0.23	0.19	0.20
TFP	-0.02	-0.02	0.03	-0.01	-0.01	-0.02	-0.02
w	0.47	0.46	0.34	0.36	0.37	0.30	0.30

Notes: This table compares the aggregate effects of Post 2014 Reform on the baseline case and cases with alternative assumptions and extensions. SOE stands for Small Open Economy; ME stands for Measurement Error; LI stands for Lumpy Investment; Debt stands for Debt Financing; Equity stands for Costly External Equity.