PRI Discussion Paper Series (No.22A-02)

Tax Avoidance or Compliance Costs Avoidance? Evidence from VAT Reforms in Japan

London School of Economics and Visiting Scholar, Policy Research Institute, Ministry of Finance, Japan
Takafumi Kawakubo
Lecturer, Aichi Shukutoku University
Takafumi Suzuki
Visiting Scholar, Policy Research Institute, Ministry of Finance, Japan
Kohei Asao

June 2022

Research Department Policy Research Institute, MOF
3-1-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8940, Japan
TEL 03-3581-4111

Tax Avoidance or Compliance Costs Avoidance? Evidence from VAT Reforms in Japan*

Takafumi Kawakubo† Takafumi Suzuki‡ Kohei Asao§

June 8, 2022

Abstract

This paper disentangles the motivations behind how enterprises respond to size-dependent tax regulations by exploiting the value-added tax (VAT) reforms in Japan. In Japan, both tax threshold and tax rate have been changed over the past three decades since the introduction of VAT. We build on the model of Harju et al. (2019) to incorporate various tax reforms and derive empirically testable implications. By using a novel panel of Japanese Census of Manufacture covering the period over VAT introduction and reforms, we conducted bunching estimation. The local estimates imply that the observed output response by enterprises is mainly caused by compliance costs rather than tax rates for small enterprises in Japan. The results suggest that easing compliance costs could be more effective support for small enterprises rather than reducing tax rate/burden.

Keywords: compliance costs; value-added tax; sole proprietor; firm behavior
JEL classification codes: D22; H25; H32; L11

*We would like to thank Shunichiro Bessho, Masahiro Chikushi, Masayoshi Hayashi, Yohei Kobayashi, Kazunari Koide, Makito Nishibatake, Hikaru Ogawa, Kazuki Onji, Motohiro Sato, Junji Ueda, and participants at the University of Tokyo, IIPF Annual Congress, JIPF Annual Conference for helpful comments. This research has been started when both Kawakubo and Asao became visiting researchers at Policy Research Institute, Japan. We gratefully acknowledge the financial support from Tokyo Center for Economic Research, Daiko Foundation, and the Nitto Foundation. Usual disclaimers apply.

†London School of Economics. Email: t.kawakubo@lse.ac.uk
‡Aichi Shukutoku University. Email: tsuzuki@asu.aasa.ac.jp
§Ministry of Finance, Japan. Email: kohei.asao.t5y@cas.go.jp

1 Introduction

Size-dependent regulations are common for tax systems all over the world, and it is known that these regulations create undesirable incentives for enterprises to avoid exceeding the threshold. Kleven and Waseem (2013) and Best et al. (2015) exploited Pakistani tax administrative data to demonstrate that its tax systems provide enterprises with incentives to avoid taxes. Garicano et al. (2016) discussed how French regulation, which is dependent on the number of employees, distorts firm size distribution and, eventually, productivity distribution. More recently, Aghion et al. (2021) demonstrated how these distortion created by size-dependent regulations hampers innovation activities, and the impacts are only for innovation activities but not for radical ones.

The value-added tax (VAT) exemption for small enterprises is an example of this size-dependent regulation. The VAT system in most countries has a certain threshold, and businesses whose taxable sales fall below the threshold are exempted from paying VAT. Moreover, businesses in certain countries are granted to use a simplified tax scheme where enterprises can substitute the taxable purchase amount for deemed taxable purchases. This amount is the taxable sales multiplied by a pre-specified purchase rate. Similar to other tax regulations, previous studies have found that size-dependent regulations generate incentives to avoid exceeding the threshold by reducing sales or changing the organizational structure. However, to the best of our knowledge, studies that discuss the underlying mechanisms are limited. One exception is Harju et al. (2019), which employed the bunching estimation to distinguish tax compliance costs from tax rate responses. They obtained a larger estimate of compliance costs than tax rate elasticities using the Finnish institutional reform, which reduced the compliance costs of VAT.

In this paper, we refer to tax compliance costs as the sum of monetary, time, operational and psychological expenses incurred by tax payments. For instance, the compliance costs include remitting and accounting for tax imposed on the sales or profits, collecting information of legal obligations and penalties. The concept is broader in scope than the expenses which occurs when enterprises outsource to tax accountants.

We build on the theoretical model in the study of Harju et al. (2019) and extend it to incorporate Japanese tax reforms. The consumption tax (equivalent to VAT) in Japan was introduced in 1989[1]. The government has had several tax reforms, especially those affecting small enterprises with sales near the exemption threshold. We quantitatively estimate the

[1] Consumption tax in Japan is a form of VAT. One distinction from the VAT system in other countries is that enterprises are not required to issue an invoice. After the introduction of the multiple tax rates in October 2019, the government announced to introduce an invoice system from October 2023. We discuss the impacts of the VAT on enterprises in cases with and without invoicing in the next section.

size of compliance costs as compared with tax rate elasticities by analyzing the changes in the estimated bunching size in the sales distribution around the threshold before and after the reforms.

We obtain four findings. First, using Japanese firm-level data covering more than two decades, we find bunching below the tax threshold. We observe that the excess bunching is substantially large in the entire sample period. Second, we analyze how the excess bunching varies over time. We find that it increased when VAT was introduced and then sharply declined when the VAT exemption threshold was reduced. This finding is consistent with our theoretical model. Interestingly, the VAT rate hike during the period did not trigger increase of excess bunching. This finding suggests that the changes in the tax rates did not significantly impact enterprises' incentives to adjust their taxable sales. Third, we find that the bunching estimates are persistently larger for sole proprietors than for firms, as seen in the study of Harju et al. (2019). Fourth, we estimate tax elasticity and compliance costs using our theoretical model and find that compliance costs are dominant in determining enterprises' responses to taxes. During the analysis period, VAT rates ranged from 3% to 5%, whereas the estimated compliance costs were approximately 13% of enterprises' value-added. The estimated value is small compared to Harju et al.'s (2019) estimates of 13.8% or 19.4%. However, since this study focuses on larger businesses than Harju et al. (2019), the tax compliance costs are higher. We can interpret the magnitude of this estimate if we view it as a new cost faced by businesses that have never paid VAT. When a tax-exempt business becomes a tax-paying business, it incurs accounting software costs to calculate VAT, new hiring costs for tax purposes, additional tax attorney fees, etc. In addition, businesses that have no experience paying VAT may overestimate their tax compliance costs.

This study contributes to three strands of literature. The first is the literature on tax compliance costs. Although extensive studies have documented tax filing costs, only a few have quantitatively estimated the compliance costs by analyzing behavioral responses (e.g., Aghion et al. 2017; Harju et al. 2019; Benzarti 2020). Aghion et al. (2017) estimated compliance costs using French tax return data using the fact that the simplicity of tax filing systems for the self-employed varies with revenues. Benzarti (2020) estimated the costs of filing taxes using the U.S. income tax return data. Harju et al. (2019) used the Finnish administrative data and found that VAT compliance costs are higher than tax rate elasticities. Our findings add to this literature by determining the size of VAT compliance costs for small enterprises in Japan, where the tax system does not incentivize enterprises to select trading partners based on tax status, which allows us to isolate confounding factors from the estimates of compliance costs.

An invoicing system is a common system of VAT in other countries. However, the

Japanese VAT does not have this system, under which only tax-paying businesses can issue an invoice. In other countries, tax-exempt businesses are excluded from business-to-business transactions from taxpayers' perspective; however, this is not the case in Japan. Buyers can treat the VAT included in their purchases as an input tax credit regardless of whether the supplier is taxable or tax-exempt. Thus, it is appropriate to use a relatively parsimonious model that does not consider enterprises' choice of trading partners.

Regarding the taxation of businesses, tax compliance costs are particularly crucial for small and medium-sized enterprises (SMEs) because the burden of tax compliance for SMEs is higher than that for large enterprises (e.g., EC-KPMG, 2018). A study suggests that compared with other type of taxes, the VAT system requires SMEs' substantial tax compliance (Hansford and Hasseldine, 2012). Our estimates reveal that the share of compliance costs in the value added is much larger than the VAT rate, providing important evidence for policy discussions of the VAT system.

The second strand is the literature on enterprises' responses to tax notches and kinks (e.g., Chetty et al. 2011; Kleven and Waseem 2013; Best et al. 2015; Harju et al. 2019). Our study provides evidence on enterprises' responses to a tax kink and notch at the tax exemption threshold in the Japanese VAT system. The Japanese VAT reform changes a tax kink to a tax notch, whereas the Finnish VAT reform is the opposite, as shown by Harju et al. (2019).

The third strand is the literature on the size-dependent VAT regulations of Japan. Onji (2009) found that the threshold of the simplified VAT system provides businesses with an incentive to split into smaller firms and thus remain below the threshold. Ichikawa et al. (2020) estimated the size of excess bunching of firms around the exemption threshold before and after the tax hike in 2014. They argued that tax compliance cost is a major factor that couses bunching. Ichikawa et al. (2020) demonstrated that compliance costs help to explain the adjustment of firms' taxable sales. However, they did not quantitatively estimate the size of compliance costs, as is done in this present study[2].

The rest of this paper is structured as follows. In Section 2, we explain the institutional background of the Japanese VAT system and introduction and its reforms over the past three decades. We also describe our plant-level panel dataset. In Section 3, we construct a theoretical model and derive its implications, which we use for empirical analysis. In Sections 4 and 5, we document the estimation procedures and the findings about tax elasticity and compliance costs. Lastly, in Section 6, we conclude the paper and discuss the policy implications.

[2]Hosono et al. (2019) employed a different approach to examining the relationship between the bunching size and the costs of employing accountants for tax purposes at the prefectural level.

2 Institutional Background and Data

2.1 VAT in Japan

In Japan, VAT is imposed on enterprises' domestic transactions of goods, services, and imports. Enterprises are responsible for the payment of VAT to tax authorities; however, they are entitled to deduct the remitted VAT from their payment to avoid double taxation. Thus, in the supply chain, enterprises' tax liability is calculated as output VAT minus input VAT. Similarly, their tax base is equal to taxable sales minus taxable purchases.

VAT was first introduced in April 1989 with a 3% tax rate, which was raised to 5%, 8%, and 10% in April 1997, April 2014, and October 2019, respectively. Before October 2019, the tax rate was uniform for all taxed transactions, but, subsequently, it was imposed at a 10% rate on most goods and 8% on necessities, such as food and newspapers. In 2016, VAT comprised 34.3% of the total tax revenue and 6.3% of the total GDP, which are lower than the OECD members' averages of 45.4% and 11.0%, respectively. Although these ratios in Japan are low, the relative magnitude of VAT has steadily increased since 1989 (17.2% of tax revenue and 3.6% of GDP). Therefore, analyses of Japan's VAT are insightful for other countries, especially advanced economies. The repeated reforms in Japan also enable us to develop rich policy implications for the VAT system.

When VAT was introduced in April 1989, the government implemented three special measures to ease the tax burden and compliance costs for SMEs. First, the tax exemption system is applied to small enterprises. If the taxable sales of an enterprise do not exceed the threshold amount in the base period, the enterprise is exempted from remitting VAT and filing the required information. The base period is the two fiscal years before the taxation period. The exemption threshold was initially set at 30 million JPY and reduced to 10 million JPY in April 2004. Since April 2012, enterprises with more than 10 million JPY in earnings in the first half of the previous fiscal year are also subjected to paying VAT. Furthermore, new enterprises were originally exempt from VAT because they did not have sales records for the two fiscal years before the year of establishment. However, from April 1997, new enterprises were not exempted if their registered capital was 10 million JPY or more. New enterprises whose parent firm has more than 500 million JPY in sales and holds more than 50% of their stock were also subjected to VAT, although their capital is less than 10 million JPY.

Second, the simplified tax system (STS) is applied to enterprises whose taxable sales in the base period were 50 million JPY or less. Under this system, enterprises can substitute the taxable purchase amount for deemed taxable purchases. This amount is calculated as taxable sales multiplied by the deemed purchase rate. The deemed purchase rate varies between industries, as summarized in Table 1. In effect, STS is the equivalent of turnover tax.

Table 1. *Deemed Rates of Purchase under The STS*

Industry categories	1989.4	1991.10	1997.4	2015.4	2019.10
Wholesale	90	90	90	90	90
Retail	80	80	80	80	80
Food-related agriculture	80	70	70	70	80
Food-unrelated agriculture	80	70	70	70	70
Manufacture, mining and construction	80	70	70	70	70
Restaurants and others	80	60	60	60	60
Finance and insurance	80	60	60	50	50
Information, communication, and transport	80	60	50	50	50
Services	80	60	50	50	50
Real estate	80	60	50	40	40

Notes: (i) All numbers are shown in percentages. (ii) The industries shown above are the representative ones (e.g., agriculture specifically means represents the agriculture, forestry, and fisheries industries). (iii) The difference between food-related agriculture (food-related) and agriculture (food-unrelated) agriculture was created by the introduction of a reduced VAT rate for foods and beverages since October 2019.
Source: National Tax Agency

Third, the reform in April 1989 incorporated a phase-in scheme known as the marginal deduction system (MDS), which was introduced to mitigate the discrete change in tax burden at the exemption threshold. Enterprises are allowed to deduct an amount from the original VAT due as follows:

$$\text{VAT deduction} = \frac{(\text{The original Amount of VAT}) \times (\text{Upper Bound} - \text{Taxable Sales})}{\text{Upper Bound} - \text{Lower Bound}}$$

Until the abolition of this system in April 1997, the lower bound was 30 million, whereas the upper bound was originally 60 million JPY but reduced to 50 million JPY in October 1991. Figure 1 summarizes the changes mentioned above, whereas Figure 2 shows the VAT schedule reflecting the changes over the period.

The figure depicts that the introduction of VAT in 1989 generated strong incentives for enterprises to stay below the 30 million JPY threshold to avoid compliance costs and tax burdens. In October 1991[3], the MDS was amended to make the slope steeper (i.e., the tax rate increased). Although this change did not affect compliance costs, it increased

[3] This amendment was applied to firms' base period that started after October 1991. In most Japanese firms, the base period starts in April and ends in March. For sole proprietors, the base period starts in January and ends in December. That means that this reform was applied from April 1992. Thus, we refer to this reform as 1992 reform.

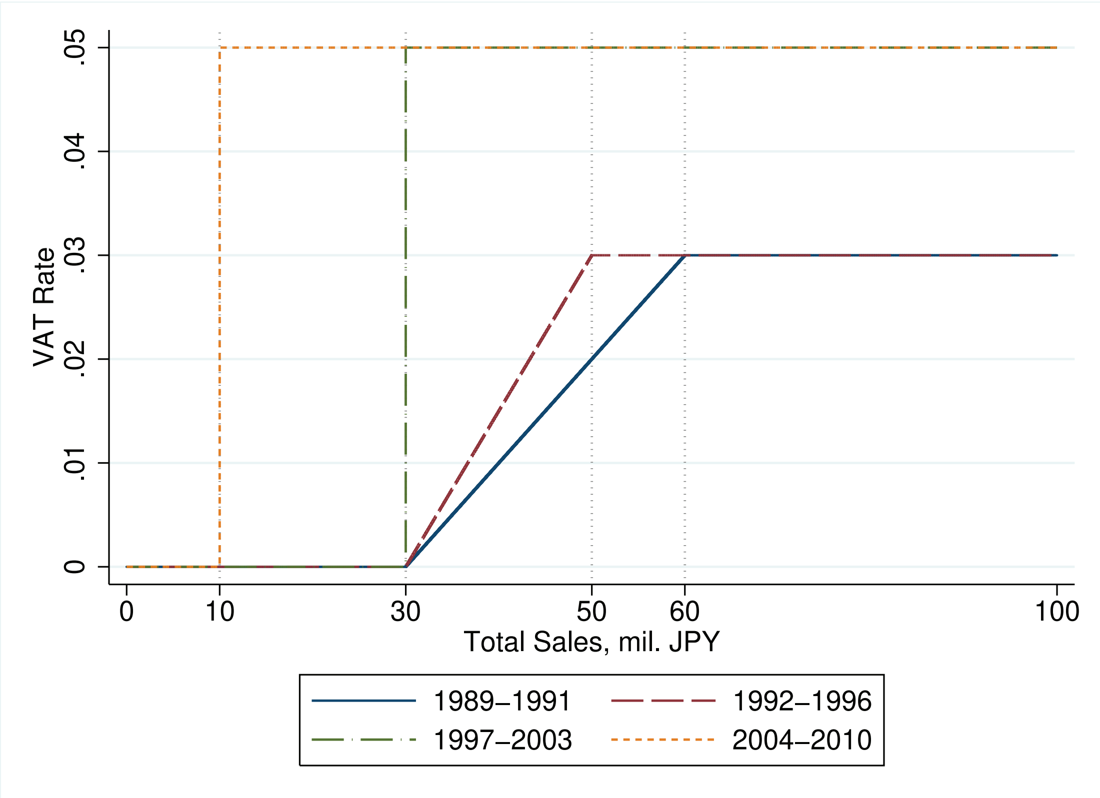
the tax burdens of enterprises above the threshold. The abolition of the MDS in 1997 changed the threshold from a kink to a notch. Compliance costs did not change, although it significantly changed tax burdens. When a notch exists, enterprises can earn more profit if they are marginally below than above the threshold as shown in Kleven and Waseem (2013). Therefore, the 1997 policy change is a significant incident as it enables us to determine the effect of tax burdens and compliance costs and make an important comparison with the study of Harju et al. (2019) that analyzed the change from notch to kink in Finnish VAT schedules, whereas we analyzed the opposite. In 2004, the threshold was reduced to 10 million JPY. Thus, enterprises around the old threshold were not basically affected by the new threshold, unlike those around the new threshold.

Figure 1. *VAT Reforms Over Time*

	1989	1992	1997	2004	2010
Statutory VAT rate	3%	→	5%	→	→
Exemption threshold (JPY million)	30	→	→	10	→
MDS upper bound (JPY million)	60 →	50 →	(abolition)		

Source: National Tax Agency

Figure 2. *Changes in VAT Schedule*



Source: National Tax Agency

The tax accounting system is another important factor that affects enterprises' incentives from a financial perspective. From 1989 to 2019, enterprises in Japan were not required to disclose the VAT rate or VAT amount applied to each product. Subsequently, the tax authority changed the rule to mandate enterprises to disclose the tax amount in response to the implementation of multiple VAT rates in October 2019. The authority has decided to implement the tax invoicing system from 2023. Under this system, enterprises will be obliged to use official tax invoices to calculate the amount of their taxable inputs.

The Japanese VAT has no invoicing system, although the invoicing system is common in other countries. This situation reveals two advantages in studying the underlying mechanisms behind enterprises' responses to VAT. First, the Japanese VAT system does not favor the selection of trading partners based on tax payment. Under the tax invoicing system, tax-paying enterprises are incentivized to trade with one another to obtain additional tax invoices and thus pay low taxes. This selection behavior has been observed in existing studies (e.g., de Paula and Scheinkman 2010; Gadenne et al. 2019; Liu et al. 2021) that used data from countries that have implemented the VAT invoicing system. However, this system is not practiced in Japan. Thus, we do not incorporate enterprises' choice of trading partners in our theoretical model and can keep it parsimonious and tractable. Second, the price set by enterprises is unlikely to vary systematically depending on whether an enterprise is exempt from VAT or not as the issuing of invoices for business-to-business transactions is not required in Japan. Thus, enterprises whose sales are around the exemption threshold can sell their products at tax-inclusive prices despite their tax exemption. Therefore, responses to the difference in pricing behaviors can be abstract depending on whether the firm is VAT-exempt or not. These two points imply that it is advantageous to use the Japanese VAT system to study enterprises' bunching behavior and estimate the compliance costs.

2.2 Data

We use the Census of Manufacture as the main dataset, which is conducted by the Japanese Ministry of Economy, Trade and Industry. The survey has been conducted since 1909, sampling from all establishments with more than three employees.[4] The survey collects various ranges of production information, such as shipment value, input value, number of employees[5], capital stock, and investment. We use shipment value as a proxy for taxable sales, which are not included in the data. This approach is justified for two reasons. First, the sales

[4]There used to be no restriction related to employees number before 2010 if a year ends with 0, 3, 5, or 8. Conversely, we can use the data of establishments with more than three employees for all the survey years.

[5]Here, employees includes regular employees, self-employed and family workers. Since 2001, regular employees are differentiated from part-time workers, temporary workers and permanent workers.

of an enterprise differ from its shipment value mostly when an establishment sells goods to another establishment within the same enterprise. However, this situation is excluded from the data as we focus only on enterprises with a single establishment. We argue that the sample adequately captures the distribution of firms—it approximately covers 90% of the establishments around the threshold. This argument still holds even if we restrict the data to a single establishment with a turnover of 30 million JPY (the VAT exemption threshold). Second, the sales and shipment value also differ when enterprises book sales and shipments at different periods. However, it is a common practice among Japanese manufacturing enterprises to book shipments and sales simultaneously. Thus, we believe that the shipment value is a valid proxy for taxable sales. We use the data from 1986 to 2010, covering the introduction of VAT in April 1989, the increase in the VAT rate from 3% to 5%, the abolition of the MDS in 1997, and the reduction of the exemption threshold from 30 million JPY to 10 million JPY since 2004.

Table 2. *Sample Distribution by Organization Types*

Year	Firms	Sole proprietors	Others	Total
1986	202,214	128,643	2,310	333,167
1989	203,083	110,732	2,170	315,985
1992	210,155	89,883	2,065	302,103
1995	200,496	78,803	1,912	281,211
1998	198,148	68,019	1,917	268,084
2001	174,630	49,298	1,671	225,599
2004	152,570	36,922	1,421	190,913
2007	145,415	29,540	1,330	176,285
2010	127,374	22,722	1,241	151,337
Total	4,512,347	1,710,157	44,460	6,266,964

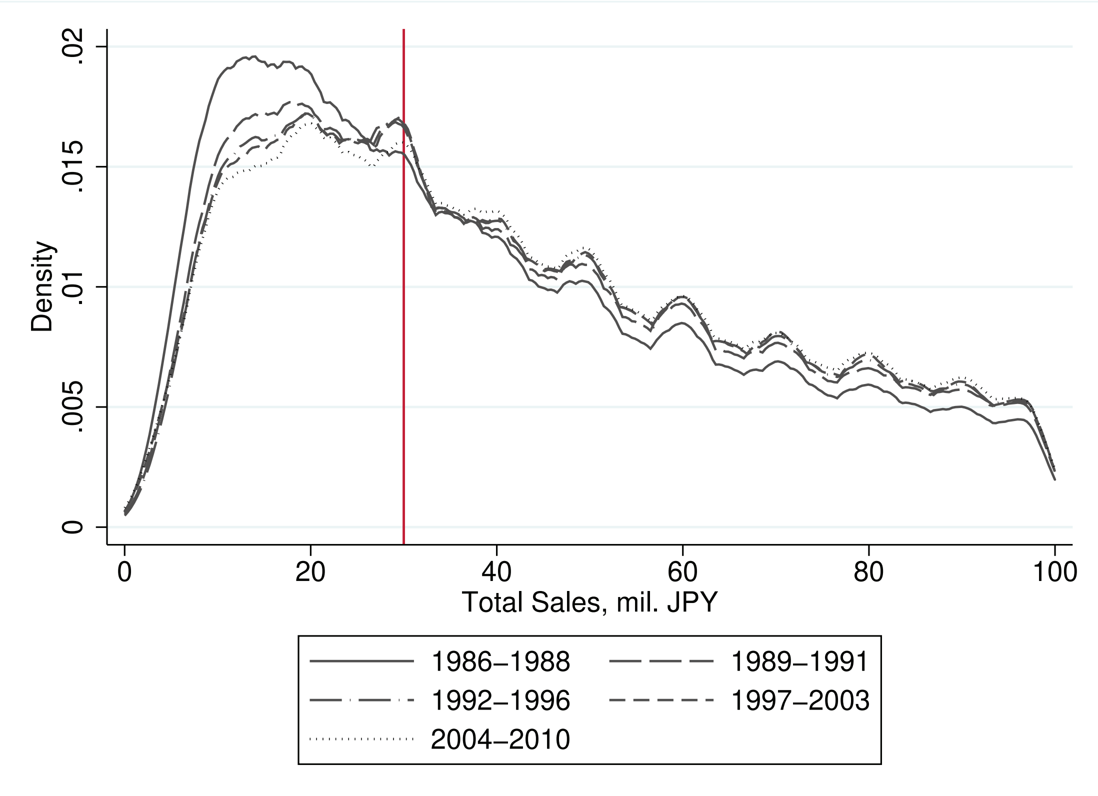
Notes: The table only lists the numbers for every three years starting from 1986 and does not list the years in-between because of lack of space. (ii) The sample only includes establishments that have the same address as their headquarters and no other establishments.
Source: Census of Manufacture (1986–2010)

2.3 Summary Statistics

Table 2 presents the distribution of the observations in our sample. Although our data comprise a yearly panel, the numbers are listed only for every three years starting from 1986, and the years in-between are skipped due to space constraints. The total number of annual observations ranges from 151,000 to 333,000. The number monotonically decreases over the sample years, which is consistent with existing studies that constructed the official panel converter of the census (e.g., Shimpo et al. 2005; Abe et al. 2012). Table A1 illustrates the sample distribution by establishment type. Firms with a single establishment in the same place are dominant in the survey data. Textile manufacturers hold the biggest share (12.8%), although they occupy less than 1% of the total output of manufacturing industries in Japan (Table omitted).

Figure 3 depicts the total sales distribution in each tax regime. A bulge can be seen below the VAT exemption threshold (30 million JPY) after the introduction of VAT, whereas the valley expected above the threshold is unclear. The density of enterprises decreases over the research period, with the total sales below the threshold, whereas those above the threshold increase. Moreover, masses at round numbers are noteworthy (e.g., 40 and 60 million JPY). We address the round number bunching in our estimation procedures.

Figure 3. *Kernel Density in Each Tax Regime*



Notes: The red vertical line shows the size of VAT exemption threshold, 30 million JPY.

Then, Table 3 summarizes the statistics of enterprise characteristics in million JPY[6]. The total sales range from 1.80 million JPY to over 18,000 million JPY, indicating a large coverage of the Japanese Census of Manufacture. Firm size is defined by the number of employees and ranges from 4 to 499[7]. The minimum number of employees is set to four because the survey targets firms with at least four employees. Additionally, the maximum number of employees is set to 499 because we currently only focus on firms with a single establishment. Without this restriction, the number would be much larger.

Table 3. *Summary Statistics for 1986–2010*

Variables	Mean	Median	SD	Min	Max
Total Sales	256.40	64.72	9.67	1.80	18,525.06
Firm Size	15.76	8.00	31.15	4.00	499.00
Total Wage	53.08	21.70	1.39	0.00	2,465.91
Capital	10.71	3.00	0.49	0.00	1,135.46
Value Added	60.72	14.12	2.38	-214.44	4,548.21
VAT Paid	1.51	0.00	0.08	-0.56	153.65
Input Cost	138.66	22.00	6.20	0.05	12,032.06
Input-Cost Ratio	0.39	0.38	0.22	0.00	1.00

Notes: (i) The number of observations is 6,266,964. The sample only includes single establishments which have the same address with their headquarters. (ii) The unit of price is one million JPY. (iii) We pooled all the sample years, and winsorized the variables with top and bottom 0.1%. (iv) Firm size is defined as the number of employees. Value added is defined as Total Sales minus the sum of Input Cost and Amount of VAT Paid. Input-cost ratio is defined as dividing Input Cost by Total Sales, and we excluded the observations with the ratio exceeding one.
Source: Census of Manufacture (1986 - 2010)

3 Theoretical Model

We build on the theoretical model in Harju et al. (2019) and extend it to incorporate various tax reforms in Japan over the last two decades. Consider a large number of owners of a small enterprise[8] that produce a single homogeneous good and sell all their products to customers.

[6]Until 2007, in the survey, the definition of total sales was the sum of manufacturing sales, process sales, and repairment sales. However, in 2007, the definition changed to the sum of manufacturing sales, process sales, and other sales. Therefore, we show the summary statistics for 1986–2006 and 2007–2010 in Tables A2 and A3, respectively.

[7]We winsorize variables with top and bottom 0.1% to deal with measurement errors.

[8]As we focus on small firms and sole proprietors, we assume that enterprise owners make enterprise-level decisions and respond to tax systems the same as enterprises, as stated by Bonzaanier et al. (2019).

Assuming that demand for a good is perfectly elastic and producer price of the good is normalized as 1, an enterprise's productivity, a, follows CDF $F(a)$ and PDF $f(a)$. We assume that the value added can be described as $v = (1-\alpha)y$ where y denotes revenue and α denotes the proportion of input costs in revenue[9]. Enterprises are assumed to have iso-elastic cost of generating output, as follows:

$$\phi(y;\alpha) = \frac{a}{1+1/e}\left(\frac{(1-\alpha)y}{a}\right)^{1+1/e}$$

where e denotes the elasticity of value added with respect to the net-of-VAT rate.

Then, the firm owner's maximization problem of its profit $\pi(y;\alpha)$ becomes

$$\max_{y} \quad \pi(y;\alpha) = (1-\alpha)y - T(y;\alpha) - \Theta(y;\alpha) - \phi(y;\alpha)$$

where $T(y;\alpha)$ denotes tax payments, and $\Theta(y;\alpha)$ denotes compliance costs. Here, we assume compliance costs are proportional to value added v such that $\Theta(y;\alpha) = \theta(1-\alpha)y$ with $\theta \in [0,1]$. Apart from tax payment costs, enterprises incur three types of costs—costs of buying raw materials, costs of producing goods, and compliance costs for paying tax.

3.1 MDS

3.1.1 Derivation of the formula

As we explain in section 2.1, there used to be the Marginal Deduction System (MDS) when the VAT was introduced in Japan. Under the MDS, the effective tax rate increases gradually above the threshold. Thus, it creates a kink in the tax system. For those below the threshold (i.e., $y \leq y^*$), the objective function of the enterprise can be rewritten as follows:

$$\begin{aligned}\pi(y;\alpha) &= (1-\alpha)y - t\alpha y - \phi(y) \\ &= (1-\alpha)y(1-t^A) - \phi(y)\end{aligned}$$

where t is VAT rate, and $t^A = \frac{t\alpha}{1-\alpha}$ is effective tax rates below the threshold.

For those above the threshold (i.e., $y > y^*$), the objective function of the enterprise can

[9] Here, we are considering input (e.g., raw materials) cost in VAT, so it does not include cost of hiring labor.

be approximated[10] as follows:

$$\begin{aligned}\pi(y;\alpha) &= (1-\alpha)y - \left(1-\frac{\bar{y}-y}{\bar{y}-y^*}\right)\left(\frac{t}{1+t}y - t\alpha y\right) - t\alpha y - \theta(1-\alpha)y - \phi(y) \\ &\approx (1-\alpha)y\left(1-t^B-\theta\right) - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t}+t\alpha\right) - \phi(y)\end{aligned}$$

where $\bar{y}$ denotes as the upper bound, and $t^B = \frac{1}{1-\alpha}\left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right)$ is the effective tax rates above the threshold. Note that it is assumed that the price for intermediates is identical across all sellers. Similarly, the final good price is identical across all buyers.[11]. We have $t^A < t^B$ as far as $\alpha \in [0, \frac{1}{1+t})$.

These can be summarized as follows:

$$\pi(y;\alpha) = \begin{cases}(1-t^A)(1-\alpha)y - \phi(y) & \text{if } y \le y^* \\ (1-t^B-\theta)(1-\alpha)y - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t}+t\alpha\right) - \phi(y) & \text{if } y > y^*,\end{cases}$$

The maximization problem leads to the following:

$$(1-\alpha)y = \begin{cases}a(1-t^A)^e & \text{if } y \le y^* \\ a(1-t^B-\theta)^e & \text{if } y > y^*\end{cases}$$

Next, we consider the behaviors of marginal bunchers whose revenues are equivalent. Marginal bunchers would be indifferent between bunching and no bunching. Through the former, they obtain the following:

$$\pi_{bunch} = (1-t^A)(1-\alpha)y^* - \frac{a^*+\Delta a^*}{1+1/e}\left(\frac{y^*(1-\alpha)}{a^*+\Delta a^*}\right)^{1+1/e}$$

Through the latter, they obtain the following:

$$\pi_{not} = (a^*+\Delta a^*)(1-t^B-\theta)^{e+1}\left(\frac{1}{e+1}\right) - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t}+t\alpha\right)$$

Marginal bunchers would satisfy the following first-order condition when they choose not to bunch: $(1-\alpha)y^* = (a^*+\Delta a^*)(1-t^B-\theta)^e$. They would also satisfy the first-order condition when there were no threshold: $(1-\alpha)(y^*+\Delta y^*) = (a^*+\Delta a^*)(1-t^A)^e$.

Then, the indifference between bunching and not bunching, i.e., $\pi_{bunch} = \pi_{not}$, leads to

[10] The details of the derivation are presented in Appendix B.

[11] In practice, the prices could be different depending on whether a business is tax-exempted or not. This is left for future research.

the following formula:

$$1-\frac{e}{e+1}\left(1+\frac{\Delta y^*}{y^*}\right)\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e}=\frac{1}{e+1}\left(\frac{1-t^B-\theta}{1-t^A}\right)^{e+1}\left(1+\frac{\Delta y^*}{y^*}\right)-\frac{y^*}{\bar{y}-y^*}\frac{-\frac{t}{1+t}+t\alpha}{(1-\alpha)(1-t^A)}$$

Arranging the terms, we obtain the following:

$$\begin{aligned}
&\frac{1}{1+\frac{\Delta y^*}{y^*}}\left[1-\frac{y^*}{\bar{y}-y^*}\frac{-t\alpha+\frac{t}{1+t}}{(1-\alpha)(1-t^A)}\right]-\frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e}-\frac{1}{e+1}\left(\frac{1-t^B-\theta}{1-t^A}\right)^{1+e}\\
=\;&\frac{1}{1+\frac{\Delta y^*}{y^*}}\left(1-t^C\right)-\frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e}-\frac{1}{e+1}\left(\frac{1-t^B-\theta}{1-t^A}\right)^{1+e}\\
=\;&0 \qquad (1)
\end{aligned}$$

where we denote $t^C=\frac{y^*}{\bar{y}-y^*}\frac{-t\alpha+\frac{t}{1+t}}{(1-\alpha)(1-t^A)}$.

3.1.2 1992 VAT Reform

In October 1991, the upper bound of VAT deduction of the MDS was reduced from 60 million to 50 million JPY. This led to a change in the effective tax rate above the threshold, i.e., $t^B=\frac{1}{1-\alpha}\left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t}+\frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right)$, but it did not affect the effective tax rate below the threshold, i.e., $t^A=\frac{t\alpha}{(1-\alpha)}$. Because $\partial t^B/\partial\bar{y}<0$[12], the VAT reform in 1992 resulted in an increase in the effective tax rate, t^B. Thus, after the reform, the last term in Equation (1), i.e., $(1-t^B-\theta)/(1-t^A)$ increased. When $\bar{y}$ declines, the first term in Equation (1), i.e., $1-t^C$, gets larger and is also seen from $\partial t^C/\partial\bar{y}<0$[13]. Based on the observation, we denote these rates as t^B_{1992} and t^C_{1992}. The formula can be written as follows:

$$\frac{1}{1+\frac{\Delta y^*_{1992}}{y^*}}\left(1-t^C_{1992}\right)-\frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*_{1992}}{y^*}}\right)^{1+1/e}-\frac{1}{e+1}\left(\frac{1-t^B_{1992}-\theta}{1-t^A}\right)^{1+e}=0 \qquad (2)$$

The positive changes in tax rate terms (t^B_{1992} and t^C_{1992}) leads to the change in the magnitude of bunching, i.e., $\Delta y^*_{1992}/y^*$.

[12]This holds as far as $\alpha\in[0,\frac{1}{1+t})$. Although the statutory tax rate did not change under the regime of marginal deduction system, we can check that $\frac{\partial t^B}{\partial t}>0$.

[13]The result comes from the relationship between t^B and t^C, i.e., $(1-t^C)=\frac{1-t^B}{1-t^A}$.

3.2 1997 VAT Reform

We observe two shifts in the VAT system in 1997. First, the MDS was abolished, and there was no deduction since then. Second, the tax rate was increased from 3% to 5%. Denoting the new tax rate as t_{1997}, we obtain the profit functions as follows:

$$\pi(y;\alpha) = \begin{cases} y - \alpha y - \alpha y t_{1997} - \phi(y) & \text{if } y \leq y^* \\ y\left(\frac{1}{1+t_{1997}} - \alpha\right) - \theta(1-\alpha)y - \phi(y) & \text{if } y > y^* \end{cases}$$
$$= \begin{cases} (1-\alpha)y(1-t^D) - \phi(y) & \text{if } y \leq y^* \\ (1-\alpha)y(1-t^E-\theta) - \phi(y) & \text{if } y > y^*, \end{cases}$$

where

$$t^D = \frac{\alpha t_{1997}}{1-\alpha} \text{ and } t^E = \frac{t_{1997}}{(1-\alpha)(1+t_{1997})}$$

are the new effective tax rates. Then, the formula becomes

$$\frac{1}{1+\frac{\Delta y^*_{1997}}{y^*}} - \frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*_{1997}}{y^*}}\right)^{1+1/e} - \frac{1}{e+1}\left(\frac{1-t^E-\theta}{1-t^D}\right)^{1+e} = 0 \tag{3}$$

Because there are two changes in the tax system, we expect the volume of the bunching to also change, and we use a different subscript in the equation above.

In the next section, we estimate the size of the excess bunching and derive the tax elasticity and the compliance costs.

4 Empirical Specifications

In Equations (1)–(3), we can observe the values of α, t^A, t^B, t^C, t^B_{1992}, t^C_{1992}, t^D, and t^E. Moreover, we can obtain the estimates $\Delta y^*/y^*$ from the bunching estimation. We explain the estimation procedures in the following paragraphs[14].

The existence of the tax threshold provides enterprises with an incentive to bunch below the threshold to avoid taxation. This is the behavioral response that we focus on. We observe the excess mass below the threshold and the hole above it in empirical turnover

[14]In our empirical analysis, we do not use the 1989 reform, when the VAT was introduced, and the 2004 reform, when the threshold was lowered to 10 million JPY, to estimate tax compliance costs. The reason for the former is that *both* the tax burden and the tax compliance cost change simultaneously at the 30 million JPY threshold. The latter is that *both* the tax rate and the compliance cost change simultaneously for firms below the threshold.

distribution. By comparing the empirical distribution with the counterfactual distribution, which would exist in the absence of the threshold at y^*, we obtain the estimates of the behavioral responses. We follow the existing bunching estimation literature (see, e.g., Chetty et al. 2011; Kleven and Waseem 2013) and estimate the counterfactual density by fitting a flexible polynomial function to the empirical distribution, eliminating an area around (below and above) the threshold y^*.

There are three steps in the bunching estimation—constructing the counterfactual density, estimating the bunching, and calculating the standard errors with bootstrapping. First, we construct the counterfactual density with the following regression. We treat the enterprises in a group of bins with sales of 0.5 million JPY and exclude the region around the threshold, i.e. $y \in [y_L,\ y_U]$, where y_L denotes the lower bound of the excluded region, and y_U denotes the upper bound.

$$c_j = \sum_{i=0}^{p} \beta_i (y_j)^i + \sum_{i=y_L}^{y_U} \gamma_i \cdot 1\{y_j = i\} + \sum_{r \in \mathbb{R}} \eta_r \cdot 1\left\{\frac{y_j}{r} \in \mathbb{N}\right\} + \epsilon_j \tag{4}$$

where c_j is the number of establishments in bin j, and y_j denotes the sales in bin j. Following the study of Chetty et al. (2011), we include polynomials up to the seventh order in the baseline estimation. Moreover, we take care of round number bunching because establishments often report round numbers, such as 50 million and 100 million JPY. The third term in Equation (4) is a set of round number dummies to control for bunching at integers, $\sum_{r \in \mathbb{R}} \eta_r \cdot 1\left\{\frac{y_j}{r} \in \mathbb{N}\right\}$, where $\mathbb{R}$ is a vector of the sales in 1, 5 and 10 million JPY, and $\mathbb{N}$ is the set of natural numbers. The counterfactual density can be constructed with the fitted values, as follows:

$$\hat{c}_j = \sum_{i=0}^{p} \hat{\beta}_i (y_j)^i + \sum_{r \in \mathbb{R}} \hat{\eta}_r \cdot 1\left\{\frac{y_j}{r} \in \mathbb{N}\right\}. \tag{5}$$

Second, we estimate the relative bunching mass as follows:

$$\hat{b}(y^*) = \frac{\sum_{i=y_L}^{y^*} (c_j - \hat{c}_j)}{\sum_{i=y_L}^{y^*} \hat{c}_j / N_j}, \tag{6}$$

where N_j is the number of bins in $[y_L,\ y^*]$. The following two factors are critical in estimating the relative bunching mass: determining y_L and y_U, which are the lower and upper bounds of the excluded region, respectively. Regarding y_L, we conduct this exercise based on visual observations of the turnover distribution, as was done in the study of Harju et al. (2019). We run several robustness checks based on the lower bound values and find similar results (table omitted).

Following Kleven and Waseem (2013) and Harju et al. (2019), we determine y_U so that the estimated excess mass below the threshold, $\hat{b}_E(y^*)$, equals the estimated missing mass above the threshold, $\hat{b}_M(y^*)$, where

$$\hat{b}_E(y^*) = \sum_{j=y_L}^{y^*} (c_j - \hat{c}_j) \tag{7}$$

$$\hat{b}_M(y^*) = \sum_{j=y>y^*}^{y_U} (\hat{c}_j - c_j). \tag{8}$$

We set a small value of y_U and increase it to derive $\hat{b}_E(y^*) = \hat{b}_M(y^*)$. This defines the sales response by the marginal buncher, and we denote the value as $\hat{y}_U$.

Lastly, we calculate the standard errors by bootstrapping, which is a common practice in the existing literature. We generate the distributions by randomly resampling the residuals derived from Equation (4) with replacement and obtain new estimates with the bootstrap procedure.

In the next section, we will exploit estimates of excess bunching size to derive the elasticity and compliance costs. However, one problem is that Equation (6) is the bunching size, which reflects the behavioral response of enterprises and not the structural one that is applicable to Equations (1)–(3). Therefore, we exploit the estimates of upper bound of excess bunching to derive the elasticity and compliance costs, which is denoted as the "convergence method" in the study of Kleven and Waseem (2013). The upper bound of excess bunching is defined as follows:

$$\hat{b}_U(y^*) = \hat{y}_U - y^*. \tag{9}$$

Kleven and Waseem (2013) also proposed the estimator of lower bound of excess bunching. However, it is complicated to construct the estimator because it contains the parameter of compliance costs, which is what we want to estimate. Thus, we stick to using only the upper bound of excess bunching size.

5 Results

5.1 Sales Distribution

We depict the changes in turnover distribution over time in Figure 4. Each panel corresponds to a different tax regime. We use the first three years of each regime in the bunching estimation, except for the regime before the introduction of VAT. We observe clear bunching around the turnover of 30 million JPY in Panels (b)–(d), which corresponds to the time that the VAT exemption threshold was introduced at 30 million JPY. We find a round number bunching in these figures. These distributions have many points for which we observe mass. This phenomenon is partly due to the use of the Census of Manufacture rather than tax administrative data. The information in the census surveys is from the responses of firms in the questionnaire and is highly prone to rounding bias. In contrast, tax administrative data provide the exact levels of the total taxable sales, total input costs, and the amount of VAT paid. We also categorize the sample into firms and sole proprietors in Figures A1 and A2. Although the shape of the distribution differs from each other, we observe clear bunching around 30 million JPY in both figures after the introduction of the VAT exemption threshold, decreasing the bunching size after the reduction of the threshold.

5.2 Bunching Estimation

We show the bunching estimates, $\hat{b}(y^*)$ in equation (6)) and $\hat{b}_U(y^*)$ in equation (9). The second and third column in Table 4 describe the estimates of excess bunching $\hat{b}(y^*)$ and their standard errors. The fourth column exhibits the lower bound used for the estimations. The fifth and sixth column present the estimates of the upper bound of excess bunching $\hat{b}_U(y^*)$ and their standard errors, following the "convergence method" in the study of Kleven and Waseem (2013). The table has five rows, corresponding to a different tax regime.

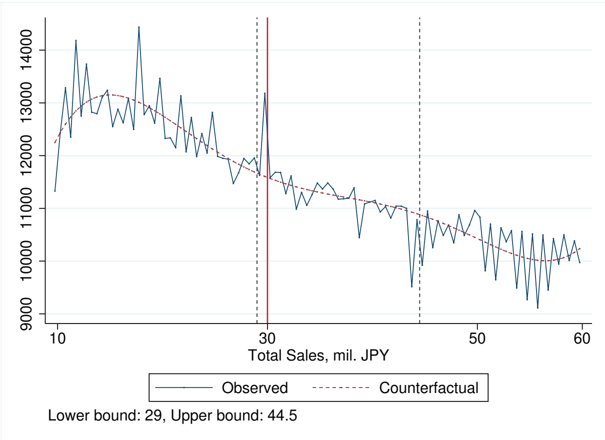
Since the introduction of VAT, the bunching estimate has increased after the tax regime changed, which is as expected. However, it decreased in 2004–2006. We assume that this phenomenon is triggered by the substantial reduction of the exemption threshold from 30 to 10 million JPY starting from April 2004, of which the base period starts from April 2002 (as explained in Section 2.1). Figure 5 confirms this effect, describing the estimates of excess bunching $\hat{b}(y^*)$ for each sample year. The excess bunching size increased around 1989—the year of the VAT introduction.

The VAT rate hike and the abolition of the MDS in 1997 did not trigger an increase in the size of excess bunching. The bunching size sharply decreased after 2004, when the threshold was reduced. The excess bunching size further decreased gradually after 2004, which reflects the extended period for production adjustment in certain industries.[15]

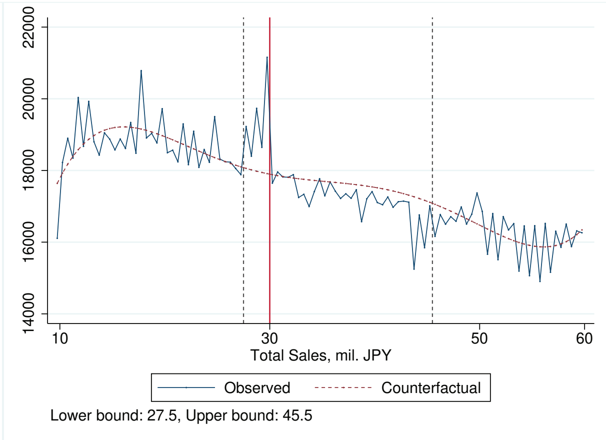
Table 5 presents the estimates for firms and sole proprietors separately, indicating larger estimates for sole proprietors than for firms. The yearly trend of bunching size is qualitatively

[15]Note that the sharp bunching in panel (e) does not mean that there was larger bunching after 2004 because panels in Figure 4 have different y-scale. As we showed in Table 4 and Figure 5, the bunching size after 2004 was indeed smaller compared to that in earlier years.

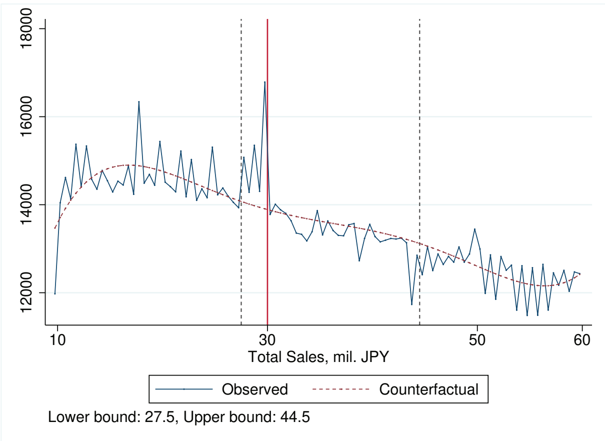
Figure 4. *Size of Excess Bunching for Each VAT Regime*



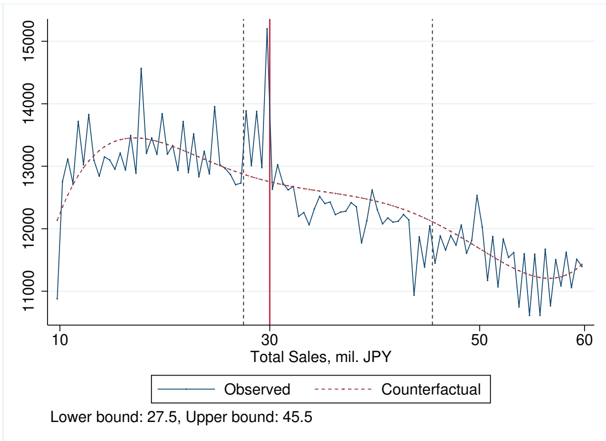
(a) Year: 1986 - 1987



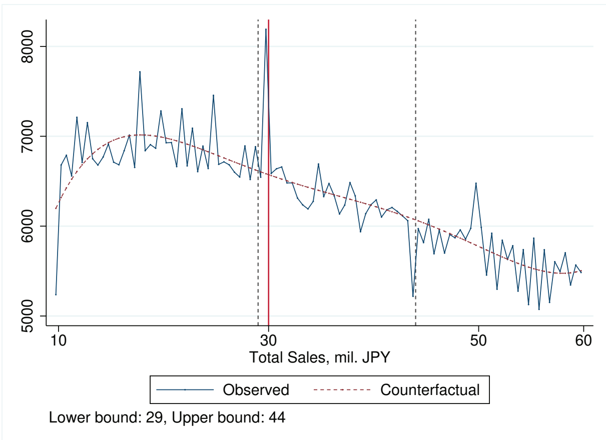
(b) Year: 1989 - 1991



(c) Year: 1992 - 1994



(d) Year: 1997 - 1999



(e) Year: 2004 - 2006

Notes: We dealt with round number bunching in our estimation procedure but it is not presented here.

the same in both cases, and the nonlinear change in bunching estimates is also apparent in this case.

In summary, the observation of these estimates with several VAT reforms in Japan implies that firms respond more to an increase in both the tax burden and compliance costs (i.e., VAT introduction in 1989 and reduction of the VAT exemption threshold in 2004) rather than just an increase in their tax burden only (i.e., 1992 and 1997 reforms of statutory VAT rate and MDS), suggesting that firms are more sensitive to tax compliance costs than tax burden.

Table 4. *Size of Excess Bunching*

Year	Excess bunching	SE	Lower bound	Upper bound of Excess bunching	SE
1986-1987	0.426	0.117	29.0	13.458	6.676
1989-1991	1.397	0.227	27.5	16.498	3.793
1992-1994	1.243	0.237	27.5	16.277	4.594
1997-1999	1.212	0.208	27.5	16.261	4.211
2004-2006	0.495	0.100	29.0	14.693	5.779

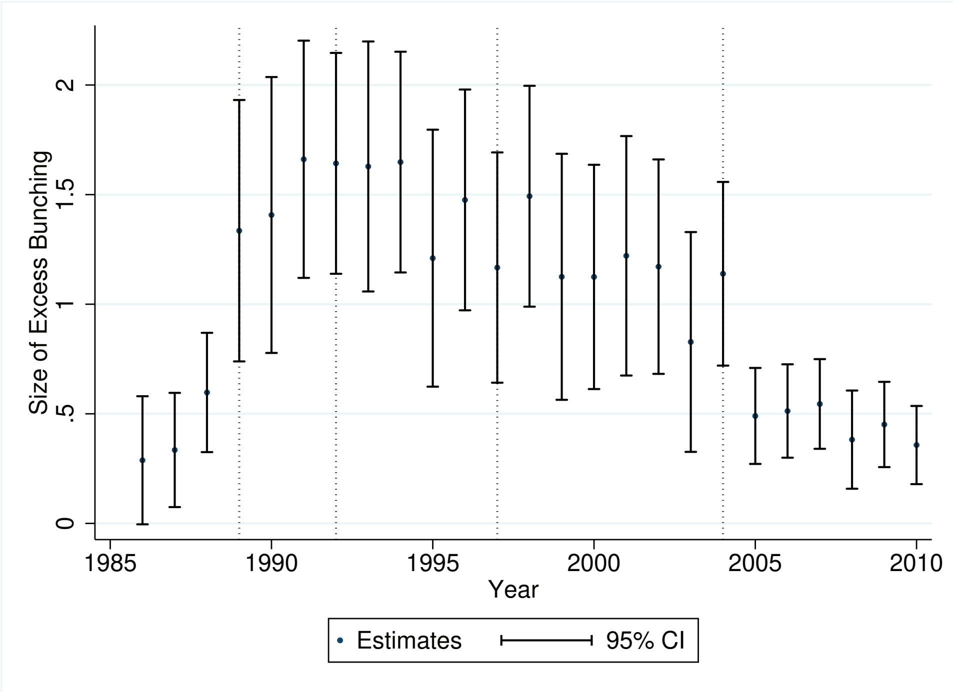
Notes: (i) "Year" refers to the sampling period of the bunching estimates for each row. (ii) "SE" refers to standard error. (iii) "Upper bound" and "Lower bound" refers to upper and lower bounds of the excess bunching window, respectively. (iv) "Excess bunching" corresponds to the estimates of Equation (6), and "Upper bound of Excess bunching" corresponds to the estimates of Equation (9).

5.3 Numerical Estimation

Third, we conduct a numerical estimation to obtain tax elasticity (e) and the parameter of compliance cost (θ) using Equations (1)–(3). From the data, we obtain the values of α, t^A, t^B, t^C, t^B_{1992}, t^C_{1992}, t^D, and t^E. From the bunching estimation in Section 5.2, we obtain the estimates of $\Delta y^*/y^* = 55.0\%$, $\Delta y^*_{1992}/y^* = 54.3\%$ and $\Delta y^*_{1997}/y^* = 54.2\%$, with standard errors 0.13, 0.15, and 0.14 respectively. With these values, we can numerically estimate tax elasticity (e) and compliance costs (θ) using Equations (1) and (2) and Equations (2) and (3), respectively. Table 6 summarizes the result. Panel A in Table 6 presents the estimation result when input cost shares $\alpha = 0.65$[16]. Columns (1) and (2) present the estimates of elasticity (e) and compliance costs (θ) obtained by simultaneously solving Equations (1) and (2), which corresponds to the periods before and after the 1992 reform, respectively.

[16]Based on the "Survey of Taxable Purchase Rate for Fiscal Year 2008" conducted by Ministry of Finance in Japan, the manufacturers' average taxable purchase rate is 62.9%. In addition, according to a survey by the Board of Audit of Japan in which the sample contains only those applying for the STS, the taxable purchase rate for firms in the category that includes manufacturers is 60.5%, and it is 64.5% for sole proprietors.

Figure 5. *Size of Excess Bunching from 1986 to 2010*



Notes: Short-dash lines refer to years of VAT reforms, and dotted lines refer to the base period of the VAT introduction.

Columns (3) and (4) present the estimates obtained from Equations (2) and (3), which corresponds to the regimes before and after the 1997 reform, respectively. In the 1992 and 1997 reforms, we observe similar elasticity and compliance cost estimates. The first and second columns present the estimates of elasticity (e) and compliance costs (θ) obtained by simultaneously solving Equations (1) and (2), which corresponds to the period before and after the 1992 reform, respectively. The third and fourth columns present the estimates obtained from solving (2) and (3), which correspond to the regime before and after the 1997 reform, respectively. In both the 1992 and 1997 reforms, we observe similar estimates of tax elasticity and compliance costs. The values of e and θ are approximately 0.08 and 0.13, respectively. The values are rather stable against the change of input cost share α, as shown in Table A4.

The compliance cost estimates are more than three times larger than the tax rate because, during this period, Japan's VAT rate was from 3% to 5%. This size of the compliance cost indicates that Japan's VAT compliance cost is relatively higher than the tax burden. For example, if we assume that an enterprise produces 30 million JPY taxable sales and its input cost percentage of taxable sales is 65%, then its compliance cost equation is Value Added $\times$

Table 5. *Size of Excess Bunching: Firms and Sole Proprietors*

Panel A: Firms

Year	Excess bunching	SE	Lower bound	Upper bound of Excess bunching	SE
1986–1987	0.238	0.074	29.0	9.080	6.411
1989–1991	0.942	0.177	27.5	14.577	4.140
1992–1994	0.857	0.153	27.5	14.596	4.202
1997–1999	0.880	0.163	27.5	14.624	4.615
2004–2006	0.449	0.090	29.0	11.827	5.762

Panel B: Sole Proprietors

Year	Excess bunching	SE	Lower bound	Upper bound of Excess bunching	SE
1986–1987	0.722	0.249	29.0	13.862	7.586
1989–1991	1.981	0.541	27.5	17.163	5.573
1992–1994	1.900	0.486	27.5	15.603	6.163
1997–1999	1.895	0.544	27.5	16.553	5.928
2004–2006	0.675	0.250	29.0	13.818	7.814

Notes: (i) SE refers to standard error. (ii) Upper bound and Lower bound refers to upper and lower bounds of the excess bunching window, respectively. (iii) Excess bunching corresponds to the estimates of Equation (6), and Upper bound of Excess bunching corresponds to the estimates of Equation (9).

$0.13 = 30 \times (1 - 0.65) \times 0.13 = 1.365$ million JPY. This value is relatively high for small enterprises. We can interpret the magnitude of this estimate if we view it as a new cost faced by businesses that have never paid VAT. When a tax-exempt business becomes a tax-paying business, it incurs accounting software costs to calculate VAT, new hiring costs for tax purposes, additional tax attorney fees, etc. In addition, businesses that have no experience paying VAT may overestimate their tax compliance costs.

We split the sample by organization type, that is, firms and sole proprietors, and perform the same operation. Panels B and C of Table 6 present the results. Panel B and C present the estimates of tax elasticity e and compliance costs θ for firms and sole proprietors, respectively. On average, in the 1992 and 1997 reforms, the compliance costs are higher for sole proprietors than for firms. In contrast, the elasticity estimates are higher for firms than sole proprietors, although they are statistically insignificant. The larger size of compliance costs (relative to value added) of sole proprietors than firms is attributable to their smaller average number of workers compared with those of firms. Similarly, Panel A confirms that the values are stable against changes in input cost shares α, as shown in Table A5 and A6.

After setting $\theta = 0$ and estimating the model, we obtained the tax elasticity estimates of 7.524, 4.880, and 1.408 for each tax regime, as shown in Table A7. These values are substantially larger than the estimates of the compliance cost parameter. This finding supports our earlier argument that enterprises' responses are mainly due to compliance costs. These are

Table 6. *Tax Elasticity and Compliance Costs*

1992 reform		1997 reform	
Elasticity (e)	Compliance Cost (θ)	Elasticity (e)	Compliance Cost (θ)
Panel A: All			
0.080	0.146	0.081	0.113
(0.107)	(0.045)	(0.182)	(0.020)
Panel B: Firms			
0.391	0.091	0.263	0.111
(0.264)	(0.036)	(0.229)	(0.055)
Panel C: Sole proprietors			
0.054	0.116	0.047	0.130
(0.164)	(0.018)	(0.096)	(0.037)

Notes: (i) The column of 1992 reform presents the estimates of tax elasticity and compliance costs calculated from the excess mass in year 1989-1991 and in 1992-1994. (ii) The column of 1997 reform shows those results in 1992–1994 and 1997–1999. (iii) The numbers in the parentheses are standard errors. (iv) The input cost share α is set at 0.65. (v) The values of the tax elasticity and compliance costs that do not converge in the estimation are excluded from the results.

novel findings in the literature about estimating tax elasticity and compliance costs using Japanese data.

5.4 Robustness check

We conducted two robustness checks. The first is the estimation under the STS, as discussed in Section 2.2. The STS has been introduced in the Japanese VAT, and enterprises with taxable sales below a certain threshold can select this system. Our data do not allow us to distinguish whether enterprises use the original VAT system or the STS. The baseline analysis assumes that the original VAT system applies to all taxable enterprises near the exemption threshold. In this robustness check, the model assumes that all taxable enterprises near the threshold use the STS[17]. The estimation results in Table A8 indicate that the compliance cost estimates are mostly invariant from the baseline results of the 1992 and 1997 reforms. In contrast, the elasticity estimates are different from the baseline results but not statistically significant. Thus, we can argue that we have obtained consistent results.

The second robustness check considers the different degrees of VAT pass-through. In the baseline model, we assume a situation where enterprises cannot pass on their VAT to their

[17]The details of the derivation are presented in Appendix C.

selling prices. However, in practice, enterprises, including small ones, may pass through the tax partially, if not completely[18]. Benedek et al. (2020) analyzed changes in the consumer price index relative to the VAT reform in the EU and found that the pass-through rate for the standard tax rate is close to 100%, whereas it is not so for the reduced tax rate. Their result about the standard tax rate is informative in our analysis. This is because, during the analysis period, VAT was uniformly imposed in Japan, except for a limited number of goods. However, we need to be cautious because of the following two reasons. First, Japanese economy has higher price rigidity than EU economy, and this can result in a lower pass-through rate. Second, our sample includes only manufacturers that mainly engage in business-to-business transactions, where the pass-through rate is different from that of business-to-consumer transactions.

Therefore, we construct a model that allows for partial pass-through[19]. Denoting the degree of pass-through as β, we check whether the estimates are stable or not. Table A9 presents the estimates of different values of β, from the case of zero pass-through, ($\beta = 0$), to complete pass-through ($\beta = 1$). Although the degree of pass-through (β) varies, the estimated compliance costs do not change significantly. This finding suggests that the size of our compliance costs is quite robust to pass-through.

6 Conclusion

As evidence to uncover the underlying mechanisms for enterprises' responses to size-dependent tax regulations is limited, we build on the theoretical model in the study of Harju et al.'s (2019) and extend it to incorporate various universally applicable tax reforms. Then, we used a panel of the Japanese Census of Manufacture covering the period of the VAT introduction and reforms to provide novel evidence of measuring compliance costs and the effects of tax rates in Japan. Our main findings and contributions are as follows. (1) Following the existing literature, we observed clear bunching below the tax threshold and (2) generated excess bunching estimates. (3) We find that the bunching estimates are persistently larger for sole proprietors than for firms. (4) We apply the theoretical implications to estimate tax elasticity and compliance costs and find that compliance costs are dominant in determining

[18]The Japan Finance Corporation, a government-affiliated financial institution, provides evidence of partial pass-through. The institution periodically conducts a "Survey of Small Business Trends," which covers small businesses with less than 30 employees. In the survey conducted in December 1997, firms were asked about the extent that they have been able to pass on the tax rate increase imposed in the 1997 reform. Of the 1,956 manufacturers surveyed, 67.1% responded; 61.2% were able to pass on all of the tax increase to their selling prices; 21.3% were able to pass on part of the increase, and 17.5% were unable to pass on any of the increase. Thus, on average, in 1997, at least, manufacturers were able to pass on about 60% to 80% of the price increase.

[19]The details of the derivation are presented in Appendix D.

enterprise responses. This finding is consistent with that of Harju et al. (2019). This study is the first to estimate excess bunching and compliance costs over time using Japanese data and obtained substantially significant estimates. The policy implication of this study is that easing compliance costs can be more effective support for small enterprises rather than reducing tax rate/burden.

7 Reference

1. Abe, T., Hitomi, K., Konishi, Y., Tomita, H., and Uchino, T. 2012. A new converter for establishments from Japan's census of manufactures: 1993-2009 (written in Japanese). *RIETI Policy discussion papers, Research Institute of Economy, Trade and Industry*, 12-P-007.

2. Aghion, P., Akcigit, U., Lequien, M., and Stantcheva, S. 2017. Tax simplicity and heterogeneous learning. *NBER Working Paper*, w24049. SSRN Electronic Journal.

3. Aghion, P., Bergeaud, A., and Van Reenen, J. 2021. The impact of regulation on innovation. *Centre for Economic Performance Working Paper*, No.1744.

4. Benedek, D., De Mooij, R. A., Keen, M., and Wingender, P. 2020. Varieties of VAT pass through. *International Tax and Public Finance*, 27(4), 890-930.

5. Benzarti, Youssef. 2020. How Taxing Is Tax Filing? Using Revealed Preferences to Estimate Compliance Costs. *American Economic Journal: Economic Policy*, 12(4), 38-57.

6. Best, M. C., Brockmeyer, A., Kleven, H. J., Spinnewijn, J., and Waseem, M. 2015. Production versus revenue efficiency with limited tax capacity: Theory and evidence from Pakistan. *Journal of Political Economy*, 123(6), 1311–1355.

7. Boonzaaier, W., Harju, J., Matikka, T., and Pirttil, J. 2019. How do small firms respond to tax schedule discontinuities? Evidence from South African tax registers. *International Tax and Public Finance*, 26(5), 1104-1136.

8. Chetty, R., Friedman, J. N., Olsen, T., and Pistaferri, L. 2011. Adjustment costs, firm responses, and micro vs. macro labor supply elasticities: Evidence from Danish tax records. *Quarterly journal of economics*, 126(2), 749-804.

9. De Paula, ., and Scheinkman, J. A. 2010. Value-added taxes, chain effects, and informality. *American Economic Journal: Macroeconomics*, 2(4), 195-221.

10. Gadenne, L., Nandi, T. K., and Rathelot, R. 2019. Taxation and supplier networks: Evidence from India. *IFS Working Papers*, No. W19/21.

11. Garicano, L., LeLarge, C., and Van Reenen, J. 2016. Firm size distortions and the productivity distribution: Evidence from France. *American Economic Review*, 106(11), 3439–3479.

12. Hansford, A., and Hasseldine, J. 2012. Tax compliance costs for small and medium sized enterprises: The case of the UK. *EJournal of Tax Research* 10, 288.

13. Harju, J., Matikka, T., and Rauhanen, T. 2019. Compliance costs vs. tax incentives: Why do entrepreneurs respond to size-based regulations?. *Journal of Public Economics*, 173, 139-164.

14. Hosono, K., Hotei, M., and Miyakawa, D. 2019. Size-dependent VAT, compliance costs, and firm growth. *RIETI Discussion Papers, Research Institute of Economy, Trade and Industry*, 19-E-041.

15. Ichikawa, T., Arudchelvan, M., and Onji, K. Forthcoming. Bunching of small businesses at the value-added tax threshold in Japan: Lessons for the 2019 tax hike. *Nihon Keizai Kenkyu* (written in Japanese).

16. Kleven, H. J., and Waseem, M. 2013. Using notches to uncover optimization frictions and structural elasticities: Theory and evidence from Pakistan. *Quarterly Journal of Economics*, 128(2), 669–723.

17. Liu, L., Lockwood, B., Almunia, M., and Tam, E. H. F. 2021. VAT notches, voluntary registration, and bunching: Theory and UK evidence. *Review of Economics and Statistics*, 103(1), 151-164.

18. Onji, K. 2009. The response of firms to eligibility thresholds: Evidence from the Japanese value-added tax. *Journal of Public Economics*, 93(5-6), 766-775.

19. Shimpo, K., Takahashi, M., and Omori, T. 2005. Creation of panel data from the census of manufacturers: A component of the industrial structure database (written in Japanese). *RIETI Policy Discussion Papers, Research Institute of Economy, Trade and Industry*, 05-P-001.

20. EC-KPMG. 2018. Study on Tax Compliance Costs for SMEs: Final Report. Luxembourg : Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/0ed32649-fe8e-11e8-a96d-01aa75ed71a1

A Appendix A: Tables and Figures

Table A1. *Sample Distribution by Establishment Types*

Year	Single & Same Place	Single & Different Place	Others	Total
1986	333,167	42,680	60,162	436,009
1989	315,985	42,856	62,916	421,757
1992	302,103	44,255	68,754	415,112
1995	281,211	42,839	63,676	387,726
1998	268,084	44,210	61,419	373,713
2001	225,599	37,664	53,004	316,267
2004	190,913	32,379	47,613	270,905
2007	176,285	32,671	49,276	258,232
2010	151,337	28,233	44,833	224,403
Total	6,266,964	968,785	1,423,289	8,659,038

Notes: (i) “Single & Same Place” refers to firms that have a single manufacturing plant and their plant is located at the same place as their headquarters. “Single & Different Place” refers to firms that have single manufacturing plant and their plant is locating at different place as their headquarters. (ii) The table only list the numbers every three years starting 1986, and skip listing them in years between.
Source: Census Survey of Manufactures (1986–2010)

Table A2. *Summary Statistics from 1986 to 2006*

Variables	Mean	Median	SD	Min	Max
Total Sales	248.07	63.46	9.35	1.80	18,525.06
Process Sales	27.71	0.00	1.01	0.00	1,762.29
Repairment Sales	0.58	0.00	0.07	0.00	165.51
Manufacturing Sales	217.88	40.00	9.14	0.00	18,170.52
Firm Size	15.49	8.00	30.54	4.00	499.00
Total Wage	51.91	21.39	1.36	0.00	2,465.91
Value Added	58.98	13.95	2.31	–214.44	4,548.21
Capital	10.13	3.00	0.47	0.00	1,135.46
Amount of VAT	1.66	0.00	0.08	–0.56	153.65
Input Cost	133.30	21.55	5.97	0.05	12,032.06
Input Cost Ratio	0.39	0.38	0.22	0.00	1.00

Notes: (i) The number of observation is 5,597,435. The sample only includes establishments that have the same address as their headquarters and no other establishments. (ii) The unit price is in million JPY. We pool all the sample years and winsorize the variables at 0.1% and 99.9%. (iii) Until 2007, the definition of "Total Sales" was the sum of "Manufacturing Sales," "Process Sales," and "Repairment Sales." However, in 2007, the definition changed to the sum of "Manufacturing Sales," "Process sales," and "Other Sales." (iv) "Firm Size" is defined as the number of employees. "Value Added" is defined as "Total sales" minus the sum of "Input Cost" and "Amount of VAT." "Input-Cost Ratio" is defined as dividing "Input Cost" by "Total Sales," and we are excluding observations that exceed one.
Source: Census Survey of Manufactures (1986–2006)

Table A3. *Summary Statistics from 2007 to 2010*

Variables	Mean	Median	SD	Min	Max
Total Sales	326.03	74.00	12.00	1.80	18525.06
Process Sales	30.34	0.00	1.16	0.00	1762.29
Repairment Sales	0.78	0.00	0.09	0.00	165.51
Manufacturing Sales	279.23	47.67	11.38	0.00	18170.52
Other Sales	11.67	0.00	0.99	0.00	2082.02
Firm Size	18.01	8.00	35.77	4.00	499.00
Total Wage	62.80	24.31	1.63	0.00	2465.91
Value Added	75.25	16.01	2.85	–214.44	4548.21
Capital	15.58	8.00	0.62	0.00	1135.46
Input Cost	183.46	26.48	7.83	0.05	12032.06
Input-Cost Ratio	0.38	0.40	0.22	0.00	1.00

Notes: (i) The number of observation is 669,529. The sample only includes establishments that have the same address as their headquarters and no other establishments. (ii) The unit price is in million JPY. We pool all the sample years and winsorize the variables at 0.1% and 99.9%. (iii) Until 2007, the definition of "Total Sales" was the sum of "Manufacturing Sales," "Process Sales," and "Repairment Sales." However, in 2007, the definition changed to the sum of "Manufacturing Sales," "Process sales," and "Other Sales." (iv) "Firm Size" is defined as the number of employees. "Value Added" is defined as "Total sales" minus the sum of "Input Cost" and "Amount of VAT." "Input-Cost Ratio" is defined as dividing "Input Cost" by "Total Sales," and we are excluding observations that exceed one. (v) Since we cannot obtain a variable of "Amount of VAT" after 2001, we do not list it.
Source: Census Survey of Manufactures (2007–2010)

Table A4. Tax Elasticity and Compliance Costs

	1992 reform		1997 reform	
Input Cost Share (α)	Elasticity (e)	Compliance Cost (θ)	Elasticity (e)	Compliance Cost (θ)
0.5	0.070	0.116	0.097	0.141
	(0.157)	(0.015)	(0.132)	(0.047)
0.55	0.067	0.151	0.076	0.114
	(0.080)	(0.047)	(0.171)	(0.018)
0.6	0.071	0.115	0.104	0.137
	(0.161)	(0.016)	(0.147)	(0.044)
0.65	0.080	0.146	0.081	0.113
	(0.107)	(0.045)	(0.182)	(0.020)
0.7	0.073	0.115	0.094	0.135
	(0.165)	(0.017)	(0.111)	(0.037)

Notes: (i) The column of 1992 reform indicates the estimates of elasticity and compliance costs calculated from the excess mass in year 1989–1991 and 1992–1994. (ii) The column of 1997 reform presents the results for 1992–1994 and 1997–1999. (iii) The numbers in the parentheses are standard errors.

Table A5. Tax Elasticity and Compliance Costs: Firms

	1992 reform		1997 reform	
Input Cost Share (α)	Elasticity (e)	Compliance Cost (θ)	Elasticity (e)	Compliance Cost (θ)
0.5	0.369	0.098	0.184	0.149
	(0.277)	(0.033)	(0.262)	(0.045)
0.55	0.374	0.097	0.200	0.137
	(0.275)	(0.037)	(0.208)	(0.047)
0.6	0.381	0.094	0.232	0.123
	(0.267)	(0.036)	(0.232)	(0.053)
0.65	0.391	0.091	0.263	0.111
	(0.264)	(0.036)	(0.229)	(0.055)
0.7	0.409	0.087	0.139	0.134
	(0.252)	(0.037)	(0.128)	(0.049)

Notes: (i) The column of 1992 reform indicates the estimates of elasticity and compliance costs calculated from the excess mass in year 1989–1991 and 1992–1994. (ii) The column of 1997 reform presents the results for 1992–1994 and 1997–1999. (iii) The numbers in the parentheses are standard errors.

Table A6. *Tax Elasticity and Compliance Costs: Sole proprietors*

	1992 reform		1997 reform	
Input Cost Share (α)	Elasticity (e)	Compliance Cost (θ)	Elasticity (e)	Compliance Cost (θ)
0.5	0.054	0.116	0.046	0.132
	(0.174)	(0.016)	(0.153)	(0.043)
0.55	0.054	0.116	0.048	0.130
	(0.175)	(0.016)	(0.111)	(0.041)
0.6	0.054	0.116	0.052	0.131
	(0.170)	(0.016)	(0.127)	(0.044)
0.65	0.054	0.116	0.047	0.130
	(0.164)	(0.018)	(0.096)	(0.037)
0.7	0.057	0.117	0.052	0.128
	(0.169)	(0.029)	(0.102)	(0.038)

Notes: (i) The column of 1992 reform indicates the estimates of elasticity and compliance costs calculated from the excess mass in year 1989–1991 and 1992–1994. (ii) The column of 1997 reform presents the results for 1992–1994 and 1997–1999. (iii) The numbers in the parentheses are standard errors.

Table A7. *Tax Elasticity: When Compliance Costs are Set at Zero*

Tax Regime	Elasticity (e)	Standard Errors
Regime 1: 1989–1991	7.524	1.827
Regime 2: 1992–1994	4.880	1.476
Regime 3: 1997–1999	1.408	0.544

Notes: The column of Elasticity presents the estimates of tax elasticity when compliance costs are equal to zero.

Table A8. *Simplified Tax: Tax Elasticity and Compliance Costs*

1992 reform		1997 reform	
Elasticity (e)	Compliance Cost (θ)	Elasticity (e)	Compliance Cost (θ)
1.391	0.131	0.504	0.125
(2.795)	(0.084)	(0.905)	(0.068)

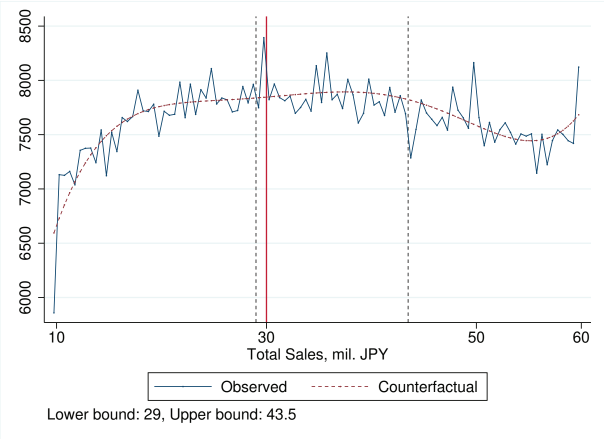
Notes: (i) The column of 1992 reform presents the estimates of tax elasticity and compliance costs calculated from the excess mass in 1989–1991 and 1992–1994. (ii) The column of 1997 reform presents the results for 1992–1994 and 1997–1999. (iii) The numbers in parentheses are standard errors. (iv) The input-cost share α is set at 0.65. (v) The values of the tax elasticity and compliance costs that did not converge in the estimation are excluded from the results.

Table A9. *Pass-through: Tax Elasticity and Compliance Costs with* $\alpha = 0.65$

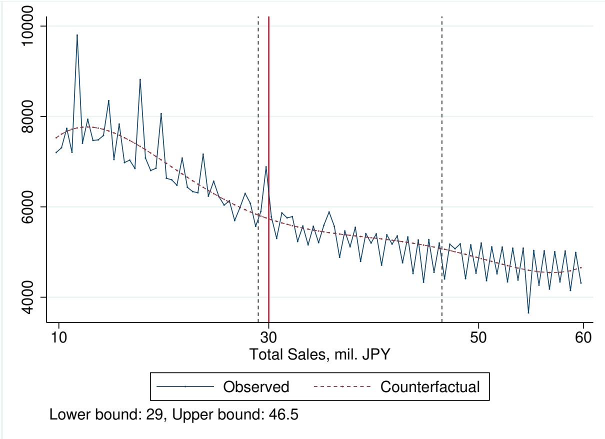
	Pass-through ratio (β)					
	0	0.2	0.4	0.6	0.8	1
1992 reform						
Elasticity	0.028	0.027	0.026	0.026	0.025	0.025
	(0.067)	(0.062)	(0.058)	(0.057)	(0.057)	(0.057)
Compliance Cost	0.130	0.132	0.133	0.134	0.135	0.136
	(0.027)	(0.028)	(0.03)	(0.032)	(0.033)	(0.034)
1997 reform						
Elasticity	0.073	0.059	0.051	0.030	0.101	0.108
	(0.082)	(0.07)	(0.059)	(0.037)	(0.233)	(0.234)
Compliance Cost	0.140	0.148	0.150	0.157	0.107	0.115
	(0.040)	(0.043)	(0.051)	(0.062)	(0.026)	(0.039)

Notes: (i) The panel of 1992 reform presents the estimates of tax elasticity and compliance costs calculated from the excess mass in 1989–1991 and 1992–1994. (ii) The panel of 1997 reform presents the results for 1992–1994 and 1997–1999. (iii) The numbers in parentheses are standard errors. (iv) The input-cost share α is set at 0.65. (v) We introduce pass-through parameter β so that producer price becomes $(1 + t\beta)$.

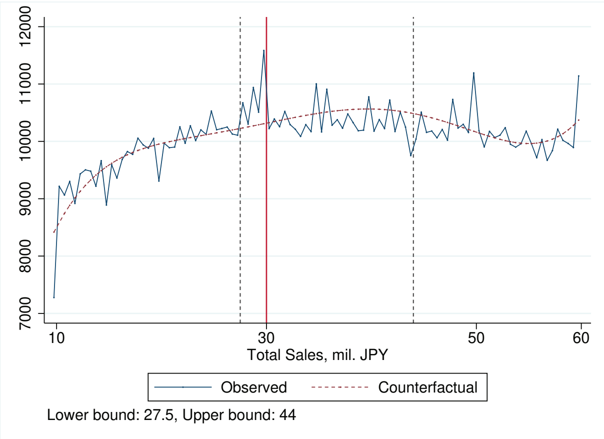
Figure A1. *Size of excess bunching for Firms and Sole Proprietors*



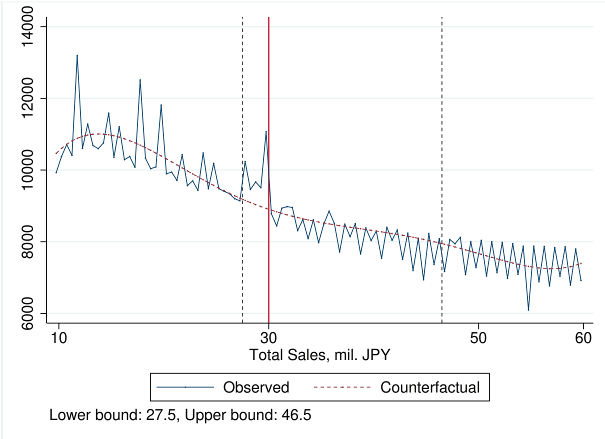
(a) Firms, Year: 1986 - 1987



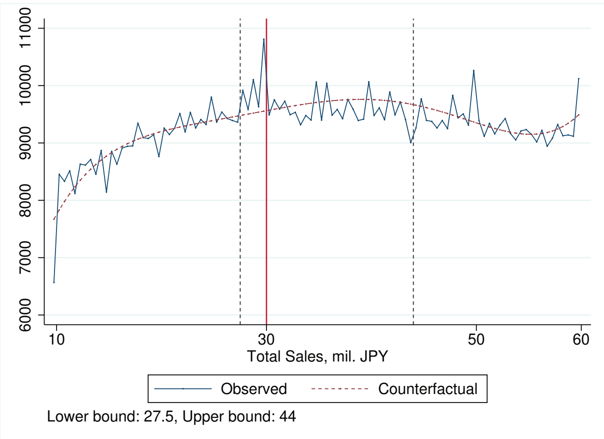
(b) sole proprietors, Year: 1986 - 1987



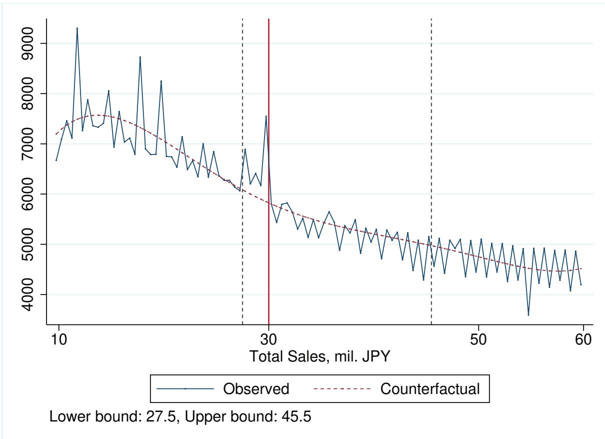
(c) Firms, Year: 1989 - 1991



(d) sole proprietors, Year: 1989 - 1991



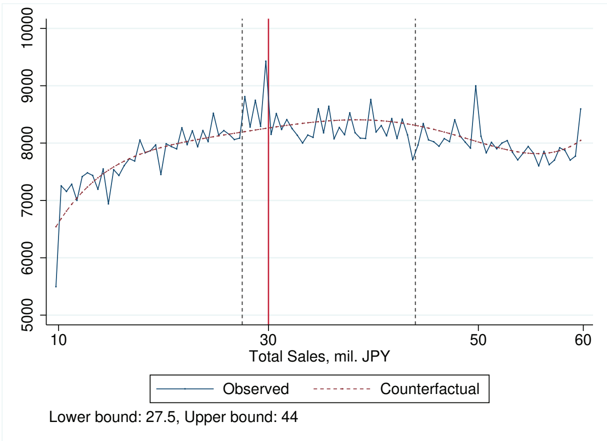
(e) Firms, Year: 1992 - 1994



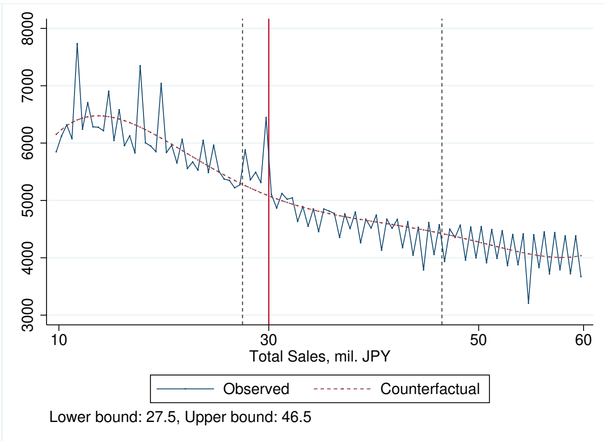
(f) sole proprietors, Year: 1992 - 1994

Notes: We deal with round number bunching in our estimation procedures, but it are not presented here.

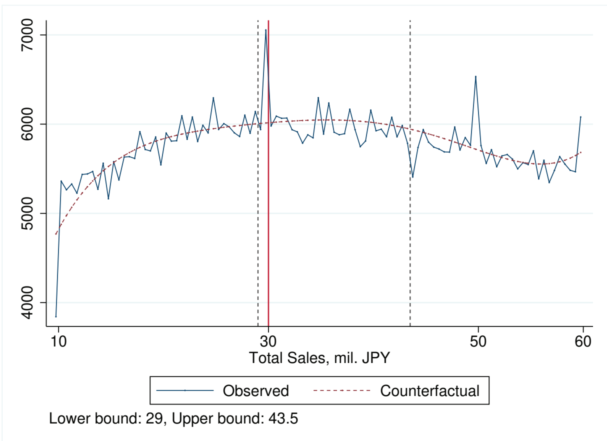
Figure A2. Size of excess bunching for Firms and Sole Proprietors, Cont'd



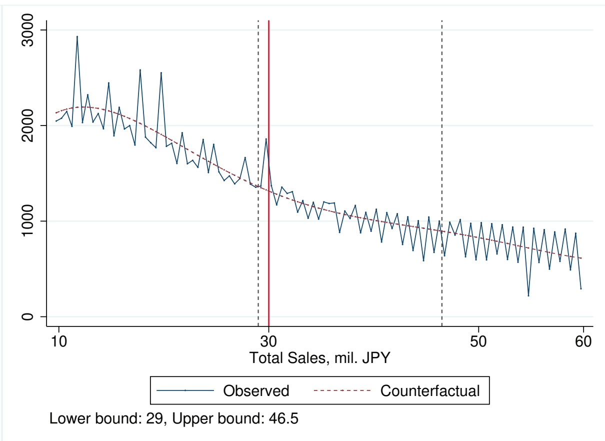
(a) Firms, Year: 1997 - 1999



(b) sole proprietors, Year: 1997 - 1999



(c) Firms, Year: 2004 - 2006



(d) sole proprietors, Year: 2004 - 2006

Notes: We deal with round number bunching in our estimation procedures, but it are not presented here.

B The derivation of owner's objective function under the Marginal Deduction System

For above the threshold (i.e., $y > y^*$), the objective function of the enterprise owner is as follows:

$$\pi(y) = (1-\alpha)y - \frac{y-y^*}{\bar{y}-y^*}\left(\frac{t}{1+t}y - t\alpha y\right) - t\alpha y - \theta(1-\alpha)y - \phi(y)$$

where t is the VAT rate, and $\bar{y}$ is upper bound of the marginal deduction formula, which we discussed in section 2.1. Here, we define $T(y) \equiv \frac{y-y^*}{\bar{y}-y^*}\left(\frac{t}{1+t}y - t\alpha y\right) + t\alpha y$, and derive the following:

$$\begin{aligned} T(y) &= \frac{y-y^*}{\bar{y}-y^*}\left(\frac{t}{1+t}y - t\alpha y\right) + t\alpha y \\ &= \frac{1}{\bar{y}-y^*}\left[\frac{t}{1+t} - t\alpha\right]y^2 + \left[\frac{-y^*}{\bar{y}-y^*}\left(\frac{t}{1+t} - t\alpha\right) + t\alpha\right]y \\ &= \frac{1}{\bar{y}-y^*}\left(\frac{t}{1+t} - t\alpha\right)y^2 + \left(-\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}}{\bar{y}-y^*}t\alpha\right)y. \end{aligned}$$

We focus on enterprises around the threshold y^* for bunching behavior. To compare profits by bunching and not bunching, we conduct a first-order Taylor approximation of the tax burden function, $T(y)$, around $y = y^*$

$$\begin{aligned} T(y) &\approx T(y^*) + T'(y^*) \times (y - y^*) \\ &= T'(y^*) \times y + [-T'(y^*) \times y^* + T(y^*)] \\ &= \left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right) \times y + \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t} + t\alpha\right). \end{aligned}$$

Substituting $T(y,\alpha)$ into $\pi(y)$ yields, we get

$$\begin{aligned} \pi(y) &\approx (1-\alpha)y - T(y) - \theta(1-\alpha)y - \phi(y) \\ &= (1-\alpha)y - \left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right) \times y - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t} + t\alpha\right) - \theta(1-\alpha)y - \phi(y) \\ &= (1-\alpha)y\left[1 - \frac{1}{1-\alpha}\left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right) - \theta\right] - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t} + t\alpha\right) - \phi(y) \\ &= (1-\alpha)y\left(1 - t^B - \theta\right) - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t}{1+t} + t\alpha\right) - \phi(y). \end{aligned}$$

where $t^B = \frac{1}{1-\alpha}\left(\frac{y^*}{\bar{y}-y^*}\frac{t}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right)$.

C Simplified Tax System

C.1 Derivation of Formula

In this section, we model the Simplified Tax System (STS). Under the STS, the tax authority does not require enterprises to submit information about their input costs but presume that the share of their inputs costs is γ[20]. As the enterprises are not required to submit information about their input costs under the STS, the resulting compliance cost is smaller. We denote the compliance cost under the STS as $\theta^S < \theta$ to differentiate them. The threshold of the STS is denoted as $\tilde{y}$[21].

Then, the objective function is as follows:

$$\pi(y) = \begin{cases} y - \alpha y - \alpha y t - \phi(y) & \text{if } y \leq y^* \\ y\left[\frac{1}{1+t} - (1+t)\alpha + t\gamma\right] - \theta^S(1-\alpha)y - \phi(y) & \text{if } y^* < y \leq \tilde{y} \\ y\left(\frac{1}{1+t} - \alpha\right) - \theta(1-\alpha)y - \phi(y) & \text{if } y > \tilde{y}. \end{cases}$$

Using the following notations for the effective tax rates

$$t^F = \frac{\alpha t}{1-\alpha},\ t^G = 1 - \frac{1}{1-\alpha}\left[\frac{1}{1+t} - (1+t)\alpha + t\gamma\right],\ \text{and } t^H = \frac{t}{(1-\alpha)(1+t)}$$

it can be simplified as

$$\pi(y) = \begin{cases} (1-\alpha)y(1-t^F) - \phi(y) & \text{if } y \leq y^* \\ (1-\alpha)y(1-t^G-\theta^S) - \phi(y) & \text{if } y^* < y \leq \tilde{y} \\ (1-\alpha)y(1-t^H-\theta) - \phi(y) & \text{if } y > \tilde{y}. \end{cases}$$

Then, the formula becomes

$$\frac{1}{1+\frac{\Delta y^*}{y^*}} - \frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e} - \frac{1}{e+1}\left(\frac{1-t^G-\theta^S}{1-t^F}\right)^{1+e} = 0. \qquad (10)$$

Because there are two changes in the tax system, we expect the volume of the bunching to also change, and we use a different subscript in the equation above.

[20] This share differs across industries, as we described in Section 2.

[21] The upper bound of the STS, i.e., $\tilde{y}$, is strictly larger than the upper bound of the MDS, i.e., $\bar{y}$

C.2 Dual System: Marginal Deduction System and Simplified Tax System

In this subsection, we model a case where firms are under both the STS and under the MDS. When the turnover satisfied $y^* < y \leq \tilde{y}$, the objective function becomes

$$\begin{aligned}\pi(y) &= y\left[1-(1+t)\alpha\right] - \frac{y-y^*}{\bar{y}-y^*}\left(\frac{t}{1+t}y - \gamma t y\right) - \theta^S(1-\alpha)y - \phi(y) \\ &\approx (1-\alpha)y\left[1 - \frac{t}{1-\alpha}\left\{\alpha + \frac{y^*}{\bar{y}-y^*}\left(\frac{1}{1+t}-\gamma\right)\right\} - \theta^S\right] + \frac{(y^*)^2}{\bar{y}-y^*}\left(\frac{t}{1+t}-t\gamma\right) - \phi(y).\end{aligned}$$

Using the following notations for the effective tax rates

$$t^F = \frac{\alpha t}{1-\alpha},\ t^I = \frac{t}{1-\alpha}\left\{\alpha + \frac{y^*}{\bar{y}-y^*}\left(\frac{1}{1+t}-\gamma\right)\right\},\ \text{and}\ t^H = \frac{t}{(1-\alpha)(1+t)},$$

it can be simplified as

$$\pi(y) = \begin{cases}(1-\alpha)y(1-t^F) - \phi(y) & \text{if } y \leq y^* \\ (1-\alpha)y(1-t^I-\theta^S) + \frac{(y^*)^2}{\bar{y}-y^*}\left(\frac{t}{1+t}-t\gamma\right) - \phi(y) & \text{if } y^* < y \leq \tilde{y} \\ (1-\alpha)y(1-t^H-\theta) - \phi(y) & \text{if } y > \tilde{y}.\end{cases}$$

Note that we have $t^I = t^B$ when $\gamma = \alpha$.

Then, the formula becomes

$$\frac{1}{1+\frac{\Delta y^*}{y^*}}\left(1-t^J\right) - \frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e} - \frac{1}{e+1}\left(\frac{1-t^I-\theta^S}{1-t^F}\right)^{1+e} = 0 \qquad (11)$$

where we denote $t^J = \frac{y^*}{\bar{y}-y^*}\frac{\frac{t}{1+t}-t\gamma}{(1-\alpha)(1-t^F)}$. Due to the changes in the tax system, we expect the volume of the bunching to also change, and we use a different subscript in the equation above.

D Pass-through

We now assume that producer price of the good is not fixed. Rather, we assume that firms can pass VAT through to some extent, and we denote the extent as β, which means that the producer price becomes $(1 + t\beta)$ rather than 1[22]. When $\beta = 0$, it becomes the same with the benchmark. When $\beta = 1$, firms can perfectly pass through. In other words, the model with $\beta \in [0, 1)$ can describe the world with imperfect pass-through. We investigate how the estimates of elasticity and compliance cost vary with the parameter β.

D.1 Standard Regime

As we explain in section 2.1, there used to be the MDS when the VAT was introduced in Japan. Under the MDS, the effective tax rate increases gradually above the threshold. In other words, it creates a kink in the tax system. For those below the threshold (i.e., $y \leq y^*$), the objective function of the enterprise can be rewritten as follows:

$$\begin{aligned}
\pi(y) &= (1 + t\beta)y - (1 + t)\alpha y - \phi(y) \\
&= [(1 - \alpha) - t(-\beta + \alpha)]y - \phi(y) \\
&= [(1 - \alpha) - t\alpha + t\beta]y - \phi(y) \\
&= (1 - \alpha)y\left(1 - \frac{t\alpha}{1 - \alpha} + \beta\frac{t}{1 - \alpha}\right) - \phi(y) \\
&= (1 - \alpha)y\left(1 - t^A + t^B\beta\right) - \phi(y)
\end{aligned}$$

where t is VAT rate, and

$$t^A = \frac{t\alpha}{1 - \alpha} \text{ and } t^B = \frac{t}{1 - \alpha}$$

are effective tax rates below the threshold.

For those above the threshold (i.e., $y > y^*$), the objective function can be written as

[22] It is allowed by law in Japan that a tax-exempt business sets price tax-inclusive.

follows:

$$
\begin{aligned}
\pi(y) &= (1+t\beta)y - (1+t)\alpha y - \left(\frac{t(1+t\beta)}{1+t}y - t\alpha y\right) - \theta(1-\alpha)y - \phi(y) \\
&= [(1-\alpha) - t(-\beta+\alpha) - \frac{t(1+t\beta)}{1+t} + t\alpha]y - \theta(1-\alpha)y - \phi(y) \\
&= [(1-\alpha) + t\beta - \frac{t(1+t\beta)}{1+t} - \theta(1-\alpha)]y - \phi(y) \\
&= (1-\alpha)y\left(1 - \frac{(1-\beta)t}{(1-\alpha)(1+t)} - \theta\right) - \phi(y) \\
&= (1-\alpha)y(1 - t^E(1-\beta) - \theta) - \phi(y).
\end{aligned}
$$

where

$$
t^E = \frac{t}{(1-\alpha)(1+t)}.
$$

These can be summarized as follows:

$$
\pi(y) = \begin{cases} (1 - t^A + t^B\beta)(1-\alpha)y - \phi(y) & \text{if } y \leq y^* \\ (1 - t^E(1-\beta) - \theta)(1-\alpha)y - \phi(y) & \text{if } y > y^*, \end{cases}
$$

The maximization problem leads to

$$
(1-\alpha)y = \begin{cases} a(1 - t^A + t^B\beta)^e & \text{if } y \leq y^* \\ a(1 - t^E(1-\beta) - \theta)^e & \text{if } y > y^*. \end{cases}
$$

Next, we consider the behaviors of the marginal bunchers whose revenues are equivalent. Marginal bunchers would be indifferent between bunching and not bunching. Through the former, they obtain

$$
\pi_{bunch} = (1 - t^A + t^B\beta)(1-\alpha)y^* - \frac{a^* + \Delta a^*}{1+1/e}\left(\frac{y^*(1-\alpha)}{a^* + \Delta a^*}\right)^{1+1/e}
$$

Through the latter, they obtain

$$
\pi_{not} = (a^* + \Delta a^*)(1 - t^E(1-\beta) - \theta)^{e+1}\left(\frac{1}{e+1}\right)
$$

Marginal bunchers satisfy the following first-order condition when they choose not to bunch: $(1-\alpha)y^* = (a^* + \Delta a^*)(1 - t^E(1-\beta) - \theta)^e$. Moreover, they satisfy the first-order condition when there were no threshold: $(1-\alpha)(y^* + \Delta y^*) = (a^* + \Delta a^*)(1 - t^A + t^B\beta)^e$.

Then, the indifference between bunching and not bunching, i.e., $\pi_{bunch} = \pi_{not}$, leads to the derivation of the following formula:

$$\frac{1}{1+\frac{\Delta y^*}{y^*}} - \frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e} - \frac{1}{e+1}\left(\frac{1-t^E(1-\beta)-\theta}{1-t^A+t^B\beta}\right)^{1+e} = 0 \qquad (12)$$

There are three parameters to be estimated—tax elasticity (e), pass-through parameter (β), and compliance cost θ. The effective tax rates, t^A, t^B, and t^E can be calculated.

D.2 Marginal Deduction System

D.2.1 Derivation of the formula

As we explain in section 2.1, there used to be the MDS when the VAT was introduced in Japan. Under the MDS, the effective tax rate gradually increases above the threshold. Thus, it creates a kink in the tax system. For those below the threshold (i.e., $y \leq y^*$), the objective function of the enterprise can be rewritten as follows:

$$\begin{aligned}
\pi(y) &= (1+t\beta)y - (1+t)\alpha y - \phi(y) \\
&= [(1-\alpha) - t(-\beta+\alpha)]y - \phi(y) \\
&= [(1-\alpha) - t\alpha + t\beta]y - \phi(y) \\
&= (1-\alpha)y\left(1 - \frac{t\alpha}{1-\alpha} + \beta\frac{t}{1-\alpha}\right) - \phi(y) \\
&= (1-\alpha)y\left(1 - t^A + t^B\beta\right) - \phi(y)
\end{aligned}$$

where t is VAT rate, and

$$t^A = \frac{t\alpha}{1-\alpha} \text{ and } t^B = \frac{t}{1-\alpha}$$

is effective tax rates below the threshold.

For those above the threshold (i.e., $y > y^*$), the objective function of the enterprise can be rewritten as follows:

$$\begin{aligned}
\pi(y) &= (1+t\beta)y - (1+t)\alpha y - \left(1 - \frac{\bar{y}-y}{\bar{y}-y^*}\right)\left(\frac{t(1+t\beta)}{1+t}y - t\alpha y\right) - \theta(1-\alpha)y - \phi(y) \\
&\approx (1-\alpha)y\left(1 - t^C + t^B\beta - \theta\right) - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t(1+t\beta)}{1+t} + t\alpha\right) - \phi(y)
\end{aligned}$$

where $\bar{y}$ denotes as the upper bound, $t^C = \frac{1}{1-\alpha}\left(\frac{y^*}{\bar{y}-y^*}\frac{t(1+t\beta)}{1+t} + \frac{\bar{y}-2y^*}{\bar{y}-y^*}t\alpha\right)$ as effective tax rates above the threshold.

These can be summarized as follows:

$$\pi(y) = \begin{cases} (1-\alpha)y\left(1-t^A+t^B\beta\right)-\phi(y) & \text{if } y \le y^* \\ (1-\alpha)y\left(1-t^C+t^B\beta-\theta\right)-\frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t(1+t\beta)}{1+t}+t\alpha\right)-\phi(y) & \text{if } y > y^*, \end{cases}$$

The maximization problem leads to

$$(1-\alpha)y = \begin{cases} a(1-t^A+t^B\beta)^e & \text{if } y \le y^* \\ a(1-t^C+t^B\beta-\theta)^e & \text{if } y > y^*. \end{cases}$$

Next, we consider the behaviors of marginal bunchers whose revenues are equivalent. Marginal bunchers would be indifferent between bunching and no bunching. Through the former, they obtain

$$\pi_{bunch} = (1-t^A+t^B\beta)(1-\alpha)y^* - \frac{a^*+\Delta a^*}{1+1/e}\left(\frac{y^*(1-\alpha)}{a^*+\Delta a^*}\right)^{1+1/e}$$

Through the latter, they obtain

$$\pi_{not} = (a^*+\Delta a^*)(1-t^C+t^B\beta-\theta)^{e+1}\left(\frac{1}{e+1}\right) - \frac{(y^*)^2}{\bar{y}-y^*}\left(-\frac{t(1+t\beta)}{1+t}+t\alpha\right)$$

Marginal bunchers satisfy the following first-order condition when they choose not to bunch: $(1-\alpha)y^* = (a^*+\Delta a^*)(1-t^C+t^B\beta-\theta)^e$. Moreover, they satisfy the first-order condition when there were no threshold: $(1-\alpha)(y^*+\Delta y^*) = (a^*+\Delta a^*)(1-t^A+t^B\beta)^e$.

Then, the indifference between bunching and no bunching leads to the derivation of the following formula:

$$\begin{aligned} & 1-\frac{e}{e+1}\left(1+\frac{\Delta y^*}{y^*}\right)\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e} \\ = \quad & \frac{1}{e+1}\left(\frac{1-t^C+t^B\beta-\theta}{1-t^A+t^B\beta}\right)^{e+1}\left(1+\frac{\Delta y^*}{y^*}\right)-\frac{y^*}{\bar{y}-y^*}\frac{-\frac{t(t+t\beta)}{1+t}+t\alpha}{(1-\alpha)(1-t^A+t^B\beta)} \end{aligned} \tag{13}$$

Arranging terms, we obtain

$$
\begin{aligned}
& \frac{1}{1+\frac{\Delta y^*}{y^*}}\left[1-\frac{y^*}{\bar{y}-y^*}\frac{-t\alpha+\frac{t(t+t\beta)}{1+t}}{(1-\alpha)(1-t^A+t^B\beta)}\right]-\frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e} \\
- & \frac{1}{e+1}\left(\frac{1-t^D+t^B\beta-\theta}{1-t^A+t^B\beta}\right)^{1+e} \\
= & \frac{1}{1+\frac{\Delta y^*}{y^*}}\left(1-t^D\right)-\frac{e}{e+1}\left(\frac{1}{1+\frac{\Delta y^*}{y^*}}\right)^{1+1/e}-\frac{1}{e+1}\left(\frac{1-t^C+t^B\beta-\theta}{1-t^A+t^B\beta}\right)^{1+e} \\
= & 0
\end{aligned}
\tag{14}
$$

where we denote $t^D = \frac{y^*}{\bar{y}-y^*}\frac{-t\alpha+\frac{t(1+t\beta)}{1+t}}{(1-\alpha)(1-t^A+t^B\beta)}$.