

Behavioral Responses to Estate Taxation: Evidence from Taiwan

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- **Increasing** evidence of wealth concentration and inheritance
 - Share of wealth held by the top 0.1% in the U.S. has increased ([Saez and Zucman, 2016](#); [Smith et al., 2023](#))
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 - Over 10 OECD countries abolished estate/inheritance taxes ([OECD, 2018](#))
 - In the U.S., the exemption threshold has increased 12-fold
- Unsettled consensus regarding its **behavioral responses**
 - Estate taxes may impact savings and inequality, but many believe the wealthy avoid
 - Limited empirical evidence due to challenges in data and identification

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- Leverage a tax **increase** and a tax **cut** in Taiwan to exploit variation in levels and directions of tax rate changes
- Use admin data on all **estates** and link them with **wealth** records
- Combine **diff-in-diff** + **machine learning** to tackle identification challenges
- Examine source of response and mechanism
- Model **reversible** and **irreversible** avoidance to explain the asymmetry and clarify which elasticity is relevant for policy

Preview of Findings

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- The patterns are consistent with tax avoidance with sunk costs
- Tax-hike elasticity better reflects the unconstrained long-run response, implying a **21%** rev-maximizing rate (vs. 23% OECD average)

Content

Institutional context & Data

Empirical Strategy & Results

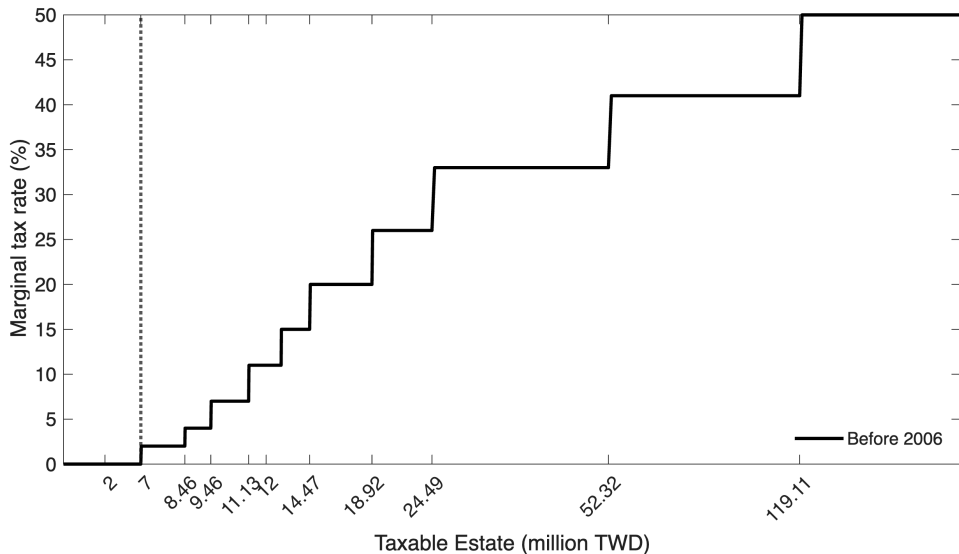
Mechanism

Conclusion

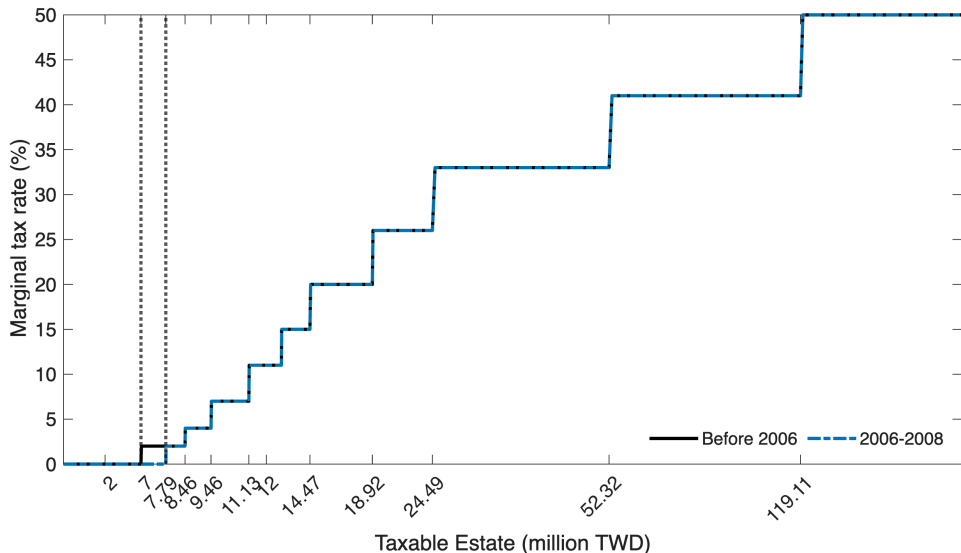
Institutional context: Overview

- In 2022, **mean** wealth per adult in Taiwan is **274K** USD (cf. U.S. 551K, U.K. 303K, Sweden 297K, Germany 256K, South Korea 231K) ([Credit Suisse, 2023](#))
- Estate taxes are levied on **decedents** (like U.S., U.K., South Korea)
- Among annual deaths, **4%** liable for estate taxes (cf. U.S. < 0.1%; U.K. 4%)

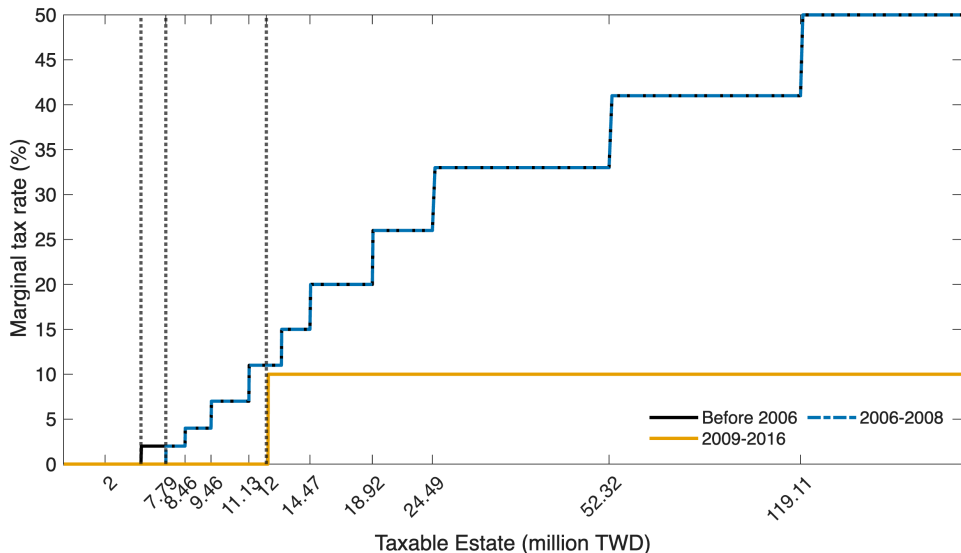
Institutional context: Estate Tax Schedule



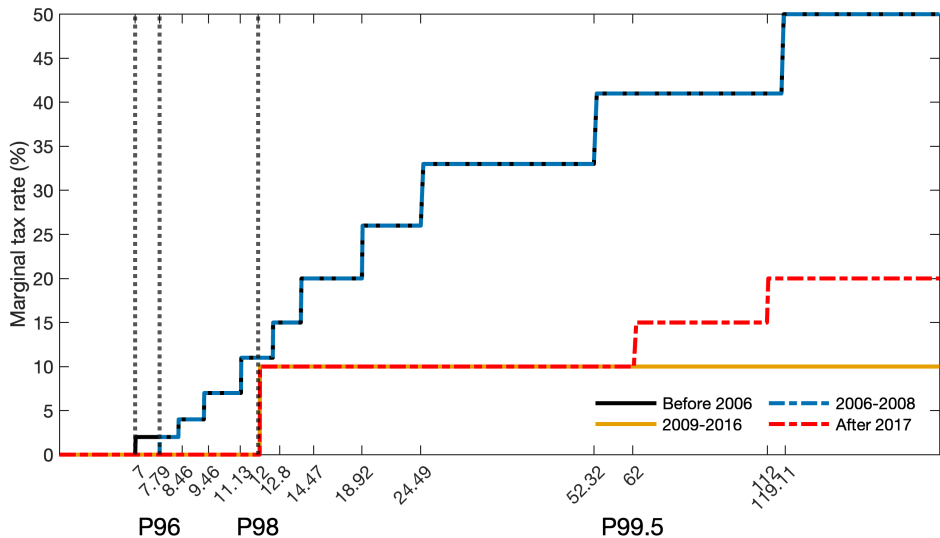
Institutional context: Estate Tax Schedule



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Institutional context: Estate Tax Schedule



Institutional context: Tax Base

Taxable Estate = Assets — Exclusions — Deductions

Assessment

Insurance

Agg Trust

Offshore

Chari Trust

Gift Tax

Two-Year

Penalty

Exclusion

Institutional context: Tax Base

$$\text{Taxable Estate} = \underbrace{\text{Assets}}_{\substack{\text{Housing} \\ + \text{Deposit Savings} \\ + \text{Financial Assets}}} - \text{Exclusions} - \text{Deductions}$$

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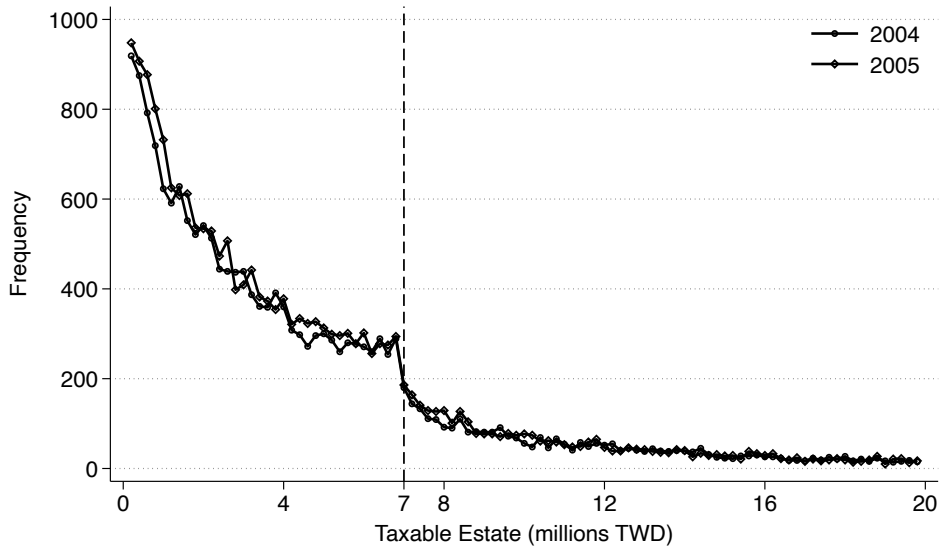
- **Estate records (2004-2019)**

- The universe of estate tax return files
- Death dates, taxable estate and the breakdown of it by item

- **Wealth records (2004-2019)**

- Housing: property ID, quantity, value
- Stocks (publicly-listed and privately-listed): firm ID, quantity, value
- Breakdown of annual income
- Demographics like gender, marital status, birth place, age, kinship info

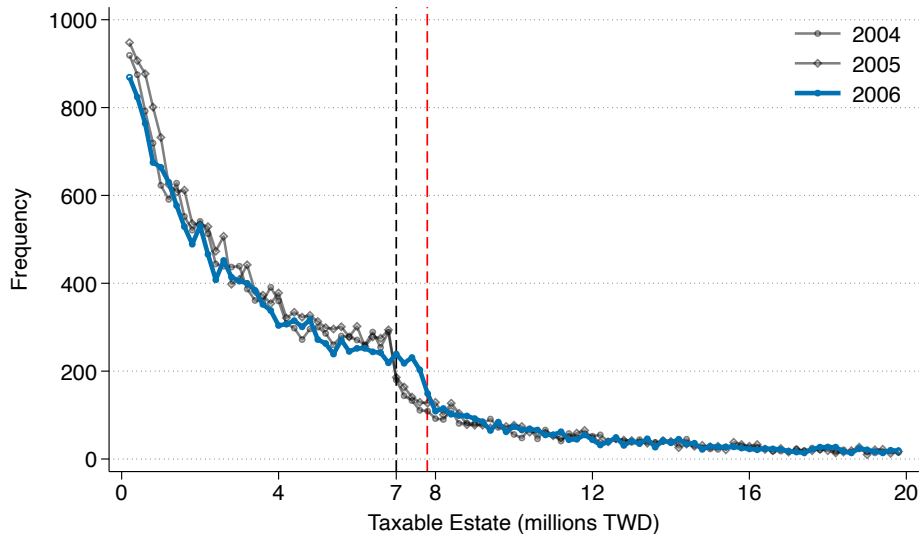
Attentiveness to Exemption Thresholds



Bunching Pure

Bunching Exemp

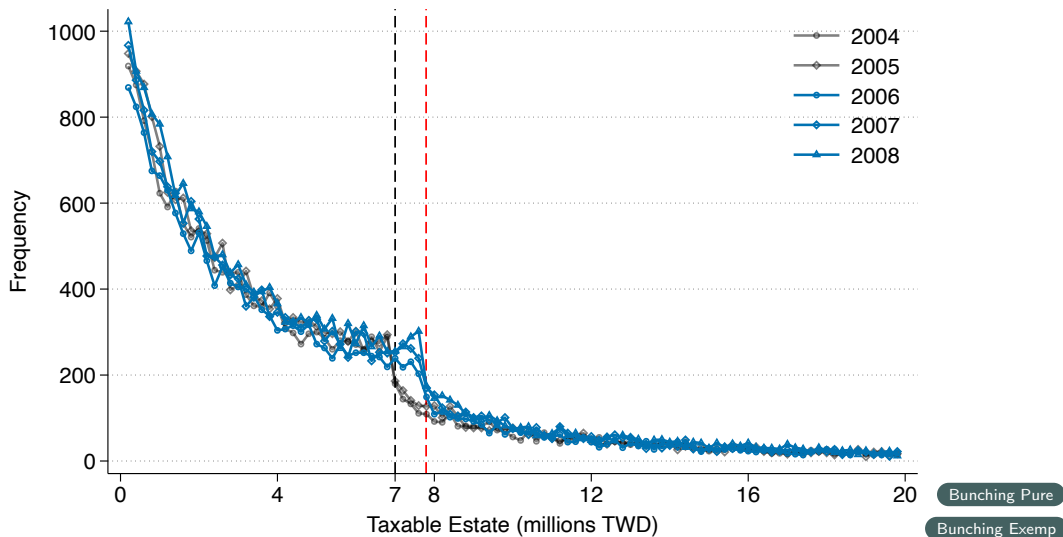
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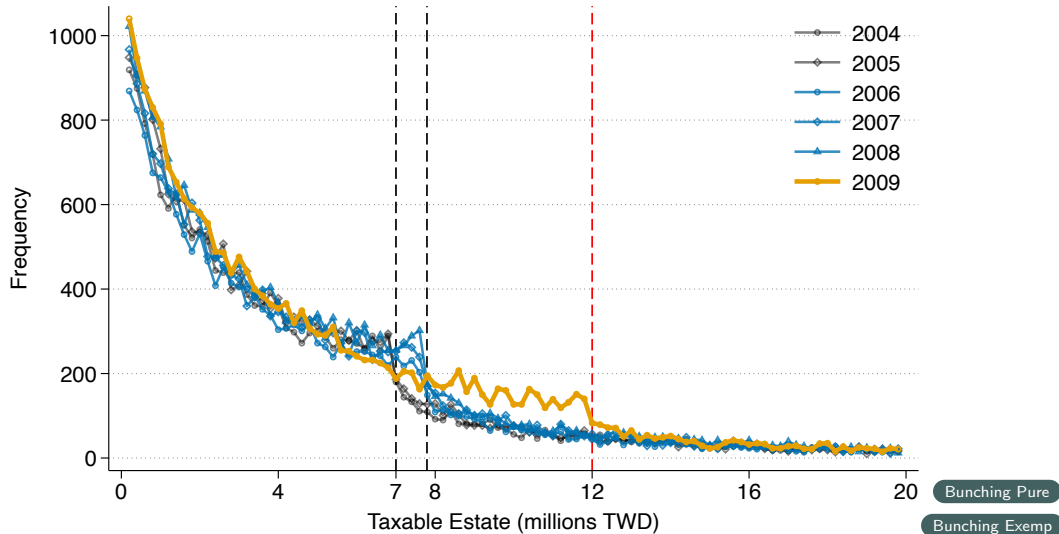
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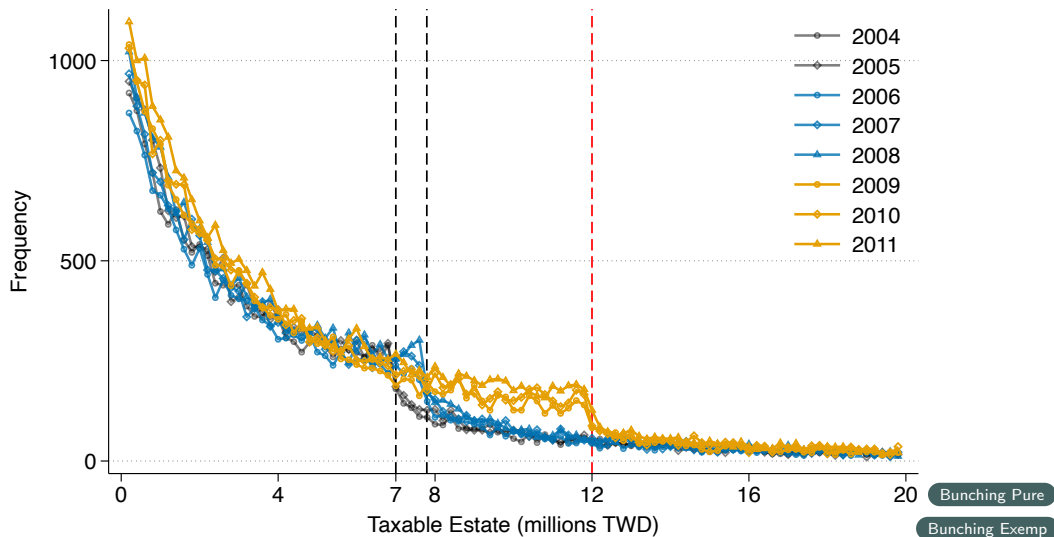
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Empirical Strategy: Goal and Challenge

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- **Challenge:** For post-reform decedents, we don't observe their pre-reform estates
- **Idea:** Predict treatment status using wealth measured before reform and demographic characteristics [Details](#)

2017 Tax Increase

Empirical Strategy: Prediction Implementation

1. Classify pre-2017 decedents into: $<P90$, $P90-P96$, $P96-P99.5$, $>P99.5$

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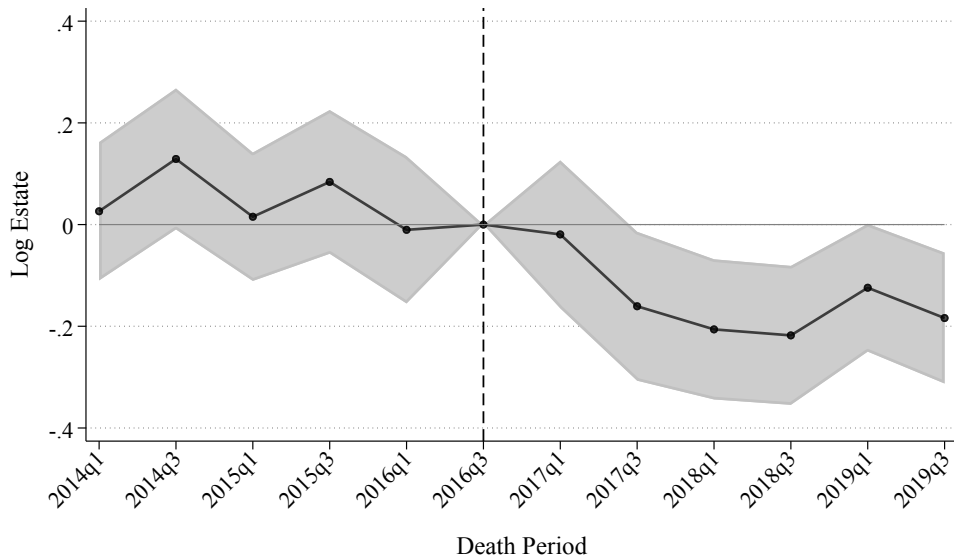
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4. Estimate

$$y_i = \alpha_0 + \alpha_1 \hat{T}_i \times Post_i + \alpha_2 \hat{T}_i + \alpha_3 Post_i + u_i$$

$$\text{where } \hat{T}_i = \begin{cases} 1 & \text{if the predicted class of } i \text{ is } >P99.5 \\ 0 & \text{if the predicted class of } i \text{ is } P90-P96 \end{cases}$$

Results: Log Estate of 2017 Tax Increase, Top 0.5%



Empirical Strategy: Elasticity Calculation

$$\begin{aligned}\varepsilon &= \frac{\% \text{Change in Taxable Estate}}{\% \text{Change in Net-of-tax Rate}} \\ &= \frac{\mathbb{E}[\Delta \log Estate | T = 1] - \mathbb{E}[\Delta \log Estate | T = 0]}{\mathbb{E}[\Delta \log(1 - \tau) | T = 1] - \mathbb{E}[\Delta \log(1 - \tau) | T = 0]}\end{aligned}$$

- Elasticity is the reduced-form scaled by the first-stage

Results: Elasticity

	2017 Tax Increase
	All Top 0.5%
First stage	-0.074 (0.001)
Reduced form	-0.204 (0.029)
Elasticity	2.757 (0.394)

Alternative

Robustness

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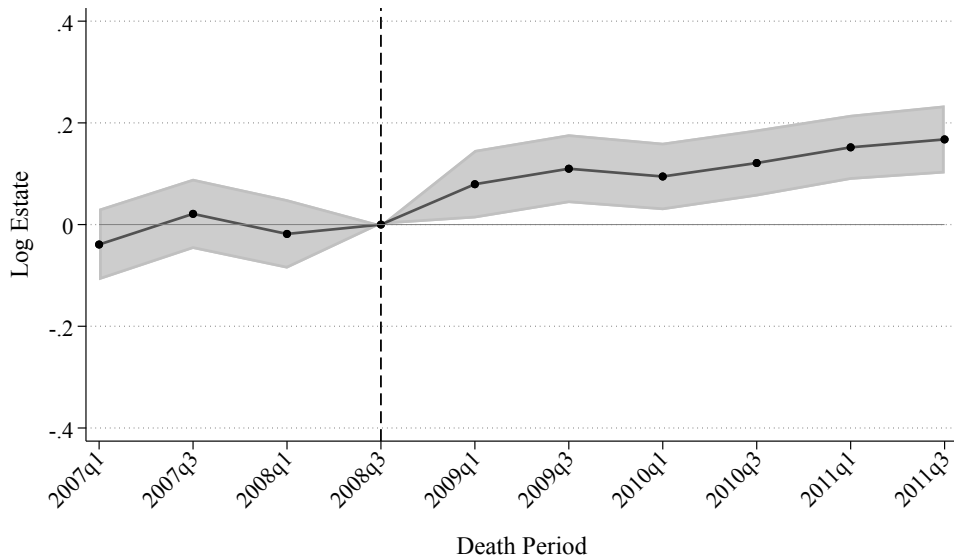
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2009 Tax Cut

Results: Log Estate of 2009 Tax Cut, Top 4%



	2017 Tax Increase	2009 Tax Cut
	All Top 0.5%	All Top 4%
First stage	-0.074 (0.001)	0.099 (0.001)
Reduced form	-0.204 (0.029)	0.131 (0.016)
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Results: Elasticity

	2017 Tax Increase		2009 Tax Cut	
	All	All	Splitting into subgroups	
	Top 0.5%	Top 4%	Top 4%-0.5%	Top 0.5%
First stage	-0.074 (0.001)	0.099 (0.001)	0.072 (0.001)	0.331 (0.005)
Reduced form	-0.204 (0.029)	0.131 (0.016)	0.138 (0.015)	0.154 (0.044)
Elasticity	2.757 (0.394)	1.323 (0.162)	1.917 (0.210)	0.465 (0.133)

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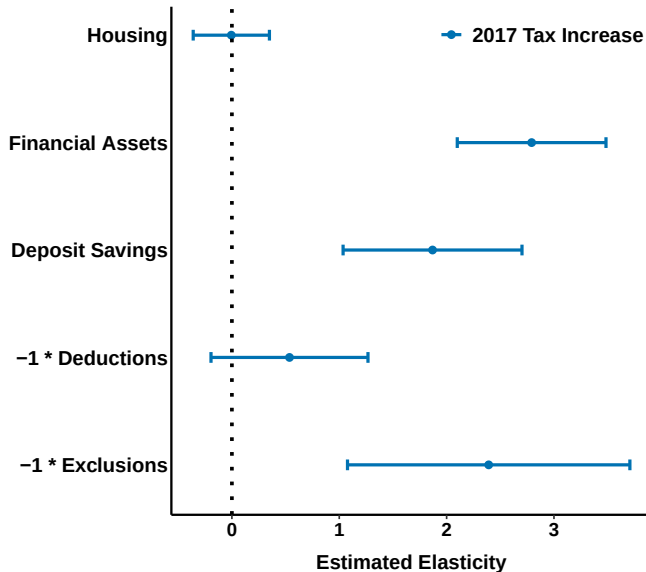
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Anatomy of Estate Items

Elasticity of different estate items

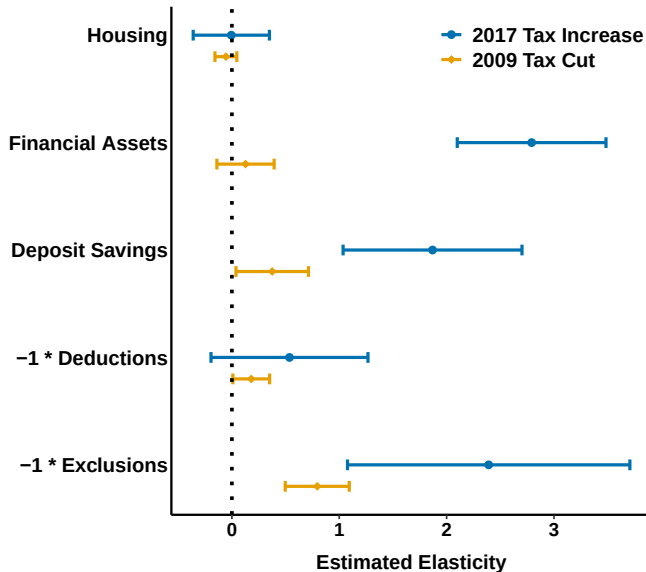


Robustness

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Alternative

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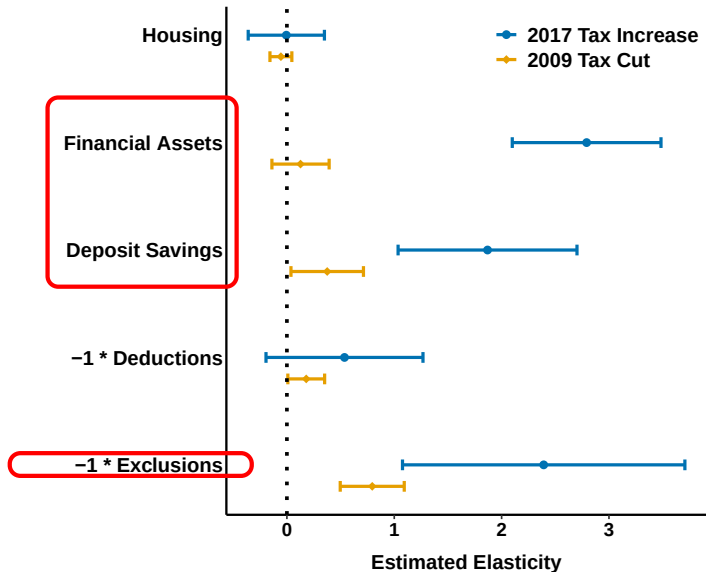


Robustness

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Robustness

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Are the Responses Coming Through Tax
Avoidance? Real Changes in Wealth?

We show it is mainly from avoidance because

- **On decedents' side**

- Compare asset values at death vs. one year prior [Details](#)
 - ◇ Larger discrepancies in stocks and deposits, but no change in housing

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- **On heirs' side**

- Treated heirs reduce labor supply after parents' deaths, but this reduction does not differ before vs. after the reforms [Details](#)

Discussion & Implications

- Some avoidance is reversible, while some is **irreversible** with sunk costs

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- **Asymmetry:** Tax cuts unwind only the reversible part, while tax increases expand both forms of avoidance
- **Implications:**
 1. Tax-increase elasticity better captures the fully adjusted response relevant for policy
 2. Using $a = 1.34$ and $\varepsilon = 2.76$ yields a revenue-maximizing rate of $\tau^{revmax} \approx 21\%$, close to the OECD average top rate of 23%

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Findings

- Individuals responded to estate tax changes quickly and persistently
- Heterogeneity in direction of tax rate changes and across estate distribution
- The asymmetrical patterns suggest a tax avoidance with sunk cost story

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Policy Implications

- Ignoring behavioral asymmetries may lead to misinformed policy decisions
- Stronger enforcement and international collaboration are crucial
- Findings extend to other capital taxes, like corporate income and wealth taxes

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Appendix

Empirical Strategy: Prediction Idea

- **Idea:** Predict one's treatment status using their pre-death info
- Take only the **pre-reform** decedents and model

$$T_i = \mathbb{1}[f(\mathbf{W}_{t(i)-k}, \mathbf{W}_{t(i)-k-1}, \dots, \mathbf{X}_i) + \eta_i \geq a]$$

- $f(\cdot)$ maps pre-death covariates into a latent index
 - $\mathbf{W}_{t(i)-k}$ is a vector of wealth variables measured k years before i 's death year t
 - k is large enough to ensure that for post-reform decedents, these are predetermined and unaffected by the reform
 - $\mathbf{X}_i$ is a vector of demographic variables
- Predicted treatment status is

$$\hat{T}_i = \mathbb{1}[\hat{f}(\mathbf{W}_{t(i)-k}, \mathbf{W}_{t(i)-k-1}, \dots, \mathbf{X}_i) \geq a]$$

Empirical Strategy: Identification Assumptions

1. Classic parallel trends

- Show no pretrends in taxable estates in event study

2. Performance of the prediction algorithm would have been the same pre- and post-reform absent the reform

- Show prediction performance has been stable before the reform
- Show most important predictors have been stable before the reform

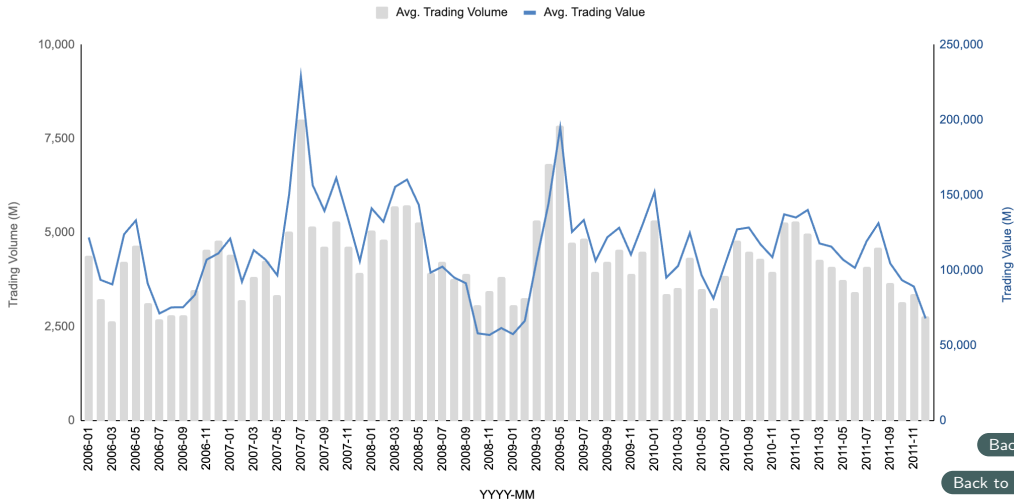
Comparing assets reported at death vs. a year prior

	$\frac{\Delta \text{Housing}}{\text{Wealth}_{t-3}}$	$\frac{\Delta \text{Financial}}{\text{Wealth}_{t-3}}$	$\frac{\Delta \text{Deposit}}{\text{Wealth}_{t-3}}$
Panel A: 2017 Tax Increase			
Treated $\times$ Post	0.003 (0.042)	-0.108*** (0.013)	-0.015** (0.007)
Baseline mean (treated)	0.397	0.277	0.060
Num of decedents	63,459	63,459	63,459
Panel B: 2009 Tax Cut			
Treated $\times$ Post	0.086 (0.065)	0.007 (0.012)	0.102*** (0.008)
Baseline mean (treated)	0.405	0.101	0.035
Num of decedents	46,272	46,272	46,272

- Outcome variables: difference between the value of the item at death and the value held one year before death, scaled by total wealth three years before death

Taiwanese Stock Exchange 2006-2011

Taiwanese Stock Market Between 2006 and 2011

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Heterogeneity in Fraction of Stockholding in 2009 Reform

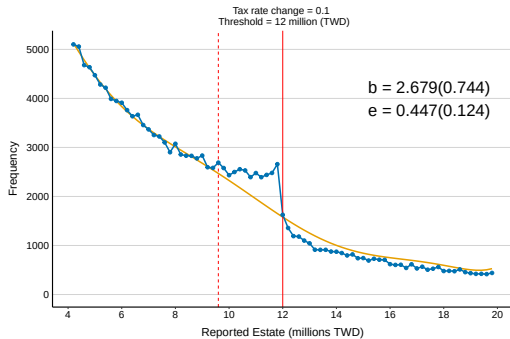
- **Motivation:** During the financial crisis, individuals could be more constrained and therefore have a smaller response during the tax cut
- **Hypothesis:** Within the tax cut, those who are exposed to the financial crisis should have a smaller response $\Rightarrow$ However, **no** difference is detected

	Low Stock	High Stock
First stage	0.312 (0.006)	0.366 (0.009)
Reduced form	0.142 (0.051)	0.151 (0.082)
Implied Elasticity	0.455 (0.164)	0.413 (0.224)

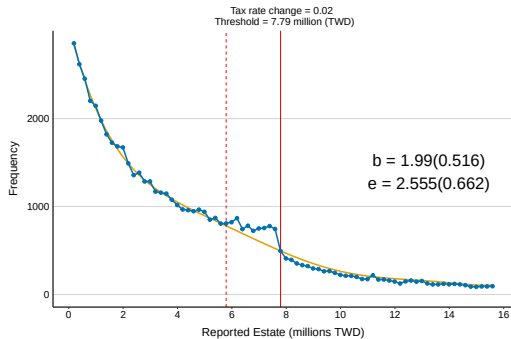
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Exemption-threshold Kinks

(a) Exemption-kink: 12M TWD, 2009-2019



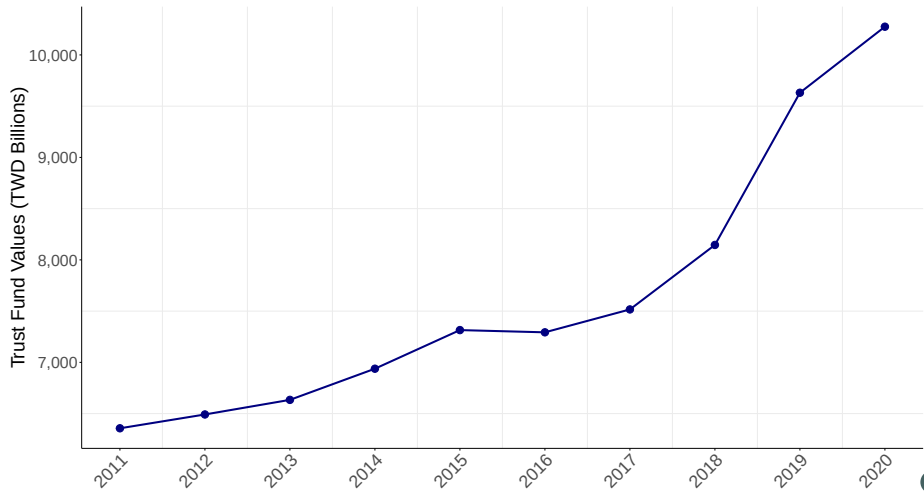
(b) Exemption-kink: 7.79M TWD, 2006-2008



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Aggregate Trust Fund Sizes Over Time

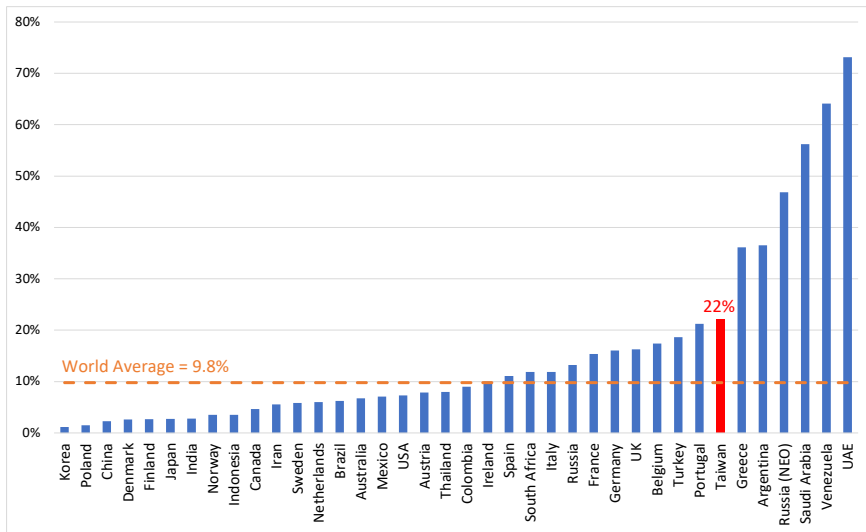


Notes: Data source: Taiwanese Trust Association

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Taiwanese Fraction of Offshore Wealth Over GDP



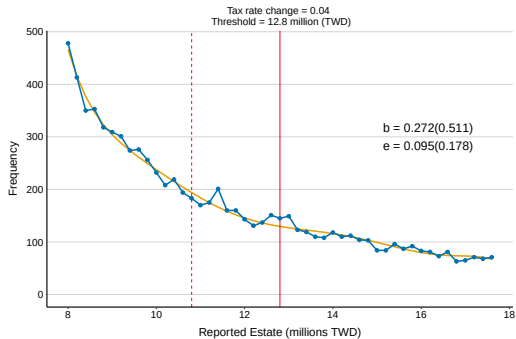
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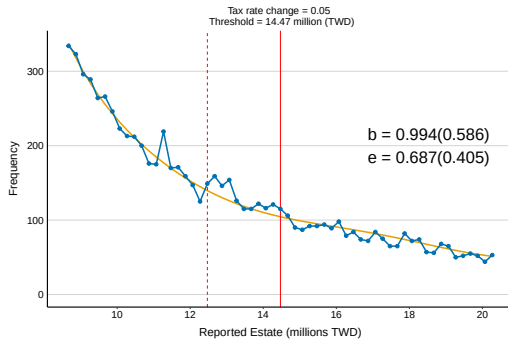
Notes: Data source: [Alstadsæter et al. \(2018\)](#)

Pure Kinks

(a) Pure kink: 12.8M TWD, 2006-2008

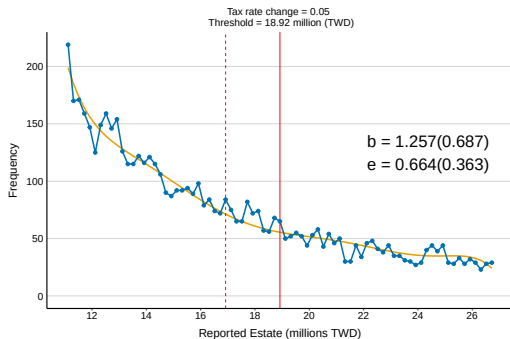


(b) Pure kink: 14.47M TWD, 2006-2008

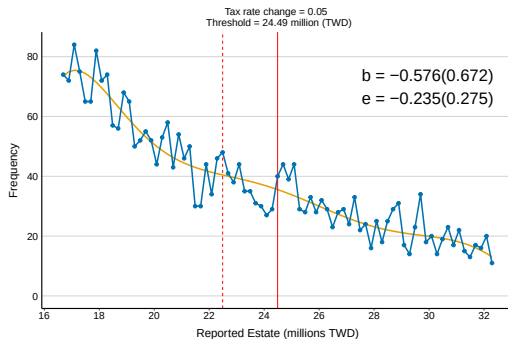


Pure Kinks (continued)

(a) Pure kink: 18.92M TWD, 2006-2008



(b) Pure kink: 24.49M TWD, 2006-2008



Past Literature

Paper	Variation	Context	Outcome variable	Elasticity w.r.t. $1 - \tau$
Panel A: Diff-in-diff				
Mas-Montserrat (2019)	Decrease (top 5%-1%)	Spain	Inheritance	1.88 (s.e. 0.23)
Our study [†]	Decrease (top 4%-0.5%)	Taiwan	Estate	1.92 (s.e. 0.21)
Our study [†]	Decrease (top 0.5%)	Taiwan	Estate	0.47 (s.e. 0.13)
Our study [†]	Increase (top 0.5%)	Taiwan	Estate	2.76 (s.e. 0.39)
Panel B: Bunching (exemption kink)				
Escobar et al. (2019)	Bunching (0% to 10%)	Sweden	Inheritance	1.53 (s.e. 0.10)
Our study [†]	Bunching (0% to 2%)	Taiwan	Estate	2.56 (s.e. 0.66)
Our study [†]	Bunching (0% to 10%)	Taiwan	Estate	0.45 (s.e. 0.12)

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Past Literature (continued)

Paper	Variation	Context	Outcome variable	Est. elasticity w.r.t. $1 - \tau$
Panel C: Bunching (within-positive kink)				
?	Bunching (7% to 50%)	Germany	Inheritance	0.03 (s.e. 0.01)
Escobar et al. (2019)	Bunching (10% to 20%)	Sweden	Inheritance	0.34 (s.e. 0.10)
Escobar et al. (2019)	Bunching (20% to 30%)	Sweden	Inheritance	0.02 (s.e. 0.10)
Our study [†]	Bunching (11% to 15%)	Taiwan	Estate	0.10 (s.e. 0.19)
Our study [†]	Bunching (15% to 20%)	Taiwan	Estate	0.27 (s.e. 0.19)
Our study [†]	Bunching (20% to 25%)	Taiwan	Estate	0.28 (s.e. 0.19)
Our study [†]	Bunching (25% to 33%)	Taiwan	Estate	0.04 (s.e. 0.26)

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Past Literature (continued)

Paper	Variation	Context	Outcome variable	Est. elasticity w.r.t. $1 - \tau$
Panel D: RDD				
Escobar (2017)	Decrease	Sweden	Inheritance	0.76 (s.e. 0.31)
Panel E: OLS				
Kopczuk and Slemrod (2001)	Time-series	U.S.	Estate	Noisy, [-0.11, 0.09]
Joulfaian (2006)	Time-series	U.S.	Tax rev/Avg tax rate	0.14 (s.e. 0.05)

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Institutional context: Assessment rule

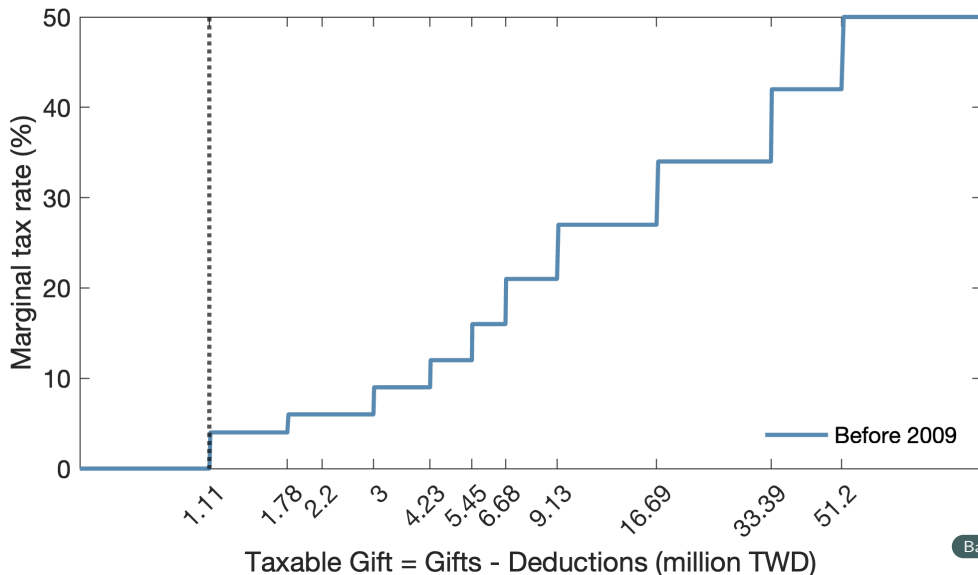
Third-party reported



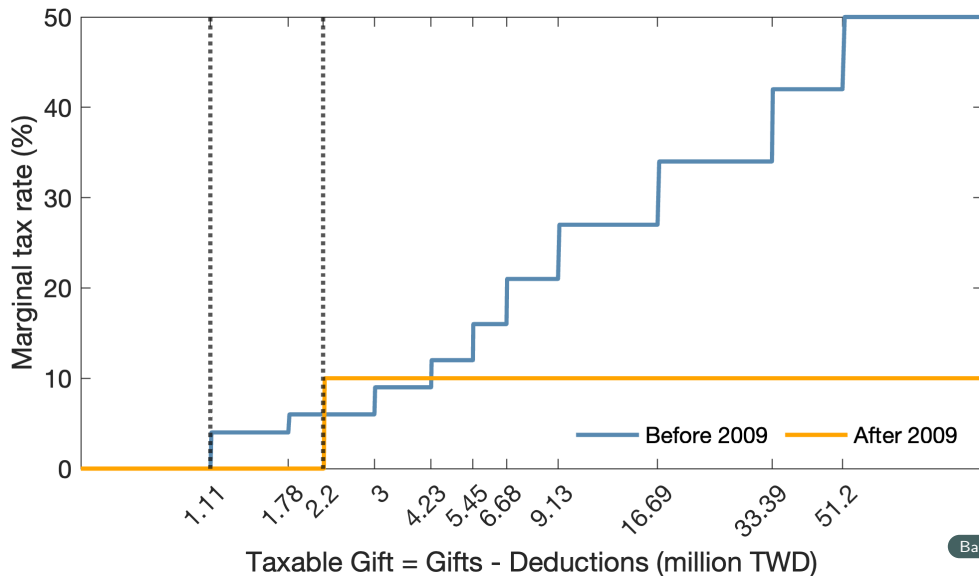
Self-reported

- **Housing:** valued at a government-announced price, which is usually updated every two years and is lower than the market price
- **Deposit savings:** statement of balance of domestic banks
- **Publicly-listed stock:** valued at the market price on the death date
- **Privately-listed stock:** valued at the reported net value of the company on the death date
- **Other financial:** bonds, futures, fund, trust, insurance, and other self-reported items

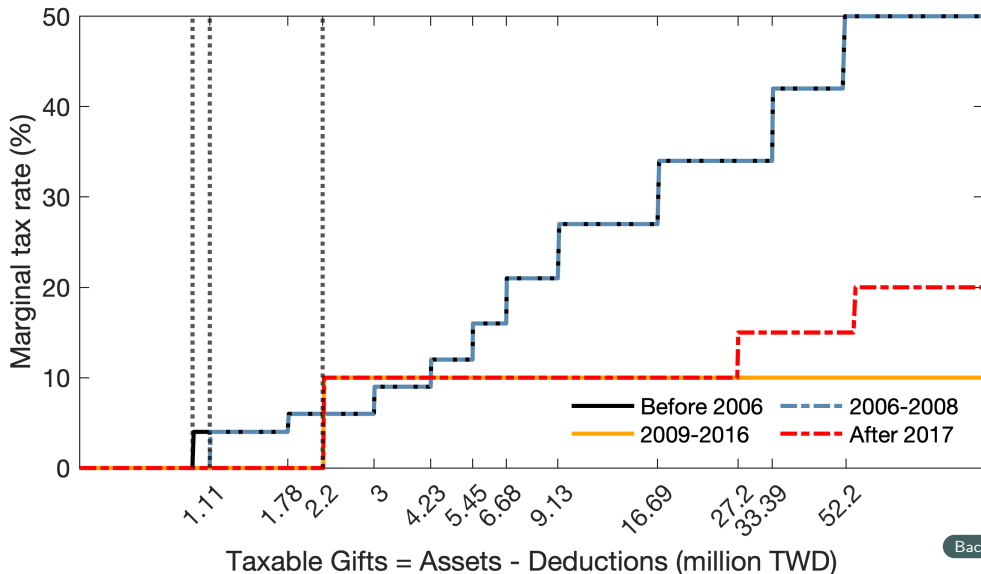
Institutional context: Gift tax schedule



Institutional context: Gift tax schedule



Institutional context: Gift tax schedule



Exemptions

- Gifts for government, educational, cultural, and philanthropic organizations
- Decedents' copyright, patents, and creation
- Essential living tools ($< 720\text{K TWD} \approx 24\text{K USD}$)
- Estates that are inherited and have paid for taxes within 5 years before death
- Land properties for public use
- Residual marital property: if the decedent has more wealth than their living spouse, the exempted amount is $(\text{decedent's marital wealth} - \text{living spouse's marital wealth})/2$

Other Details of Estate Taxes

- Penalties
 - For tax amounts owed under 35K TWD ($\approx 1,200$ USD), one must pay the tax with interest but incurs no fine
 - For amounts exceeding 35K TWD, fines range from 1-2 times the tax owed
- Installments
 - For tax amounts owed more than 300K (≈ 10 K USD), can pay in up to 18 installments, each of which should not exceed two months, plus interests
 - If one bequeathed estates which had already been paid for taxes within 6 to 9 years before her death, 80%, 60%, 40%, and 20% of that estate portion can be deducted on an annual basis respectively

Other Details of Estate & Gift Taxes

- Two-year rules
 - Anything given within 2 years before death to spouses, children, grandchildren, parents, siblings, grandparents, and their spouses will be counted as estate tax base, unless the relation no longer applies at death
 - Reassess the values at the time of death
 - Paid gift taxes can be deducted

Insurance

Policyholder	Insured person	Beneficiary	A's estate tax base
A	A	B	X
A	B	B	V
A	B	A	V
B	A	B	X
B	B	A	X

Using Trusts to Avoid Taxes

- Save estate taxes: Irrevocable trust
- Save gift taxes: Exploit the valuation of the present value of the annuity payments
 - $\text{Gift value} = \text{Transferred assets} - \text{Present value of retained annuity payments}$
- Save income taxes: If the beneficiary faces a lower tax rate than the settlor
- Save all types of taxes: If the beneficiary is a non-profit charity
 - The settlor and their family can often sit on the board
 - e.g. fund initiatives enhancing the family's reputation; get paid; use the real estate

Donors' Pre-death Gifting Outcomes

Table: The Effect of Reforms on Gifts Within Two Years Before Death

	2017 Tax Increase	2009 Tax Cut
Treated $\times$ Post	-0.026 (0.006)	0.003 (0.005)
Num of obs	63,627	46,410

Detailed steps of algorithm I

- Within those who died before the reform (2014-2016), select 70% as a training sample and the remaining 30% as a testing sample
- Train a random forest model where the outcome variable is a discrete variable indicating the group of the individual: i) below P90, ii) P90-P96, iii) P96-P99.5, iv) above P99.5
- Predictors are the values and quantities of land, houses, stocks, capitalized interest income, cars, earned income, unearned income, whether a business owner [4 years, 5 years,..., 10 years before death], and gender, age, number of kids, marriage status, born place, parents alive etc
- In the above step, tune parameters for the number of trees, number of variables possibly split at each node, minimal node size

Detailed steps of algorithm II

- Repeat the above step for each set of parameters and calculate the corresponding precision and recall rates for each set of parameters. Choose the best parameter set
- Apply it to the hold-out testing sample in the beginning and compute the precision and recall rates
- In the final step, we apply the trained algorithm to ALL death samples in our studied period (2014-2019)

Detailed steps of algorithm I

- Within those who died before the reform (2007-2008), select 70% as a training sample and the remaining 30% as a testing sample
- Train a random forest model where the outcome variable is a discrete variable indicating the group of the individual: i) below P90, ii) P90-P96, iii) P96-P98, iv) P98-P99.5, v) above P99.5
- Predictors are the values and quantities of land, houses, stocks, capitalized interest income, cars, earned income, unearned income, whether a business owner [3 years before death], and gender, age, number of kids, marriage status, born place, parents alive etc
- In the above step, tune parameters for the number of trees, number of variables possibly split at each node, minimal node size

Detailed steps of algorithm II

- Repeat the above step for each set of parameters and calculate the corresponding precision and recall rates for each set of parameters. Choose the best parameter set
- Apply it to the hold-out testing sample in the beginning and compute the precision and recall rates
- In the final step, we apply the trained algorithm to ALL death samples in our studied period (2007-2011)

Empirical strategy: elasticity

First Stage (Using only pre-reform samples)

$$\log(1 - \tau_i^{Post}) - \log(1 - \tau_i^{Pre}) = \gamma_0 + \gamma_1 \widehat{Treated}_i + u_i$$

- Based on $Estate_i$, τ_i^{Post} is from the post-reform schedule and τ_i^{Pre} is pre-reform
- γ_1 : % tax rate change induced by reform if being predicted to be treated

Reduced Form (Using all samples)

$$\log Estate_i = \beta_0 + \beta_1 \widehat{Treated}_i + \beta_2 Post_i + \beta_3 \widehat{Treated}_i \times Post_i + e_i$$

Measurement Errors in Binary Treatment Dummy (Reduced-form)

$$y_i = \beta_0 + \beta_1 T_i + \beta_2 Post_i + \beta_3 T_i \times Post_i + e_i$$

$\hat{T}_i$ is the variable with prediction error. Take expectations of the above conditional on $\hat{T}_i$ and $Post_i$:

$$E(y_i | \hat{T}_i = 1, Post_i = 1) = \beta_0 + (\beta_1 + \beta_3) \cdot P(T_i = 1 | \hat{T}_i = 1) + \beta_2$$

$$E(y_i | \hat{T}_i = 1, Post_i = 0) = \beta_0 + \beta_1 \cdot P(T_i = 1 | \hat{T}_i = 1)$$

$$E(y_i | \hat{T}_i = 0, Post_i = 1) = \beta_0 + (\beta_1 + \beta_3) \cdot P(T_i = 1 | \hat{T}_i = 0) + \beta_2$$

$$E(y_i | \hat{T}_i = 0, Post_i = 0) = \beta_0 + \beta_1 \cdot P(T_i = 1 | \hat{T}_i = 0)$$

Conditional on the sample,

$$\hat{\beta}_3 \xrightarrow{P} \beta_3 \cdot [P(T_i = 1 | \hat{T}_i = 1) - P(T_i = 1 | \hat{T}_i = 0)]$$

Het

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Measurement Errors in Binary Treatment Dummy (First-stage)

$$\Delta\tau_i = \gamma_0 + \gamma_1 T_i + u_i$$

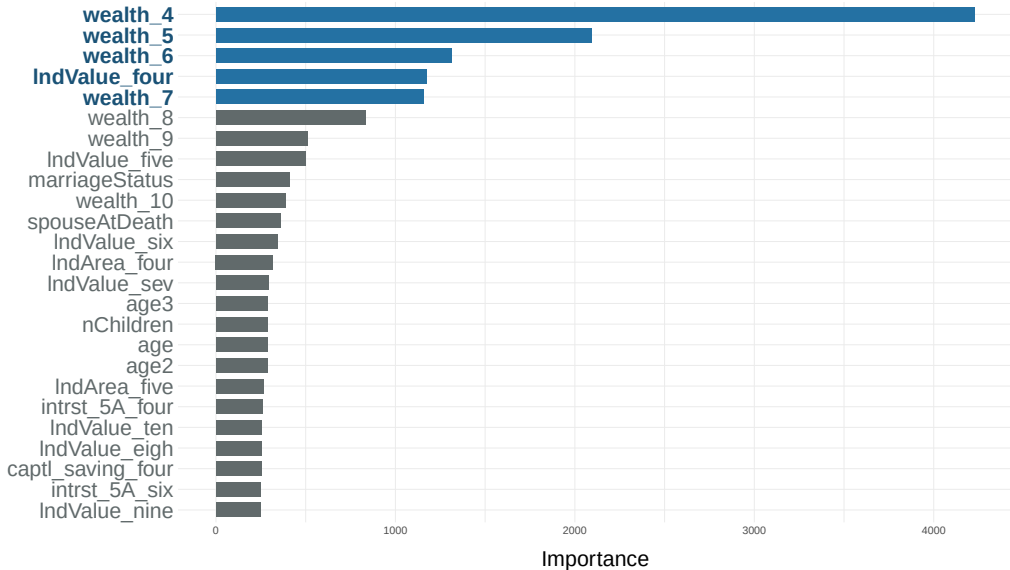
The same thing applies to the first stage:

$$\hat{\gamma}_1 \xrightarrow{P} \gamma_1 \cdot [P(T_i = 1 | \hat{T}_i = 1) - P(T_i = 1 | \hat{T}_i = 0)]$$

ML-predicted Heterogeneous Measurement Errors

- ML predictions may introduce heterogeneous error rates
 - Classic result: constant misclassification $\rightarrow$ attenuation bias
 - ML: error varies across observations $\rightarrow$ bias direction unknown
- Battaglia et al. (2025) show that the measurement bias from using ML-predicted treatments is proportional to the true coefficient itself

Top 25 Important Predictors 2014-2016

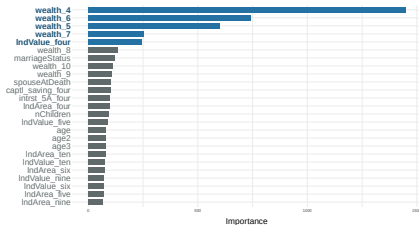


Empirical Strategy: Next Steps

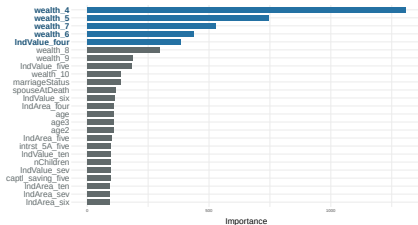
Prediction error in $\hat{T}_i$ could be correlated with the error term in diff-in-diff

- Bootstrap standard errors
- Sample-splitting
 - Use a sample to train the algorithm
 - Then use only the hold-out sample to run the diff-in-diff
- Cross-fitting
 - In fold A, use subset A to train, then apply it to subset B
 - In fold B, use subset B to train, then apply it to subset A
 - Combine both and run diff-in-diff on entire sample

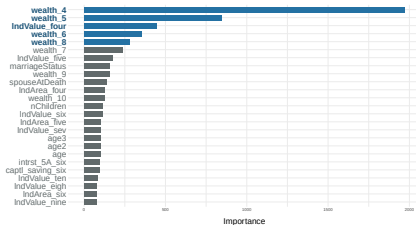
Stability of Important Predictors



(a) 2014

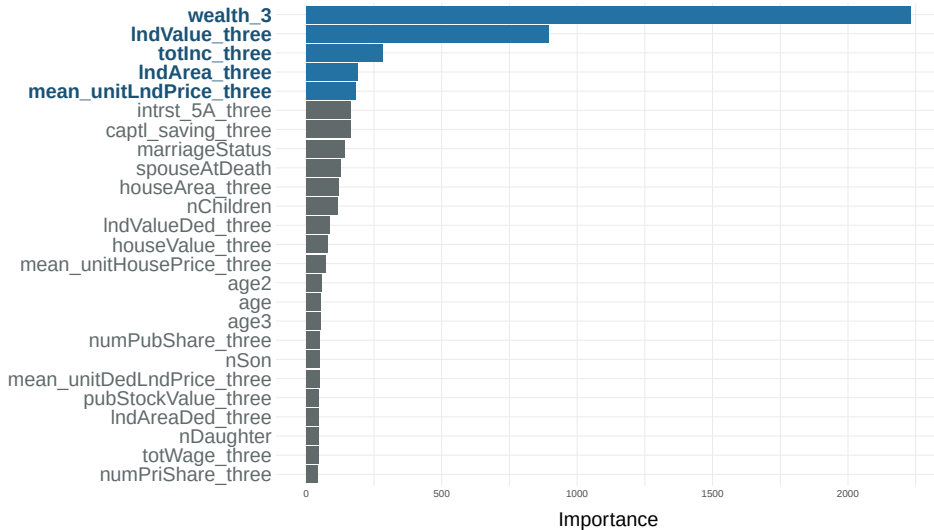


(b) 2015

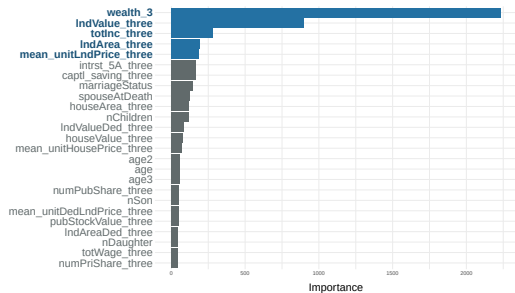


(c) 2016

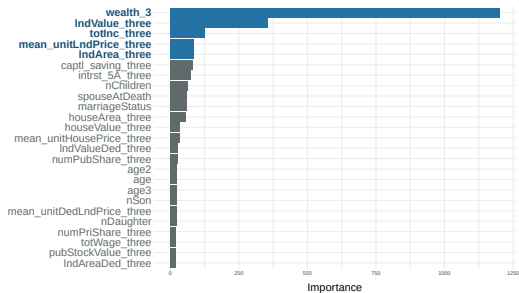
Top 25 Important Predictors 2007-2008



Stability of Important Predictors



(a) 2007-2008



(b) 2007

2017 Prediction performance

Group	Precision	Recall
P90	81.8%	87.8%
P90-P96	60.5%	55.3%
P96-P99.5	66.3%	62.1%
P99.5	76.0%	59.5%

- Precision is $\#$ of individuals being correctly predicted in that class / $\#$ of individuals being predicted in the class
- Recall is $\#$ of individuals being correctly predicted in that group / $\#$ of individuals actually in the group

2009 Prediction performance

Group	Precision	Recall
P90	70.9%	75.8%
P90-P96	60.3%	59.4%
P96-P99.5	63.1%	59.2%
P99.5	67.9%	52.7%

- Precision is $\#$ of individuals being correctly predicted in that class / $\#$ of individuals being predicted in the class
- Recall is $\#$ of individuals being correctly predicted in that group / $\#$ of individuals actually in the group

2017 Prediction performance over time

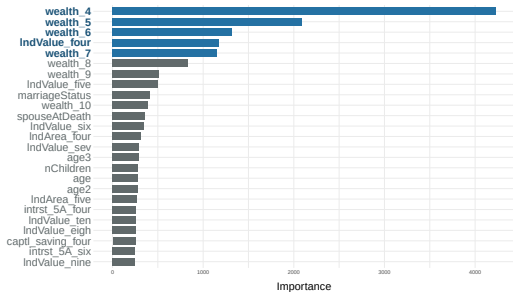
Group	2014-2016 (Baseline)		2014		2015		2016	
	Precision	Recall	Precision	Recall	Precision	Recall	Precision	Recall
P90	81.8%	87.8%	78.5%	88.1%	82.4%	88.1%	84.0%	87.5%
P90-P96	60.5%	55.3%	60.1%	54.2%	60.7%	56.1%	60.7%	55.5%
P96-P99.5	66.3%	62.1%	67.6%	57.8%	67.3%	62.0%	64.4%	66.3%
P99.5	76.0%	59.5%	78.5%	56.7%	75.3%	63.0%	74.8%	59.0%

- Precision is $\#$ of individuals being correctly predicted in that class / $\#$ of individuals being predicted in the class
- Recall is $\#$ of individuals being correctly predicted in that group / $\#$ of individuals actually in the group

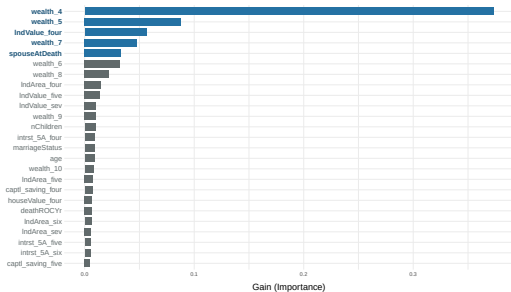
2017 Prediction performance cross-year validation

Group	Train 2014 Test 2015		Train 2015 Test 2016		Train 2014 Test 2016	
	Precision	Recall	Precision	Recall	Precision	Recall
P90	84.6%	80.8%	84.6%	85.4%	86.9%	77.5%
P90–P96	56.6%	57.0%	59.0%	58.1%	55.5%	57.1%
P96–P99.5	59.0%	67.5%	63.6%	64.3%	52.3%	69.3%
P99.5	69.7%	68.5%	69.9%	60.8%	60.7%	68.1%

Robustness check: Top predictors using gradient boosting algorithm 2017



(a) Baseline: Random forest



(b) Alternative: Gradient boosting

Robustness check: Predictive performance using gradient boosting 2017

Group	Random forest (baseline)		Gradient boosting	
	Precision	Recall	Precision	Recall
P90	81.8%	87.8%	81.7%	87.7%
P90-P96	60.5%	55.3%	60.5%	55.5%
P96-P99.5	66.3%	62.1%	66.6%	61.3%
P99.5	76.0%	59.5%	74.3%	61.6%

2009 Prediction performance

Group	Precision	Recall
P90	70.9%	75.8%
P90-P96	60.3%	59.4%
P96-P99.5	63.1%	59.2%
P99.5	67.9%	52.7%

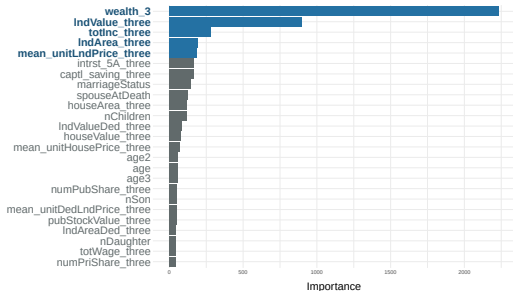
- Precision is $\#$ of individuals being correctly predicted in that class / $\#$ of individuals being predicted in the class
- Recall is $\#$ of individuals being correctly predicted in that group / $\#$ of individuals actually in the group

2009 Prediction performance over time

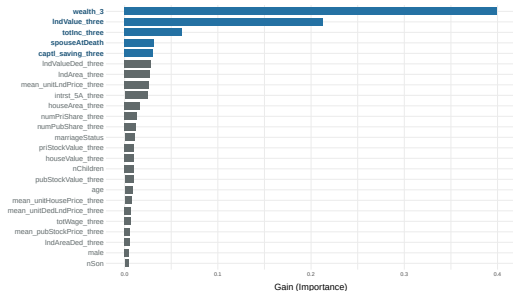
Group	2007		2008	
	Precision	Recall	Precision	Recall
P90	69.7%	75.2%	71.9%	76.4%
P90-P96	60.8%	58.8%	60.0%	60.0%
P96-P99.5	62.2%	59.4%	64.0%	59.1%
P99.5	61.8%	48.1%	73.1%	56.6%

- Precision is $\#$ of individuals being correctly predicted in that class / $\#$ of individuals being predicted in the class
- Recall is $\#$ of individuals being correctly predicted in that group / $\#$ of individuals actually in the group

Robustness check: Top predictors using gradient boosting algorithm 2009



(a) Baseline: Random forest



(b) Alternative: Gradient boosting

Robustness Checks

- Placebo reform years [Go](#)
- Alternative control group [Go](#)
- Anticipation [Go](#)
- Using pre-death wealth to assign treatment w/o ML [Go](#)
- Balance checks [Go](#)
- Macroeconomic condition [Go](#)
- Gifting [Go](#)
- Boosting algorithm [Go](#)

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Alternative Explanation for Asymmetry

- Macroeconomic condition [Go](#)
- Perception [Go](#)
- Loss aversion [Go](#)
- Magnitude

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Alternative Explanation: Perception

- **Motivation:** If one perceived the tax cut as temporary, that could explain why the response is smaller
- **Argument:** For this to work, that would mean individuals perceived the tax cut as temporary and the tax increase as more long-lasting

Alternative Explanation: Loss Aversion

- **Motivation:** If one averse losses, they'll respond to a tax increase more strongly
- **Argument:** That could explain the “magnitude” difference, but cannot explain the difference in “trend”
 - In the data, the trend during the tax cut was compounded while that during the tax increase was one-off
 - For this to explain the compounded trend during the tax cut (the “gain” case), that requires assuming people thinking it was a small gain in the beginning, but later on it became bigger

Alternative control

	(1) 2017 Tax Increase	(2)	(3) 2009 Tax Cut	(4)
	Top 0.5%	Top 4%	Top 4%-0.5%	Top 0.5%
P84-P90	2.455 (0.365)	1.212 (0.173)	1.756 (0.219)	0.417 (0.134)
P86-P92	2.867 (0.375)	1.266 (0.171)	1.913 (0.219)	0.472 (0.134)
P86-P96	2.813 (0.388)	1.183 (0.162)	1.794 (0.208)	0.443 (0.134)
P90-P96 (baseline)	2.757 (0.394)	1.323 (0.161)	1.917 (0.210)	0.465 (0.133)

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Placebo Tests

Goal: To show the treatment effects are not driven by algorithmic bias, mean reversion, or aspects unrelated to the reforms

- Take a given period and assume a placebo reform year
- Define treatment using the pre-period
- Train an algorithm and apply to all periods

Period	2009-2013	2010-2014	2011-2015	2012-2016
Placebo Reform	2012	2013	2014	2015
Treated $\times$ Post	0.043 (0.040)	-0.063 (0.041)	0.045 (0.036)	-0.044 (0.034)
Num of obs	42,265	42,758	46,600	49,991

Elasticity Assuming Anticipation, Top 0.5%

- Define reform year 2016 for the tax increase (or 2008 for tax cut)
- Retrain the algorithm and repredict
- Estimate the same diff-in-diff but redefine the post dummy

	2017 Tax Increase		2009 Tax Cut	
	Baseline	Anticipated	Baseline	Anticipated
First stage	-0.074 (0.001)	-0.067 (0.001)	0.331 (0.005)	0.333 (0.007)
Reduced form	-0.204 (0.029)	-0.166 (0.036)	0.154 (0.044)	0.151 (0.056)
Elasticity	2.757 (0.394)	2.478 (0.539)	0.465 (0.133)	0.453 (0.168)

Elasticity Using Pre-wealth-based Assignment Rule

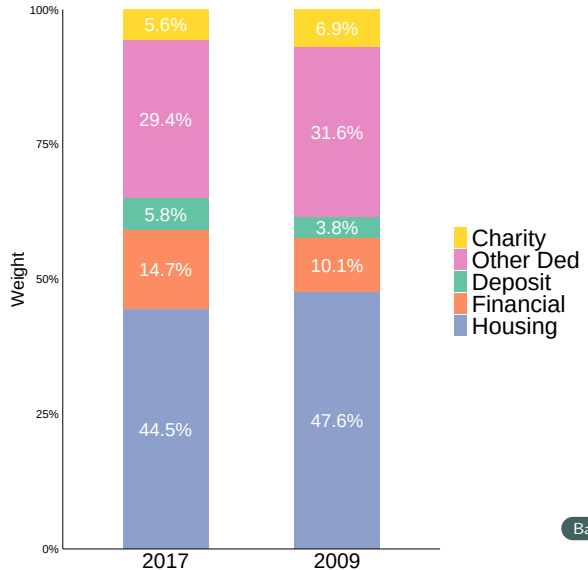
	2017 Tax Increase		2009 Tax Cut	
	All	All	Splitting into subgroups	
	Top 0.5%	Top 4%	Top 4%-0.5%	Top 0.5%
First stage	-0.060 (0.001)	0.091 (0.001)	0.061 (0.001)	0.284 (0.005)
Reduced form	-0.194 (0.037)	0.092 (0.018)	0.104 (0.017)	0.127 (0.044)
Elasticity	3.233 (0.619)	1.011 (0.198)	1.705 (0.280)	0.447 (0.155)

Contribution to the total elasticity of estate

$$\varepsilon^{Estate} = \sum_{Item} \varepsilon^{Item} \times \omega_{\frac{Item}{Estate}}$$

Contribution to the total elasticity of estate

$$\varepsilon^{Estate} = \sum_{Item} \varepsilon^{Item} \times \omega_{\frac{Item}{Estate}}$$



Summary Statistics of Predicted Treated and Control Groups Before Reforms

	2017 Tax Increase		2009 Tax Cut		
	Control	Treated	Control	Treated	
	P90-P96	>P99.5	P90-P96	P96-P99.5	>P99.5
Age	76.34	77.85	72.88	74.33	75.07
Male (%)	67.19	73.39	71.40	73.57	78.66
Spouse Alive (%)	50.32	60.47	53.76	54.40	65.40
Number of Children	3.32	3.55	3.59	3.80	3.96
Taxable Estate	8,619.5	244,126.0	5,353.5	14,033.6	119,824.1
Observations	27,407	2,169	15,575	8,935	1,059

Contribution to the total elasticity of estate

	2017 Tax Increase			2009 Tax Cut		
	Elasticity	Weight	Product	Elasticity	Weight	Product
Panel A: Asset						
Housing	-0.005 (0.181)	44.5%	-0.008			
Financial & Other	2.792 (0.353)	14.7%	1.367			
Deposit Saving	1.869 (0.425)	5.8%	0.361			
Subtotal Asset			1.720			
Panel B: Deductible						
-1*Other Deduction	0.537 (0.373)	29.4%	0.524			
-1*Charitable & Exemp.	2.392 (0.671)	5.6%	0.448			
Subtotal Deductible			0.972			
Total Estate			2.692			
% from Asset			63.9%			
% from Ded			36.1%			

Contribution to the total change in estate

	2017 Tax Increase			2009 Tax Cut		
	Elasticity	Weight	Product	Elasticity	Weight	Product
Panel A: Asset						
Housing	-0.005 (0.181)	44.5%	-0.008	-0.056 (0.052)	47.6%	-0.117
Financial & Other	2.792 (0.353)	14.7%	1.367	0.127 (0.136)	10.1%	0.055
Deposit Saving	1.869 (0.425)	5.8%	0.361	0.376 (0.172)	3.8%	0.062
Subtotal Asset			1.720			0.001
Panel B: Deductible						
-1*Other Deduction	0.537 (0.373)	29.4%	0.524	0.180 (0.087)	31.6%	0.250
-1*Charitable & Exemp.	2.392 (0.671)	5.6%	0.448	0.795 (0.152)	6.9%	0.240
Subtotal Deductible			0.972			-0.490
Total Estate			2.692			0.491
% from Asset			63.9%			0.3%
% from Ded			36.1%			99.7%

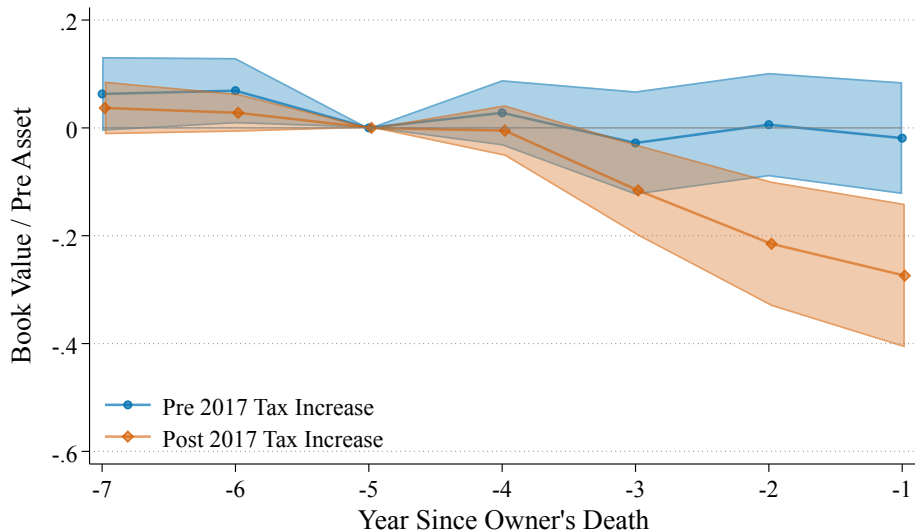
Closely Held Firms' Valuations

- Closely held firm owners have discretion over valuations and can directly affect their privately-held stock values at death
- We track firm outcomes over the 7 years before their owners' death

$$Y_{ft} = \sum_{k \neq -5} \beta_k T_f \times \mathbb{1}[t - DeathYr_f = k] + \sum_{k \neq -5} \mathbb{1}[t - DeathYr_f = k] + \alpha_f + \delta_t + u_{ft}$$

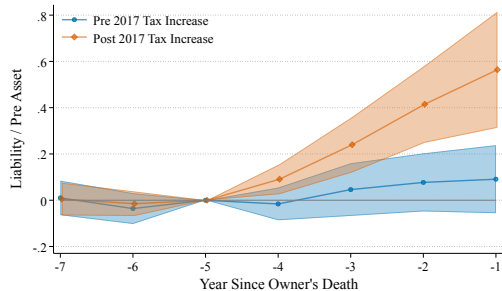
- $T_f = 1$: firms whose owners predicted to be the top 0.5% for the 2017 reform and who at any point in the 7 years held more than 1/3 of ownership
- $T_f = 0$: publicly-listed firms
- $DeathYr_f$ is the death year of the owner for the treated firms and a placebo for the control firms
- Estimate this **separately** for those who died before vs. after 2017

Book Values Decreased Among Post-reform Decedents

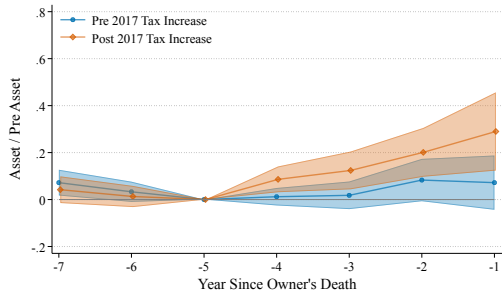


Coming Through Liabilities Inflating

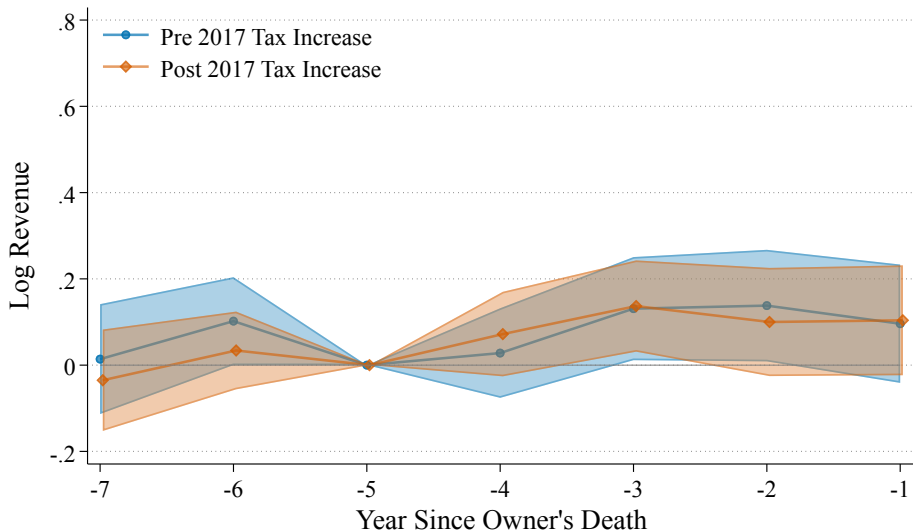
(a) Liability / Pre-Asset



(b) Asset / Pre-Asset



While Sale Revenues See No Changes



Did the Reforms Affect Heirs' Labor Supply?

- **Motivation:** Inheritance windfalls reduce labor supply ([Holtz-Eakin et al., 1993](#); [Elinder et al., 2012](#); [Bø et al., 2019](#); [Nekoei and Seim, 2023](#))
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 2. **Establish baseline windfall effect:** Use pre-reform heirs to measure how inheritance windfalls affect labor supply Reg
 3. **Predict and compare:** Apply this baseline to predict post-reform heir responses and compare with observed outcomes

The Effect of 2017 Tax Increase on Heirs' Inheritance

$$\begin{aligned} Inheritance_{j(i)} = & \alpha_0 + \alpha_1 T_{j(i)} \times Post_{j(i)} + \alpha_2 T_{j(i)} \\ & + \alpha_3 Post_{j(i)} + \epsilon_{j(i)} \end{aligned}$$

- j is heir and i is decedent
- $T_{j(i)} = 1$ if i is treated
- $Post_{j(i)} = 1$ if i died after the reform

The Effect of 2017 Tax Increase on Heirs' Inheritance

	2017 Tax Increase
Treated $\times$ Post	-44.142*** (9.535)
Baseline mean (treated)	53.94
Num of heirs	88,000

- Inherit $\approx$ 1.38 million USD less

Comparison to Past Literature

Paper	Context	Sample	Wealth gain ('000 USD)	Emp. change per 100,000 USD
Holtz-Eakin et al. (1993)	US (singles)	Random sample 1%	781 (simulated)	-1.5 pp
Nekoei and Seim (2023)	Sweden	Full population	9.35	-4.3 pp
Our study (pre-2017)	Taiwan	Top 0.5%	1,380	-0.16 pp
Our study (pre-2009)	Taiwan	Top 0.5%	272	-0.54 pp

Note: All values measured in 2016 USD. For [Holtz-Eakin et al. \(1993\)](#), we convert the 350,000 USD simulation exercise reported on page 425 to 2016 USD assuming the number was based on 1985. For [Nekoei and Seim \(2023\)](#), we convert the reported 58,000 SEK average inheritance to 2016 USD, assuming 2003 as the base year (midpoint of their 2001-2005 treatment effects).

The Effect of 2009 Tax Cut on Heirs' Inheritance

	2009 Tax Cut
Treated $\times$ Post	8.698*** (2.415)
Baseline mean (treated)	13.17
Num of heirs	70,819

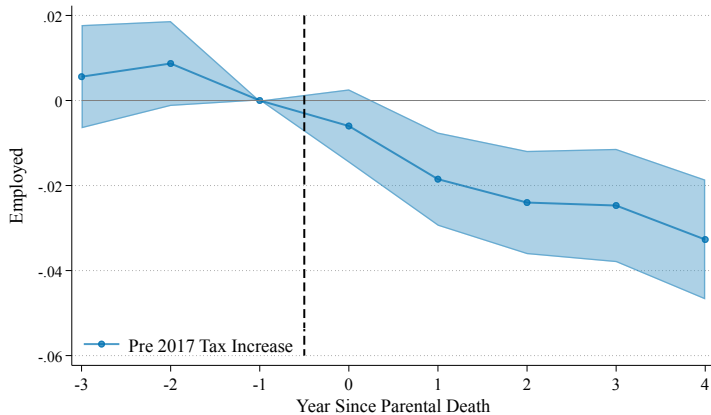
- Inherit $\approx$ 272K USD more

Empirical Strategy: The Effect of Parents' Death on Labor Supply

$$y_{j(i),t} = \sum_{k \neq -1} \beta_k \textit{Treated}_{j(i)} \times \mathbb{1}[t - \textit{DeathYear}_i = k] \\ + \sum_{k \neq -1} \mathbb{1}[t - \textit{DeathYear}_i = k] + \delta_{j(i)} + u_{j(i),t}$$

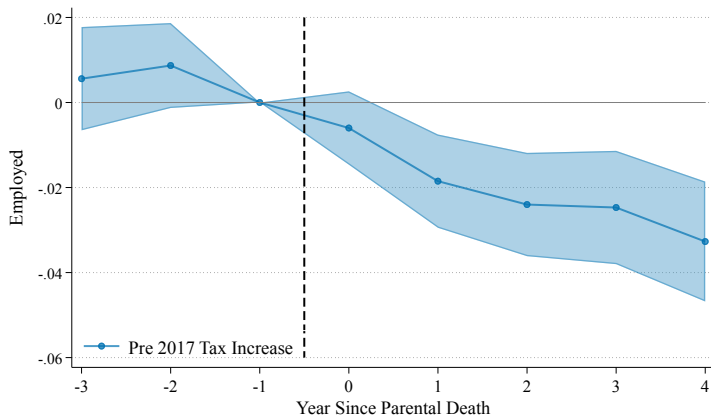
- $y_{j(i),t}$ is the outcome of heir j in time t
- $\textit{Treated}_{j(i)} = 1$ if heir j 's parent is defined as treated in the decedent specification
- $\mathbb{1}[t - \textit{DeathYear}_i = k]$ is time dummy relative to decedent i 's death year
- $\delta_{j(i)}$ is heir fixed effect and s.e. clustered at the heir level
- **Tax variation:** Separately estimate by whether parents died before or after reform

Pre-2017 Baseline Windfall Effect on Being Employed



- Baseline windfall effect: -0.05 pp per million TWD (≈ -0.16 pp per 100,000 USD)

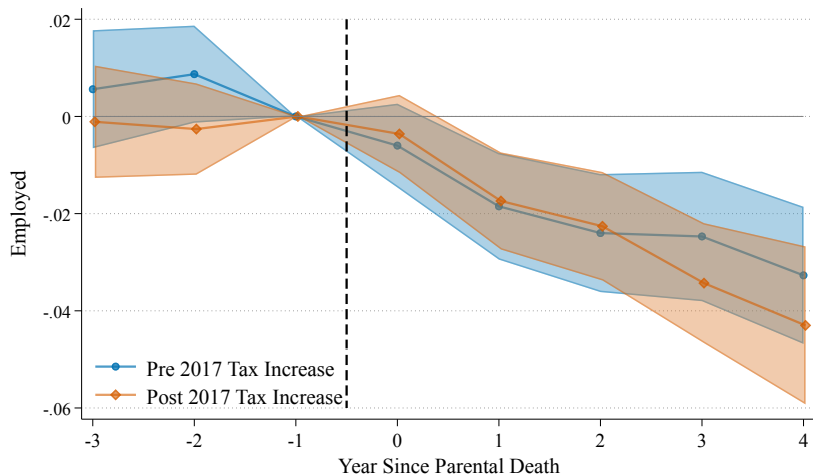
Pre-2017 Baseline Windfall Effect on Being Employed



- Baseline windfall effect: -0.05 pp per million TWD (≈ -0.16 pp per 100,000 USD)
- A 44 million TWD reduction in inheritance after 2017, would predict an increase to **-0.2pp** ($-2.4 + 0.05 \times 44$)

[Back](#)[Lit](#)[2009](#)[Intensive](#)

2017 Reform Effect on Being Employed



● Post-reform estimate 95% CI [-3.38pp, -1.14pp] $\neq$ -0.2pp

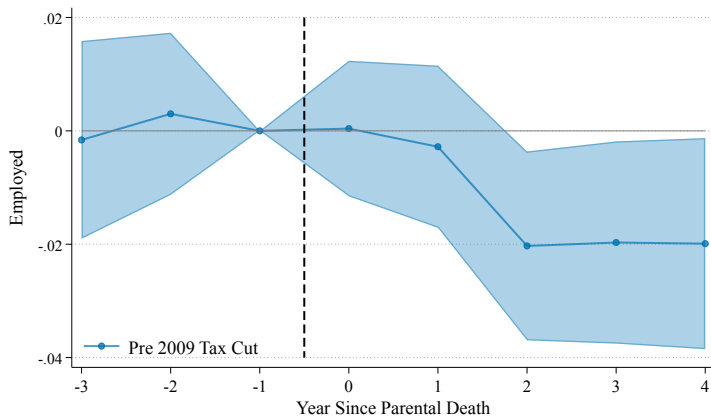
Back

Lit

2009

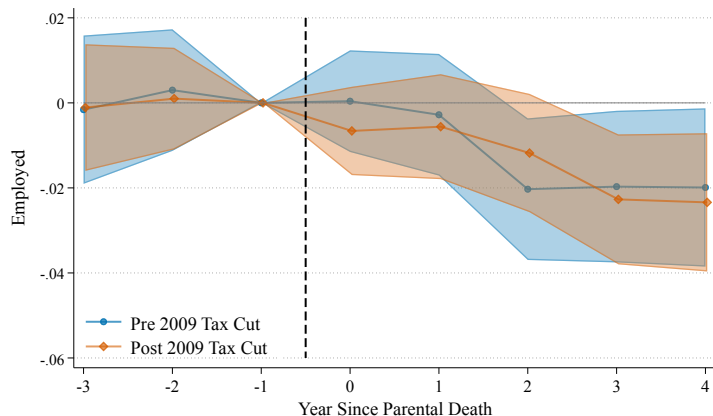
Intensive

2009 Result: Effect of Parents' Death on Being Employed



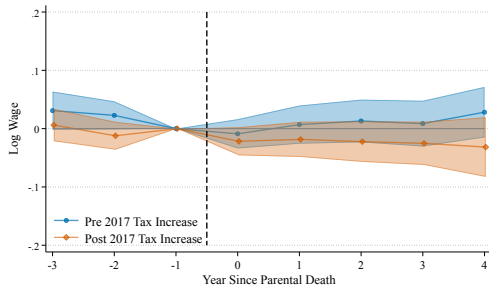
- Baseline windfall effect: -0.17 pp per million TWD (≈ -0.54 pp per 100,000 USD)
- A 8.7 million TWD reduction in inheritance after 2009, would predict a decrease to **-3.51pp** ($-2.03 - 0.17 \times 8.7$)

2009 Result: Effect of Parents' Death on Being Employed

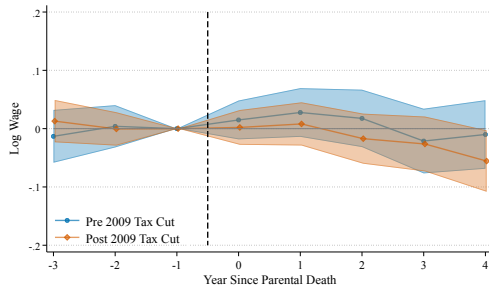


● Post-reform estimate 95% CI [-2.57pp, 0.21pp] $\neq$ -3.51pp

Results: The Effect of Parents' Death on Labor Supply



(a) 2017 Tax Increase: Intensive Margin



(b) 2009 Tax Cut: Intensive Margin

Model: Details

Setup

- Continuum of agents i , each with fixed wealth w
- Two periods: Middle Age ($t = 1$) and Near Death ($t = 2$)
- At $t = 1$: rate τ perceived as permanent; certain death in $t = 2$
- Choice: sheltered stock $s_{it} \geq 0$; remainder $(w - s_{i2})$ taxed at τ
- Objective: maximize net-of-tax bequest left to heirs

Avoidance Technology

- Fixed entry cost κ_{it} , paid once on first entry
 - Heterogeneous: $\kappa_{i1} \sim G$ on $[0, \infty)$
 - Rises with age: $\kappa_{i2} = \phi \kappa_{i1}$ with $\phi > 1$ (early planning is cheaper)
- Variable cost $\Gamma(s)$ on the sheltered stock
 - Convex: $\Gamma' > 0$, $\Gamma'' > 0$, $\Gamma'(0) = 0$, $\Gamma'(w) > 1$
 - Sunk: reducing s recovers nothing; raising $s_1 \rightarrow s_2$ costs $\Gamma(s_2) - \Gamma(s_1)$

Agent's Problem

$$\max_{s_{i1}, s_{i2} \geq 0} U_i = \underbrace{(1 - \tau)(w - s_{i2})}_{\text{after-tax estate}} + \underbrace{s_{i2}}_{\text{sheltered}} - \underbrace{\mathcal{C}(s_{i1}, s_{i2}; \kappa_{i1}, \kappa_{i2})}_{\text{sheltering cost}}$$

$$\mathcal{C} = \underbrace{\mathbb{1}[s_{i1} > 0] \kappa_{i1}}_{\substack{\text{fixed cost at } t=1 \\ \text{(paid if enter early)}}} + \underbrace{\Gamma(s_{i1})}_{\substack{\text{variable cost} \\ \text{on } t=1 \text{ stock}}}$$

$$+ \underbrace{\mathbb{1}[s_{i2} > 0, s_{i1} = 0] \kappa_{i2}}_{\substack{\text{fixed cost at } t=2 \\ \text{(only if no } t=1 \text{ entry)}}} + \underbrace{\max\{0, \Gamma(s_{i2}) - \Gamma(s_{i1})\}}_{\substack{\text{incremental variable cost} \\ \text{(zero if shrinking)}}$$

- Fixed cost paid once, on first entry, never refunded
- Variable cost on the stock is irreversible: cutting s recovers nothing

Equilibrium Under Permanent τ

Key: since $\phi > 1$, delaying entry is strictly dominated $\Rightarrow$ agents enter at $t = 1$ or never

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- Intensive margin: FOC equates marginal tax saving to marginal cost

$$\tau = \Gamma'(s^*) \quad \Rightarrow \quad s^*(\tau) \text{ strictly increasing in } \tau$$

- Extensive margin: enter iff fixed cost is below net gain

$$\kappa_{i1} \leq \tau s^*(\tau) - \Gamma(s^*(\tau)) \equiv \bar{\kappa}(\tau), \quad \bar{\kappa}'(\tau) > 0$$

- Participation share $P(\tau) = G(\bar{\kappa}(\tau))$; aggregate shelter $S_{agg}(\tau) = G(\bar{\kappa}(\tau)) \cdot s^*(\tau)$

An Unexpected Shock at $t = 2$

At $t = 2$, the rate moves $\tau \rightarrow \tau'$ unexpectedly. The $t = 1$ decisions are sunk.

- Two groups inherited from $t = 1$:
 - Non-participants: $s_{i1} = 0$, never entered
 - Participants: $s_{i1} = s^*(\tau)$, already paid κ_{i1} and $\Gamma(s^*(\tau))$
- Analyze each case separately:
 - Tax hike ($\tau' > \tau$)
 - Tax cut ($\tau' < \tau$)

Case 1: Tax Hike ($\tau' > \tau$)

- Participants reoptimize on the intensive margin:

$$\tau' = \Gamma'(s_{i2}^*) \Rightarrow s_{i2}^* = s^*(\tau') > s^*(\tau)$$

- All existing participants expand sheltering

- Non-participants face the age-2 fixed cost $\kappa_{i2} = \phi\kappa_{i1}$:

$$\text{enter} \Leftrightarrow \kappa_{i1} \leq \bar{\kappa}(\tau')/\phi$$

- Marginal hike: $\bar{\kappa}(\tau')/\phi \rightarrow \bar{\kappa}(\tau)/\phi < \bar{\kappa}(\tau) \Rightarrow$ extensive margin locally zero
- Discrete hike: new entrants with $\kappa_{i1} \in (\bar{\kappa}(\tau), \bar{\kappa}(\tau')/\phi]$

Case 2: Tax Cut ($\tau' < \tau$)

- Non-participants: threshold falls to $\bar{\kappa}(\tau') < \bar{\kappa}(\tau) \Rightarrow$ no new entry
- Participants hit a corner at $s_{i2}^* = s^*(\tau)$:
 - For $s_{i2} \leq s^*(\tau)$: cost is sunk; payoff $\propto \tau' s_{i2}$ increases in $s_{i2} \Rightarrow$ hold at $s^*(\tau)$
 - For $s_{i2} > s^*(\tau)$: marginal payoff $\tau' - \Gamma'(s^*(\tau)) = \tau' - \tau < 0 \Rightarrow$ no expansion
- Aggregate sheltered wealth unchanged: $\Delta S_{agg}^{Cut} = 0$

The Asymmetry

Marginal response of aggregate estates $E_{agg} = W - S_{agg}$ to the net-of-tax rate.

- Tax hike (decrease in $1 - \tau$): only intensive margin responds

$$\frac{dE_{agg}}{d(1 - \tau)^-} = G(\bar{\kappa}(\tau)) \cdot \frac{1}{\Gamma''(s^*)}$$

- Tax cut (increase in $1 - \tau$): neither margin moves

$$\frac{dE_{agg}}{d(1 - \tau)^+} = 0$$

- Asymmetry:

$$\frac{dE_{agg}}{d(1 - \tau)^-} - \frac{dE_{agg}}{d(1 - \tau)^+} = \frac{G(\bar{\kappa}(\tau))}{\Gamma''(s^*)} > 0$$

- Hike elasticity $>$ cut elasticity $\Rightarrow$ hike reflects the long-run response

Quantifying the Fixed Cost

Assume quadratic costs $\Gamma(s) = s^2/(2\psi)$. Combine FOC with elasticity:

$$\frac{s^*}{E} = \frac{\tau \varepsilon}{1 - \tau}, \quad \frac{\bar{\kappa}}{E} = \frac{1}{2}\tau \cdot \frac{s^*}{E}$$

- At pre-reform $\tau = 0.10$ and $\varepsilon = 2.76$:
 - Sheltered share of taxable estate: $s^*/E \approx 30.7\%$
 - Sheltered share of total wealth: $s^*/W \approx 23.5\%$ (cf. $\sim 30\%$ in Leenders et al. 2023)
 - Implied fixed cost: $\bar{\kappa}/E \approx 1.5\%$
- Average estate $\approx 244\text{M TWD} \Rightarrow$ entry cost $\approx 3.7\text{M TWD}$ ($\approx 116\text{K USD}$)
- Economically plausible: trust setup, offshore accounts, planner coordination

Policy Implication: Revenue-Maximizing Rate

- Apply $\tau^{revmax} = 1/(1 + a\varepsilon)$
- Pre-reform Pareto coefficient: $a = 1.34$ (cf. U.S. $a \approx 1.4$ in Saez & Zucman, 2016)
- With $\varepsilon = 2.76$: $\tau^{revmax} \approx 21\%$
 - Close to OECD average top rate of 23% on bequests to children
- Prior literature elasticities ~ 0.1 (mostly from cuts) imply $\tau^{revmax} \approx 90\%$
- Using cut-based elasticities understates the long-run behavioral cost

- Each assumption does one job:
 - $\phi > 1$ pins down when commitment happens: before the shock
 - Sunkness makes that commitment irreversible once the shock hits
- Mechanism in one line:
 - Hikes: existing planners intensify use of established structures
 - Cuts: sunk structures stay in place; new entrants don't materialize
- Hike elasticity is the long-run, frictionless object for policy