Aggregate implication of corporate taxation over business cycle

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Introduction

Question and Motivation

What are the aggregate implications of corporate taxation?

- Corporate taxation creates significant wedge on investment decision
- Existing analyses are limited to static and representative firm model

  (Fernández-Villaverde (2010), Occhino (2022, 2023))
- Yet, there are large and heterogeneous investment response when tax cut occurs

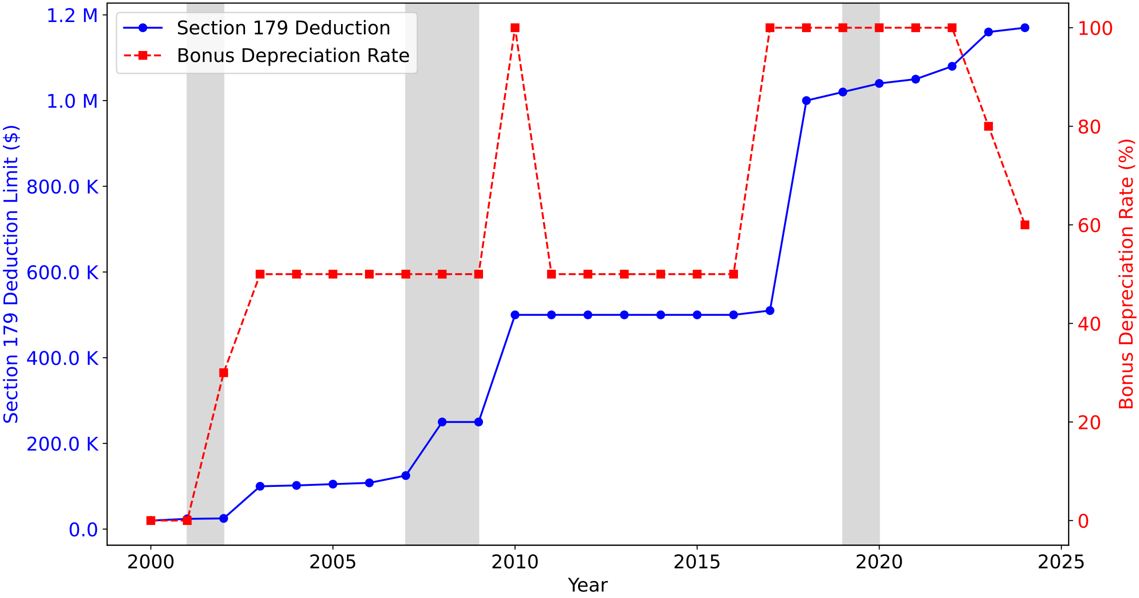
  (Zwick and Mahon (2017), Ohrn (2018, 2019))
- This paper: how does corporate tax structure affect...

  policy effectiveness? **aggregate fluctuation?** **capital allocation?**

Corporate taxation in the US

- Depreciation of equipment is deductible from firms' taxable income
- Two policies coexist: bonus depreciation (untargeted) and Section 179 (targeted)
- Consider a firm buying $\$1000$ of computer and interest rate is 4%:

Year	Cost × Depreciation %	Normal		50% Bonus	S179 eligible
0	$\$1000 \times 20.00\%$	$\$200$	$\underset{+800\times0.5}{\Longrightarrow}$	$\$600$	$\$1000$
1	$\$1000 \times 32.00\%$	$\$320$		$\$160$	$\$0$
2	$\$1000 \times 19.20\%$	$\$192$		$\$96$	$\$0$
3	$\$1000 \times 11.52\%$	$\$115.2$	$\underset{\times0.5}{\Longrightarrow}$	$\$57.5$	$\$0$
4	$\$1000 \times 11.52\%$	$\$115.2$		$\$57.5$	$\$0$
5	$\$1000 \times 5.76\%$	$\$57.6$		$\$29$	$\$0$
Total		$\$1000$		$\$1000$	$\$1000$
NPV		$\$933$		$\$966$	$\$1000$


Section 179 Deduction
Bonus Depreciation Rate
Section 179 Deduction Limit ($)
Bonus Depreciation Rate (%)
Year
1.2 M
1.0 M
800.0 K
600.0 K
400.0 K
200.0 K
0.0
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025

What I do

Dynamic model with **corporate tax deduction**, **firm heterogeneity**, and **financial frictions**

- Corporate tax deduction yields (S, s) investment decision
- Heterogeneity enables characterization on firm-level response
- Financial frictions limit capital accumulation and create roles for policies

I run experiments to examine the effectiveness of both policies:

1. Comparing four steady states: (1) baseline, (2) raise S179, (3) raise bonus rate, and (4) raise both policies, holding government cost constant
2. Response to TFP and credit shock under all four scenarios

Results and Mechanism

With each policy cost 0.3% of baseline GDP,

- Raising threshold increases GDP by 1.61% and is 50% more effective than bonus rate
- When both policies are implemented, the marginal benefit decreases by 13% (Ohrn (2019))

Why? Two effects play important roles:

- (Un)targeted matters as firms respond differently to the **drop in user cost of capital**
  - small, credit-rationed firms: increase investment
  - large, resourceful firms: decrease investment
- Polices that widen firm distribution exacerbating **misallocation**
  - S179: more concentrated distribution $\Rightarrow$ lower capital dispersion
  - Bonus: more dispersed distribution $\Rightarrow$ higher capital dispersion

Literature

- Large empirical literature on responsiveness of investment to tax credit
  - Public data: Goolsbee (1998), Cummins, Hassett and Hubbard (1996), House and Shapiro (2008), Lamont (1997); Firm/State-level data: Zwick and Mahon (2017), Ohrn (2018), Ohrn (2019)

  New - evaluates aggregate effects of both investment subsidy policies

- Representative firm model on the response of fiscal policies with simplistic tax structure
  - Hall and Jorgenson (1967), Summers, Bosworth, Tobin and White (1981), Fernández-Villaverde (2010), Occhino (2022), Occhino (2023)

  New - accounts for distributional effects and a realistic tax deduction structure

- Heterogeneous firm model on price elasticity of investment and policy transmission
  - Khan and Thomas (2013), House (2014), Koby and Wolf (2020), Winberry (2021)

  New - expands to investment subsidy policies and determines their aggregate effects

Model

Environment

Rep. household: supplies labor and pays labor tax, lends risk-free loans, and owns the firms

Government: collect (1) corporate tax R from firms, (2) labor tax $\tau^n w N^h$ and (3) lump-sum tax T from HH to fund fixed $\bar{G}$

Firms: states $(k, b, \psi, \varepsilon)$; exogenous entry and exit with shock π_d

- DRS production fcn with idio. productivity $\varepsilon \sim \text{AR}(1)$, collateral constraint $b' \leq \theta k'$
- Paying corporate tax based on rate τ^c and taxable income $\mathcal{I}(k', k, \psi)$
- Tax capital ψ depreciates at rate δ^ψ to represent normal depreciation schedule
- Policies limit to equipment $\Rightarrow$ assume on average ω fraction of investment is equipment

Corporate tax structure

Both current and past investment is deductible from taxable income $\mathcal{I}(k', k, \psi)$:

$$\mathcal{I}(k', k, \psi) = \max\left\{ z\varepsilon f(k,n) - wn - \underbrace{\mathcal{J}(k', k)\omega(k' - (1-\delta)k)}_{\text{current}} - \underbrace{\delta^{\psi}\psi}_{\text{past}}, 0 \right\},$$

where $\mathcal{J}(k', k)$ represents the fraction of current equipment investment that is deductible,

$$\mathcal{J}(k', k) = \begin{cases} 1 & \text{if } k' - (1-\delta)k \le \bar{I} \quad \text{(S179 eligible)} \\ \xi \in [0,1] & \text{if } k' - (1-\delta)k > \bar{I} \quad \text{(Not S179 eligible)} \end{cases}.$$

The rest of current equipment investment is accumulated in tax capital ψ:

$$\psi' = (1-\delta^{\psi})\psi + (1 - \mathcal{J}(k', k))\omega(k' - (1-\delta)k).$$

How corporate tax structure impact budget constraints

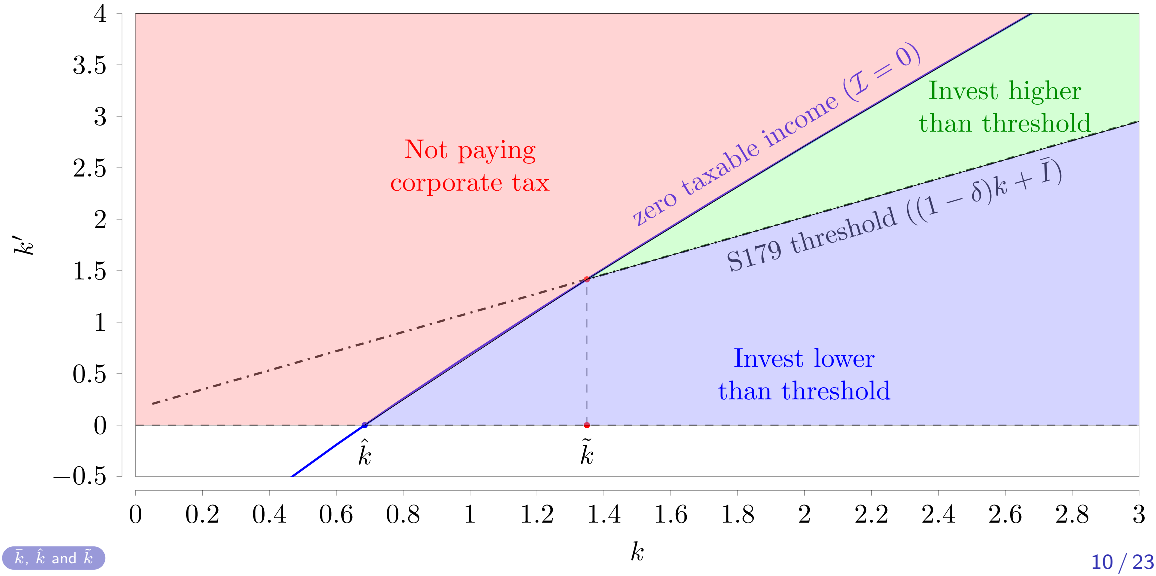
1. If taxable income is nonpositive, then this firm is not paying corporate tax,

$$D = z\varepsilon F(k,n) - wn - b + qb' - (k' - (1-\delta)k)$$

2. If taxable income is positive, then firms' budget constraints are facing tax wedge,

$$\begin{aligned} D &= z\varepsilon F(k,n) - wn - b + qb' - (k' - (1-\delta)k) - \tau^c \mathcal{I}(k',k,\psi) \\ &= \underbrace{(1-\tau^c)}_{\text{flow return: taxed}} (z\varepsilon F(k,n) - wn) - b + qb' \\ &\quad - \underbrace{(1-\tau^c \mathcal{J}(k',k)\omega)}_{\text{cost of } K\text{: subsidized}}(k' - (1-\delta)k) + \tau^c \delta^\psi \psi. \end{aligned}$$

Capital choice state space



$\bar{k}$, $\hat{k}$ and $\tilde{k}$

Value function and discrete choice

Start-of-period value:

$$v^0(k,b,\psi,\varepsilon;\mu) = \pi_d \max_n \left\{ z\varepsilon F(k,n) - wn - b + (1-\delta)k - \tau^c \mathcal{I}(0,k,\psi) \right\} + (1-\pi_d) v(k,b,\psi,\varepsilon;\mu)$$

Discrete choice over three options:

$$v(k,b,\psi,\varepsilon;\mu) = \max \left\{ v^H(k,b,\psi,\varepsilon;\mu), v^L(k,b,\psi,\varepsilon;\mu), v^N(k,b,\psi,\varepsilon;\mu) \right\}$$

For each option, firms maximize dividend and continuation value subject to (1) budget constraints, (2) collateral constraints, and (3) tax capital LoM

Firms that invest higher than threshold

$$v^H(k, b, \psi, \varepsilon_i; \mu) = \max_{D,k',b',n} D + \sum_{j=1}^{N_\varepsilon} \pi_{ij}^\varepsilon Q(\mu) v^0(k', b', \psi', \varepsilon_j; \mu'),$$

subject to

$$\begin{aligned} 0 \leq D = (1 - \tau^c)(z\varepsilon F(k, n) - wn) - b & \\ + qb' - (1 - \tau^c \xi \omega)(k' - (1 - \delta)k) + \tau^c \delta^\psi \psi. & \qquad \text{(Dividend)} \\ k' \in ((1 - \delta)k + \bar{I}, \bar{k}) \text{ and } k > \tilde{k} & \qquad \text{(Choice Sets)} \\ b' \leq \theta k' & \qquad \text{(Collateral)} \\ \psi' = (1 - \delta^\psi)\psi + (1 - \xi)\omega(k' - (1 - \delta)k) & \qquad \text{(Tax capital LoM)} \\ \mu' = \Gamma(\mu) & \qquad \text{(Distribution LoM)} \end{aligned}$$

Equilibrium

$$
\begin{aligned}
\text{Market clear :} \quad & Y = C + \left[(1-\pi_d)\left(K' - (1-\delta)K\right) - \pi_d(1-\delta)K\right] + \pi_d k_0 + \bar{G} \\
\text{Output :} \quad & Y = \int z\varepsilon f(k, n(k,\varepsilon))d\mu \\
\text{Capital :} \quad & K = \int k d\mu; \qquad k_0 = \chi K \\
\text{Labor :} \quad & N = \int n(k,\varepsilon)d\mu \\
\text{Tax Benefit :} \quad & \Psi = \int \psi(k,\psi,\varepsilon)d\mu \\
\text{Debt :} \quad & B = \int b d\mu \\
\text{Corp. revenue :} \quad & R = \tau^c\left(Y - w(\mu)N - \omega\mathcal{J}(I)(K' - (1-\delta)K) - \delta^\psi\Psi\right) \\
\text{Gov. Budget :} \quad & \bar{G} = \tau^n w N^h + R + T
\end{aligned}
$$

Calibration

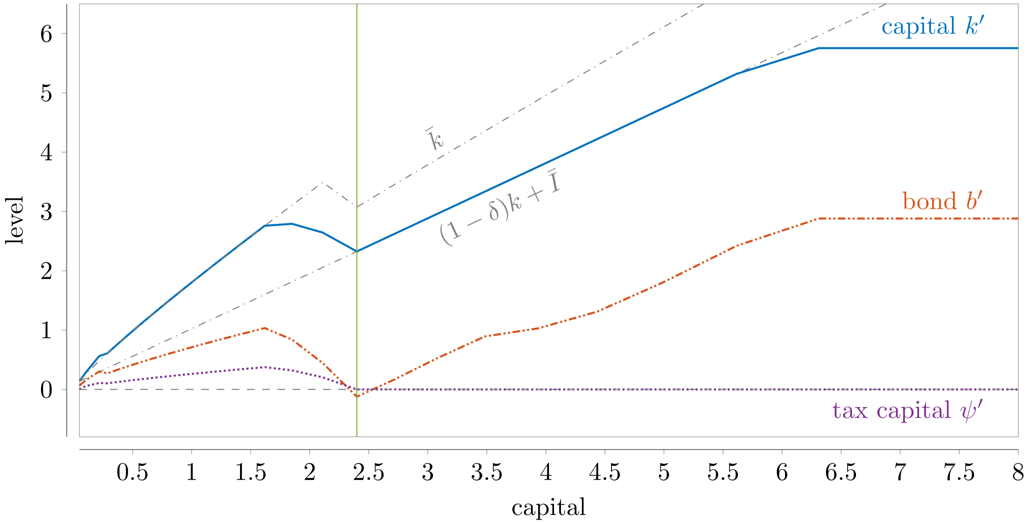
Calibrated Moments

Parameter	Target		Model
$\beta = 0.96$	real interest rate	$= 0.04$	0.04
$\alpha = 0.3$	private capital-output ratio	$= 2.3$	2.03
$\nu = 0.6$	labor share	$= 0.6$	0.6
$\tau^n = 0.25$	government spending-output ratio	$= 0.21$	0.201
$\delta = 0.069$	average investment-capital ratio	$= 0.069$	0.069
$\varphi = 2.05$	hours worked	$= 0.33$	0.33
$\theta = 0.54$	debt-to-assets ratio	$= 0.37$	0.371
$\theta_l = 0.3942$	decreases in debt	$= 0.26$	0.257
$\rho_\varepsilon = 0.6$	std. investment rate distribution	$= 0.337$	0.300
$\sigma_\varepsilon = 0.1$	corr. investment rate distribution	$= 0.058$	0.050
$\omega = 0.6$	lumpy investment $> 20\%$	$= 0.186$	0.185
$\xi = 0.5$	2015 bonus rate		
$\bar{I} = 0.092$	2015 threshold model counterpart Detail		

Exogenous parameters investment rate distribution

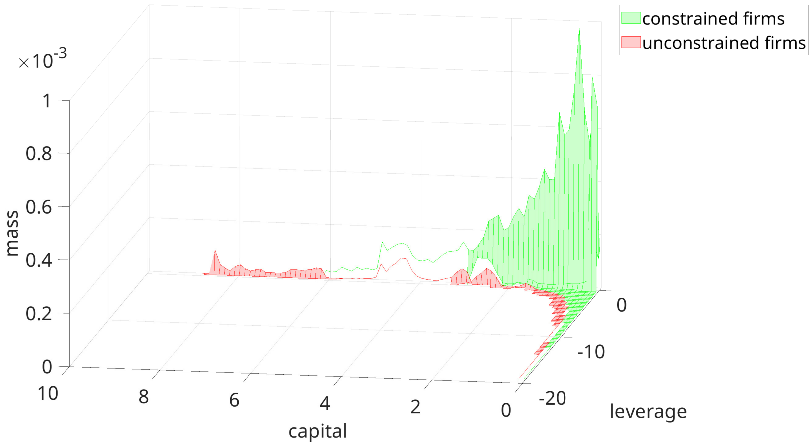
Steady State Result

Productive firms: positive size-leverage relationship ($\varepsilon = 1.1289$)



Unproductive firms

Productive firms voluntarily hold high capital & leverage



flow return $((1-\tau^c)y)$ is taxed while capital is subsidized $((1-\tau^c\omega)I) \Rightarrow$ encourage debt financing

median productivity, minimum productivity

User cost effects: financial condition determines investment behavior

	Description	baseline	S179	bonus	both
$\tilde{T}/Y$	cost of policy / baseline output	-	0.30	0.31	0.42
Y	aggregate output	100 (0.54)	101.61	101.06	102.00
$dY/\tilde{T}$	measurement of efficiency	-	5.40	3.44	4.74
C	aggregate consumption	100 (0.36)	101.55	100.92	101.91
K	aggregate capital	100 (1.10)	104.22	103.21	105.30
D	aggregate dividend	100 (0.03)	102.08	110.14	115.64
$B > 0$	aggregate debt	100 (0.41)	106.35	113.01	112.48
D/μ_{unc}	average dividend: unconstrained	100 (0.37)	87.71	89.25	72.02
$\hat{z}$	measured TFP	100 (1.02)	100.32	100.02	100.38
μ_{unc}	unconstrained firm mass	0.080	0.093	0.099	0.129
μ_{con}	constrained firm mass	0.920	0.907	0.901	0.871
$\mu_{\text{unc}}I$	investment: unconstrained	100 (0.07)	146.52	5.71	63.82
$\mu_{\text{con}}I$	investment: constrained	100 (0.20)	103.77	108.21	111.24

S179: $\bar{I} = 0.292$; bonus: $\xi = 0.69$; both: $(\bar{I}, \xi) = (0.292, 0.69)$

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Validation: raising tax credit coincide with firm-level borrowing ↑ and dividend ↓ (Zwick and Mahon, 2017)

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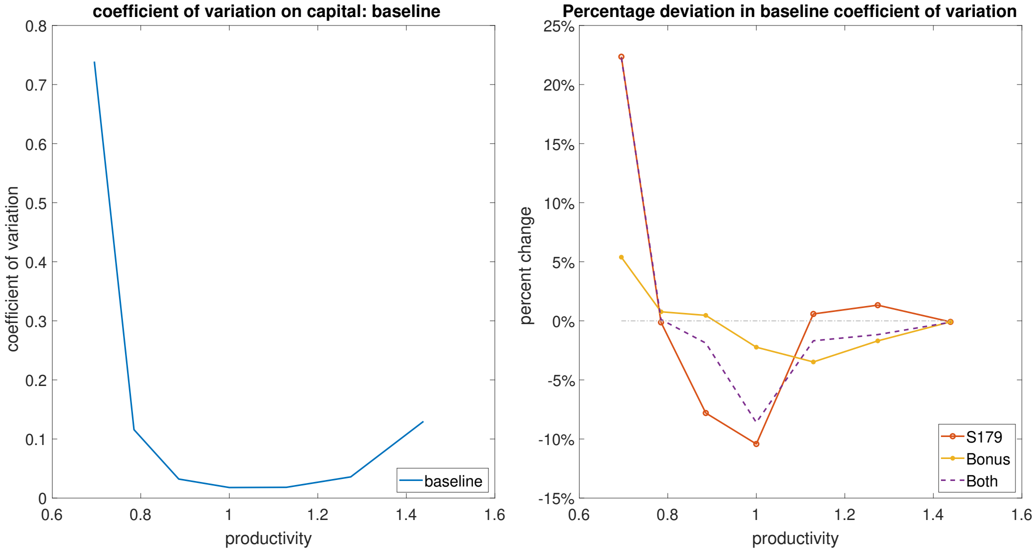
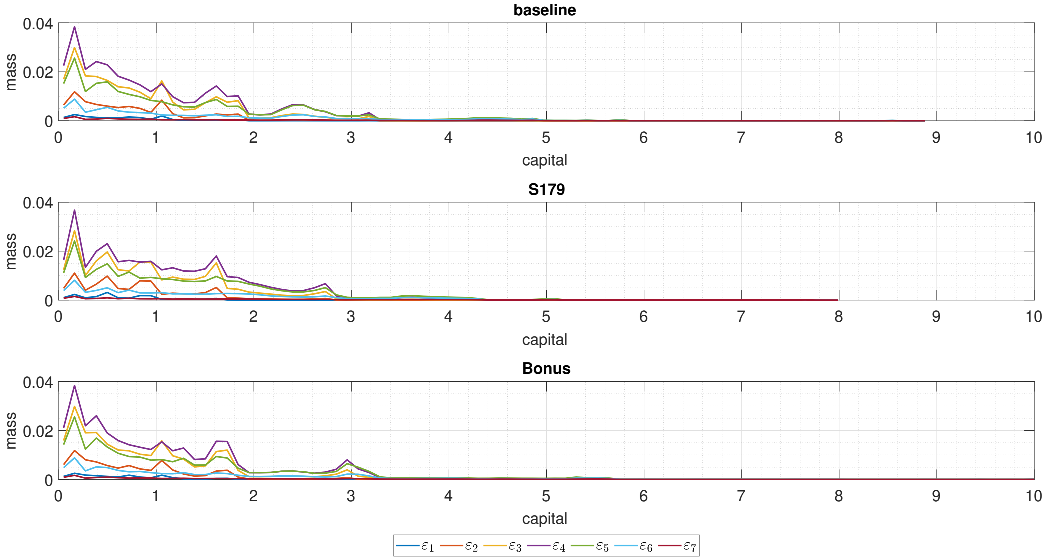
Validation: dividend payers have smaller investment response to policies (Zwick and Mahon, 2017)

Misallocation: less dispersion for median productivity firms in S179

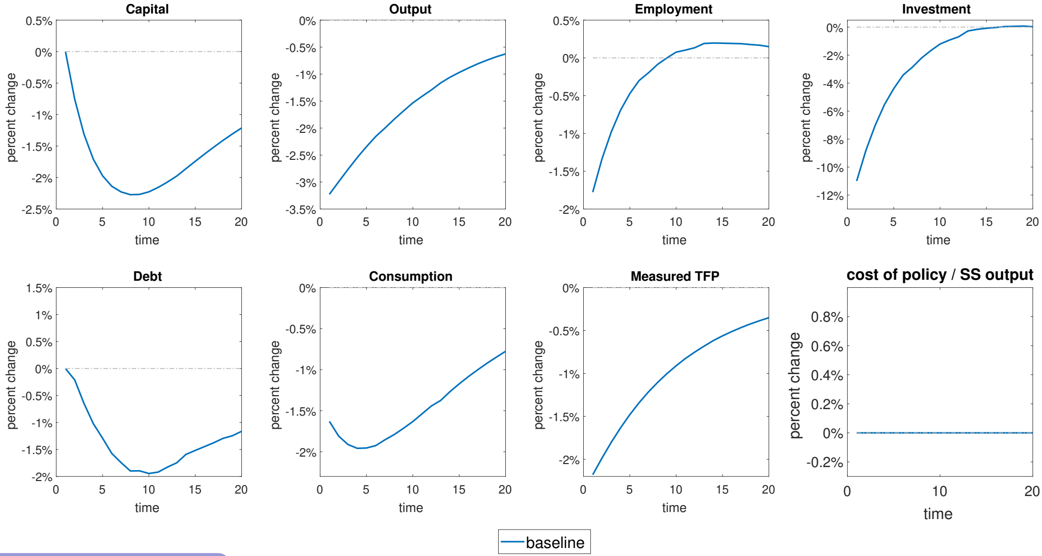


Misallocation: how policy shapes distribution



Dynamic Results

IRF: negative TFP shocks with scale 2.18% and persistence 0.909



Percentage deviation from baseline

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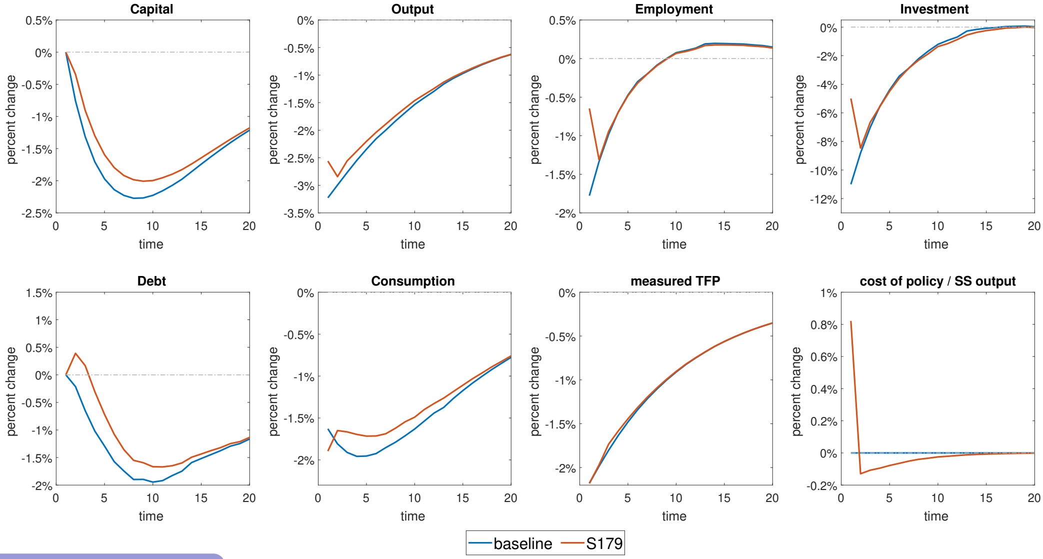

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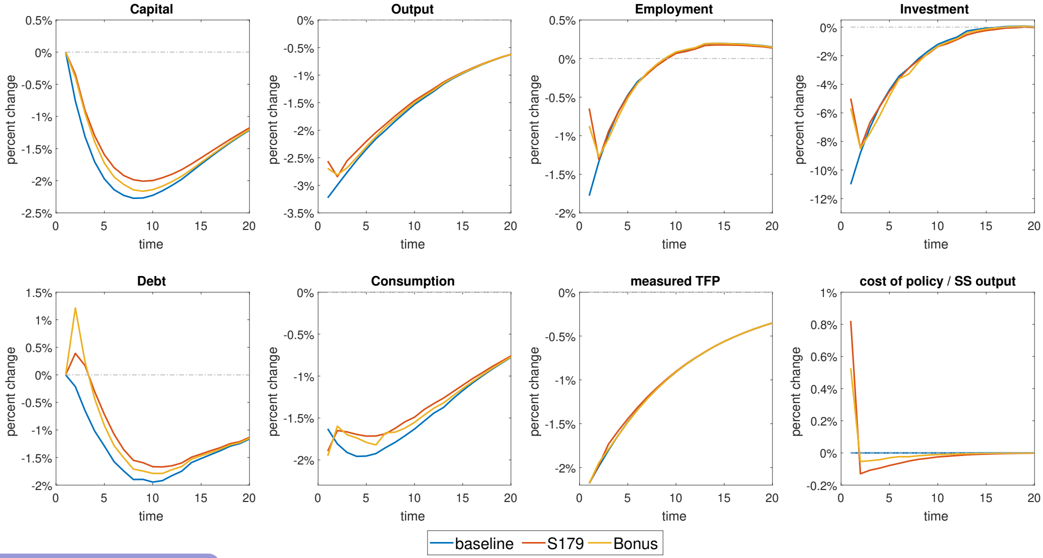

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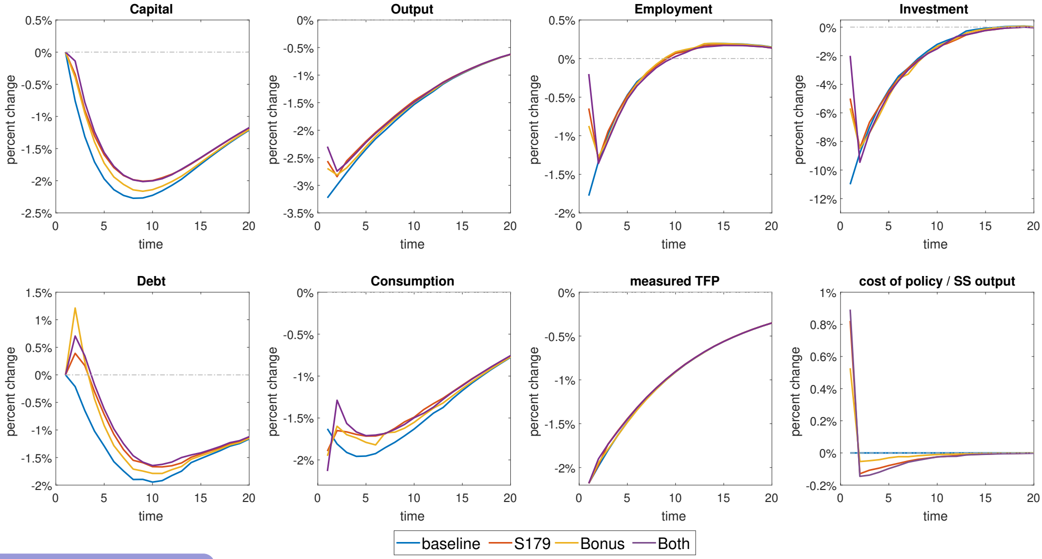

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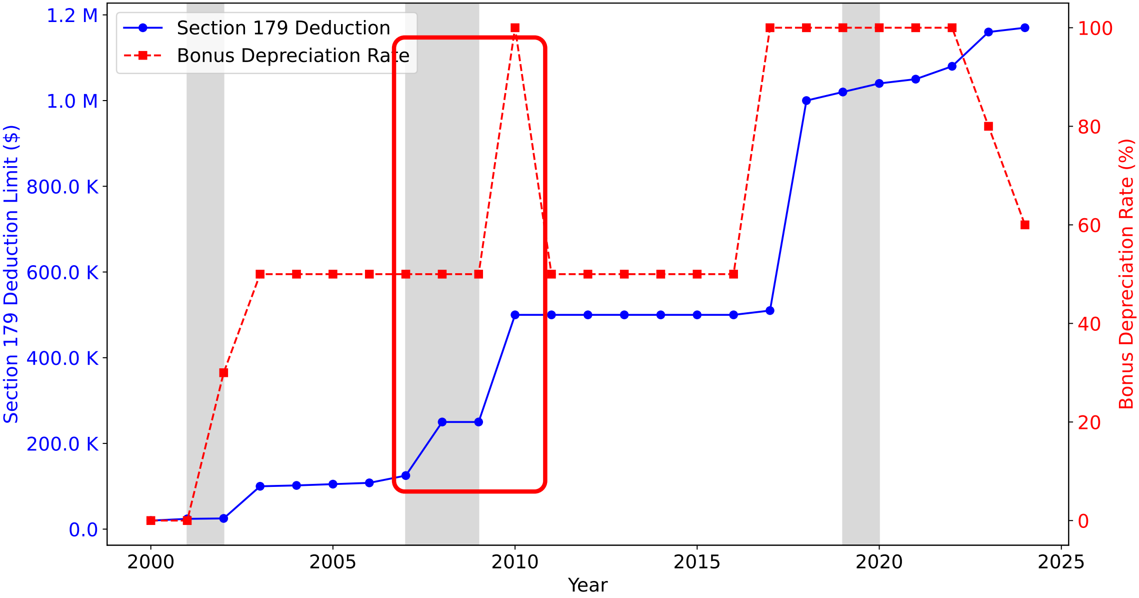
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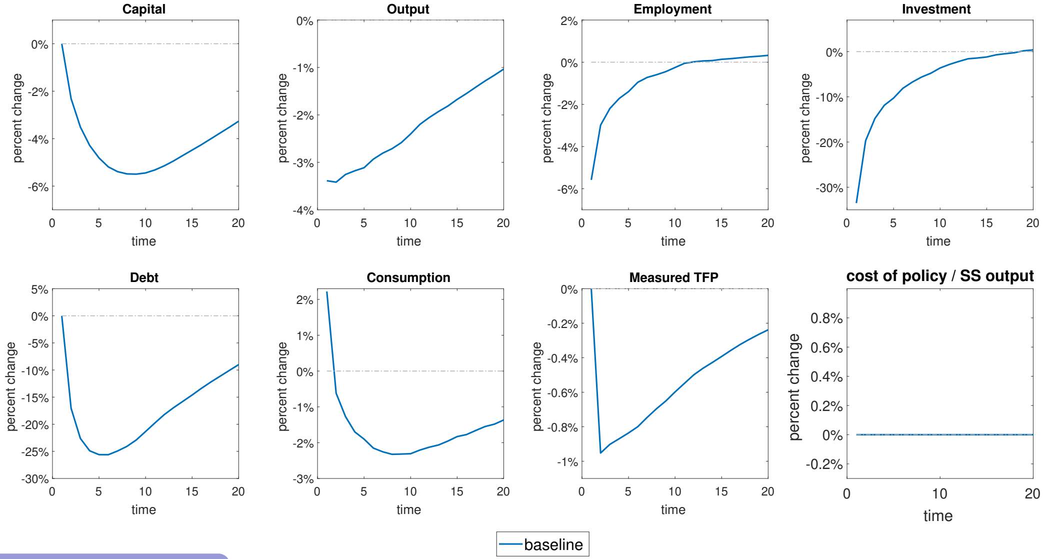

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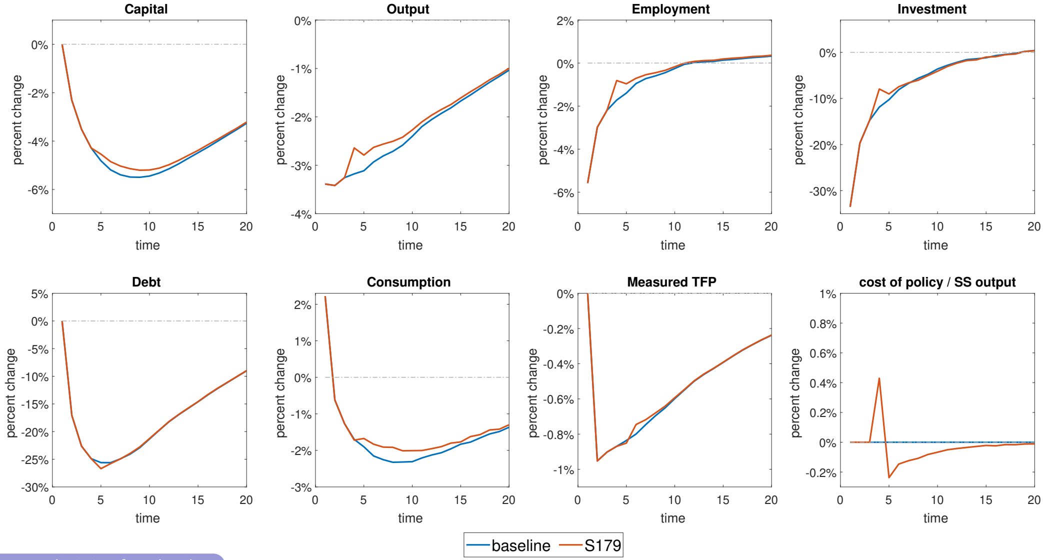

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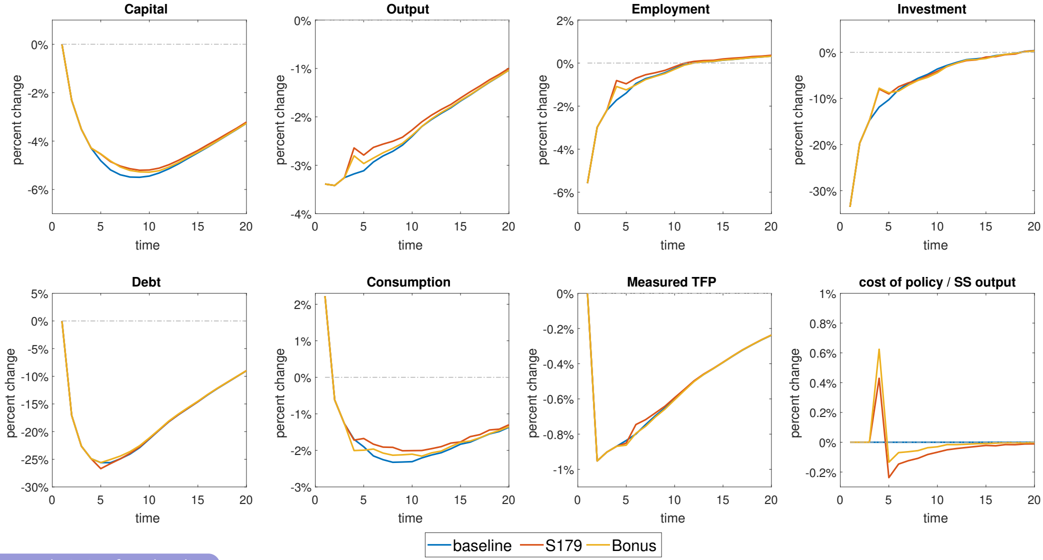

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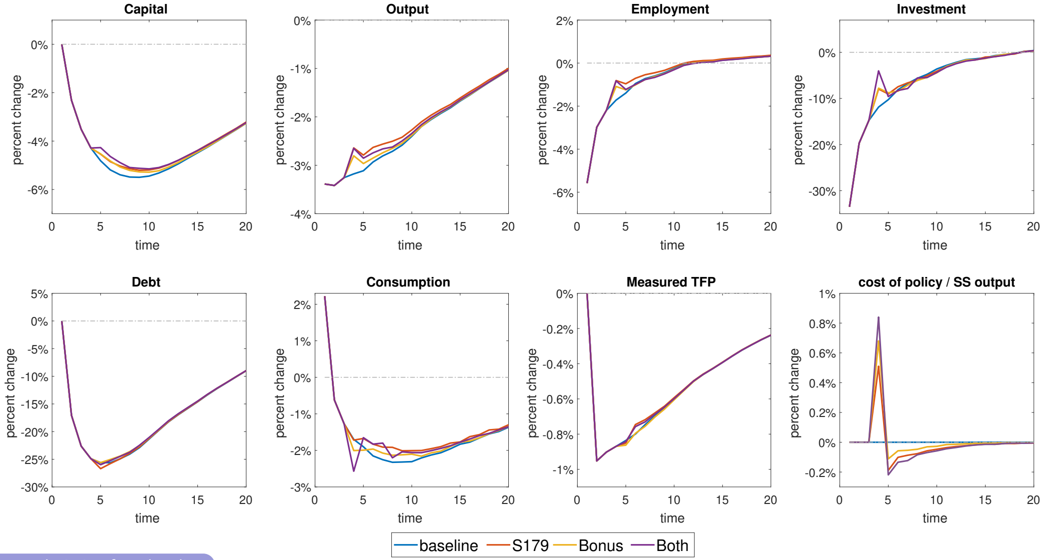

Percentage deviation from baseline

Conclusions

- Equilibrium model of how investment tax credit and subsidy policies boost economy
- Use model to quantify the macroeconomics effects of both subsidy policies:
  - S179 boost GDP by motivating marginal firms to be unconstrained and alleviate misallocation
  - Bonus depreciation is less effective as it motivates dividend payment
  - Implementing both policies simultaneously is less efficient than Section 179
- What's next:
  - Impact on permanently raise S179
  - Realistic firm size distribution using bounded Pareto distribution (Jo and Senga (2019))
    - Current analysis shows that S179 exacerbate misallocation for low productivity firms
  - Policy effectiveness under aggregate uncertainty

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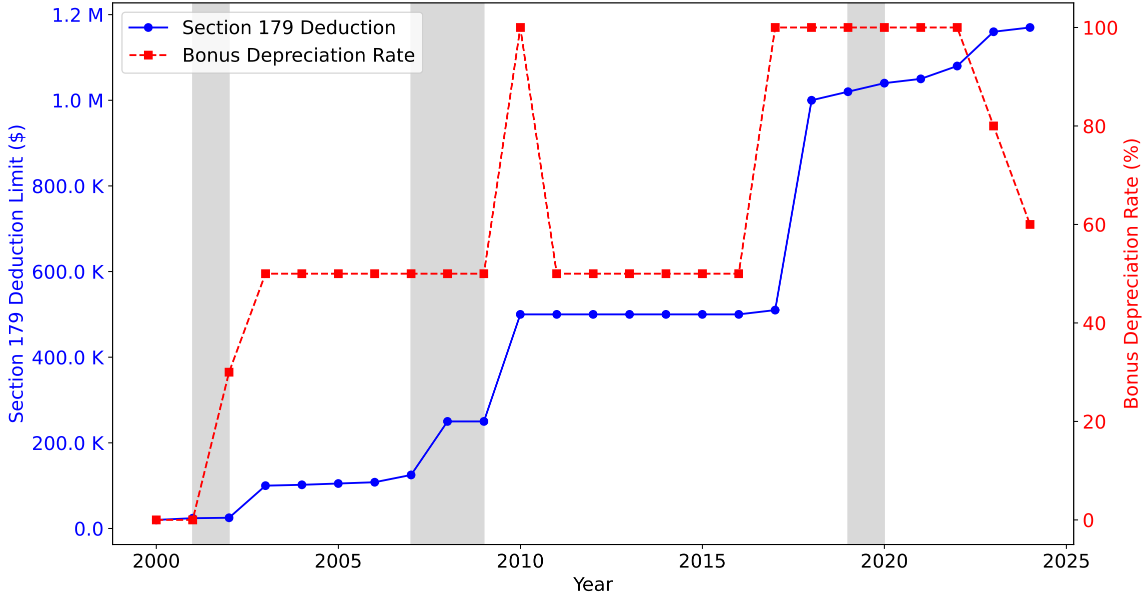
Empirical Literatures


Section 179 Deduction
Bonus Depreciation Rate
Section 179 Deduction Limit ($)
Bonus Depreciation Rate (%)
Year
1.2 M
1.0 M
800.0 K
600.0 K
400.0 K
200.0 K
0.0
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025

Why accelerated depreciation?

1. Tax deduction follows depreciation schedule $\Rightarrow$ value needs to be discounted
2. Stated purpose: boost investment in economic downturn (Committee on Ways and Means 2003)
3. Yet, such tax incentives become part of firms' expectation (Desai and Goolsbee (2004)) Policy change
4. Policy response is heterogeneous across firms and industries (Zwick and Mahon (2017))
   - firms respond to immediate cash flows but not future realization of cash flow
   - industries with longer-duration capital respond more Diff-n-diff
5. Policy adoption by states allows evaluation of effectiveness of subsidy policies (Ohrn (2019))
   - The $\$100000$ increases in Section 179 threshold boost 2.06% more investment
   - Both policies are weakening each other conforming states

Example: Modified Accelerated Cost Recovery System (MARCS)

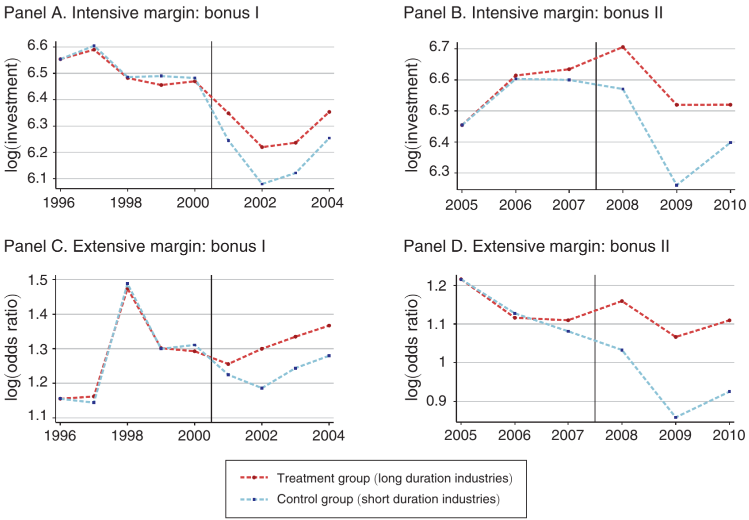
Shawn bought and placed in service a used pickup for $\$15,000$ on March 5,1998 . The pickup has a 5 year class life. His depreciation deduction for each year is computed in the following table.

Year	Cost $\times$ MACRS %	Depreciation
1998	$\$15,000 \times 20.00\%$	$\$3,000$
1999	$\$15,000 \times 32.00\%$	$\$4,800$
2000	$\$15,000 \times 19.20\%$	$\$2,880$
2001	$\$15,000 \times 11.52\%$	$\$2,880$
2002	$\$15,000 \times 11.52\%$	$\$2,880$
2003	$\$15,000 \times 5.76\%$	$\$864$
Total		$\$15,000$

MACRS Percentage Table

Year	3 Year	5 Year	7 Year
1	33.33%	20.00%	14.29%
2	44.45%	32.00%	24.49%
3	14.81%	19.20%	17.49%
4	7.41%	11.52%	12.49%
5		11.52%	8.93%
6		5.76%	8.92%
7			8.93%
8			4.46%

Long-duration industries respond more to bonus depreciation



Conforming states enjoys 18% of investment boosts

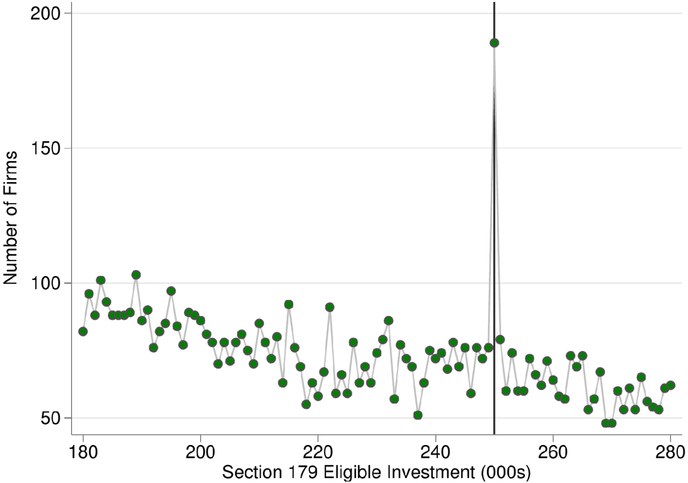
Table: Investment Impacts of State Bonus and State 179

Dependent Var:	ln CapEx			
Specification	(1)	(2)	(3)	(4)
State Bonus	0.038		0.031	0.174^{**}
	(0.036)		(0.037)	(0.073)
State 179		0.013	0.012	0.020^{**}
		(0.009)	(0.009)	(0.009)
Bonus 179 Interaction				-0.047^{***}
				(0.016)
Year FE	✓	✓	✓	✓
State Controls, Time Trends	✓	✓	✓	✓
NAICS x Year FE	✓	✓	✓	✓
Adj. R-Square	0.286	0.286	0.286	0.286
State x NAICS Groups	883	883	883	883
Observations	11,987	11,987	11,987	11,987

Notes: Table 5 presents coefficient estimates of the impact of State 179 and State Bonus on Ln CapEx. All specifications include include year fixed effects, State $\times$ NAICS fixed effects, state linear time trends, NAICS $\times$ Year fixed effects, and a robust set if time-varying state level controls to capture the effect of changes in state politics, productivity, population, and finances. Standard errors are at the state level and are reported in parentheses. Statistical significance at the 1 percent level is denoted by $***$, 5 percent by $**$, and 10 percent by $*$.

Back

Firm distribution in 2008-2009

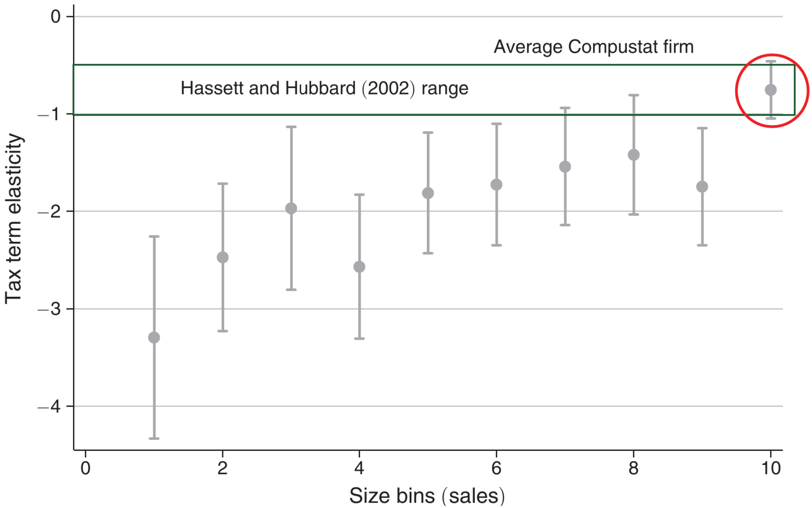


Heterogeneity in investment response

Table: Heterogeneity by Ex Ante Constraints

	Sales		Div payer?		Lagged cash	
	Small	Big	No	Yes	Low	High
$z_{N,t}$	6.29	3.22	5.98	3.67	7.21	2.76
	(1.21)	(0.76)	(0.88)	(0.97)	(1.38)	(0.88)
Equality test	$p = 0.030$		$p = 0.079$		$p = 0.000$	
Observations	177,620	255,266	274,809	127,523	176,893	180,933
Clusters (firms)	29,618	29,637	39,195	12,543	45,824	48,936
R^2	0.44	0.76	0.69	0.80	0.81	0.76

Heterogeneous response to bonus depreciation



How to determine $\bar{I}$

In 2015,

- Real investment: $\$2459.8$B (Table 3.7 BEA)
- Numbers of firms in US: $5,900,731$ (SUSB)
- Average investment: $\$416,853$
- Section 179 deduction: $\$500,000$
- Choose $\bar{I} = \frac{500{,}000}{416{,}853} \times$ aggregate investment ~ 0.092

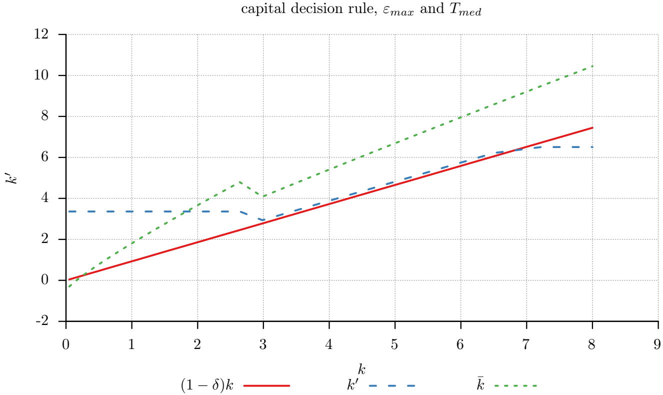
Model Appendix

Firms that pay corporate tax and those which did not

Let $\bar{k} = \frac{y - wn - \delta^{\psi}\psi}{\mathcal{J}(I)\omega} + (1-\delta)k$ be the upper bound for capital such that taxable is nonnegative.

Let $\tilde{k}$ be the intersection between k' and $\bar{k}$.

For firms with $k > \tilde{k}$: binary choice; $k \leq \tilde{k}$: no effect on capital decision and exiting cash



Unconstrained firms' problem: positive taxable income

Let W function be the value function for unconstrained firms.

The start-of-period value before the realization of exit shock is

$$W^0(k,b,\psi,\varepsilon;\mu) = p(\mu)\pi_d \max_n \left\{ z\varepsilon F(k,n) - wn - b + (1-\delta)k - \tau^c \mathcal{I}(0,k,\psi) \right\} + (1-\pi_d) W(k,b,\psi,\varepsilon;\mu)$$

Upon survival, unconstrained firms undertake binary choice,

$$W(k,b,\psi,\varepsilon;\mu) = \max \left\{ W^L(k,b,\psi,\varepsilon;\mu), W^H(k,b,\psi,\varepsilon;\mu), W^N(k,b,\psi,\varepsilon;\mu) \right\}.$$

Firm's current value: $W(k,b,\psi,\varepsilon;\mu) = W(k,0,\psi,\varepsilon;\mu) - pb$

Start-of-period value: $W^0(k,b,\psi,\varepsilon;\mu) = W^0(k,0,\psi,\varepsilon;\mu) - pb$.

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Unconstrained firms' problem (Cont.)

Given these transformation, firms' problem can be rewritten as

$$
\begin{aligned}
W^L(k,b,\psi,\varepsilon_i;\mu) = p\left((1-\tau^c)(z\varepsilon f(k,n)-wn)-b+(1-\tau^c\omega)(1-\delta)k+\tau^c\delta^\psi\psi\right) \\
+\max_{k'\leq(1-\delta)k+\bar{I}}\left\{-p(1-\tau^c\omega)k'+\beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu')\right\},\\
W^H(k,b,\psi,\varepsilon_i;\mu) = p\left((1-\tau^c)(z\varepsilon f(k,n)-wn)-b+(1-\tau^c\omega\xi)(1-\delta)k+\tau^c\delta^\psi\psi\right) \\
+\max_{k'\in((1-\delta)k+\bar{I},\bar{k})}\left\{-p(1-\tau^c\omega\xi)k'+\beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu')\right\},\\
W^N(k,b,\psi,\varepsilon_i;\mu) = p\left(z\varepsilon f(k,n)-wn-b+(1-\delta)k\right) \\
+\max_{k'\geq\bar{k}}\left\{-pk'+\beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu')\right\},
\end{aligned}
$$

Unconstrained capital decision rule

Targeted capitals are

$$k_H^*(k,\psi,\varepsilon) = \arg\max_{k' > \bar{I} + (1-\delta)k} \left\{ -p(1-\tau^c\omega\xi)k' + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} W^0(k', 0, \psi', \varepsilon_j; \mu') \right\},$$

$$k_L^*(k,\psi,\varepsilon) = \arg\max_{k' \leq \bar{I} + (1-\delta)k} \left\{ -p(1-\tau^c\omega)k' + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} W^0(k', 0, \psi', \varepsilon_j; \mu') \right\}.$$

Therefore, corresponding unconstrained capital decision rule follows (S, s) policy:

$$K^w(k,\psi,\varepsilon) = \begin{cases} k_H^*(k,\psi,\varepsilon) & \text{if } W^H(k,b,\psi,\varepsilon_i;\mu) > W^L(k,b,\psi,\varepsilon_i;\mu) \\ k_L^*(k,\psi,\varepsilon) & \text{if } W^H(k,b,\psi,\varepsilon_i;\mu) \leq W^L(k,b,\psi,\varepsilon_i;\mu) \end{cases}.$$

When taxable income is negative

When taxable income is negative, I slice the state space into two area:

1. Upper bar implied by zero taxable income: $\bar{k} = \dfrac{z\varepsilon f(k,n) - wn - \delta^{\psi}\psi}{\mathcal{J}(k',k)\omega} + (1-\delta)k$

2. $\bar{k}$ can be too low or even negative. In either case, the lower bound for capital should be solved by

$$\underline{k}^{w} = \arg\max_{k'} \left\{ -pk' + \beta \sum_{j=1}^{N_{\varepsilon}} \pi^{\varepsilon}_{ij} W^{0}(k', 0, \psi', \varepsilon_j; \mu') \right\},$$

that is, the unconstrained level of capital when firm is not paying tax and doesn't have carry-over tax credit.

Unconstrained firms' problem when taxable income is nonpositive

The following question defines the lower bound for capital when the firms are having zero or negative taxable income:

$$W^N(k, b, \psi, \varepsilon_i; \mu) = p(y - wn - b + (1-\delta)k) + \max_{k'} \left\{ -pk' + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} W^0(k', 0, \psi', \varepsilon_j; \mu') \right\},$$

where

$$\psi' = (1-\delta^\psi)\psi + (1 - \mathcal{J}(I))\omega I \qquad \text{if } (y - wn - \mathcal{J}(I)\omega I - \delta^\psi \psi) \geq 0$$
$$\psi' = \psi + \omega I - y + wn \qquad \text{if } (y - wn - \mathcal{J}(I)\omega I - \delta^\psi \psi) < 0$$

Minimum Saving Policy

The *minimum saving policy*, $B^w(k, \psi, \varepsilon)$, can be recursively calculated by the following two equations with both policy functions for labor, $N(k, \varepsilon)$, and capital, $K^w(k, \psi, \varepsilon)$,

$$
\begin{aligned}
B^w(k, \psi, \varepsilon) &= \min_{\varepsilon_j} \left(\tilde{B}(K^w(k, \psi, \varepsilon_i), \psi', \varepsilon_j) \right) \\
\tilde{B}(k, \psi, \varepsilon_i) &= \frac{1}{1 - \tau^c \tau^b} \Big((1 - \tau^c) \pi(k, \varepsilon_i) + \tau^c \delta^\psi \psi \\
&\quad - \left(1 - \tau^c \omega \mathcal{J}\left(K^w(k, \psi, \varepsilon_i) - (1 - \delta)k\right)\right) \left(K^w(k, \psi, \varepsilon_i) - (1 - \delta)k\right) \\
&\quad + q \min\left\{B^w(k, \psi, \varepsilon_i), \theta K^w(k, \psi, \varepsilon_i)\right\} \Big),
\end{aligned}
$$

I set interest deductability $\tau^b = 0$ as minimum saving policy cannot converge with positive τ^b. As $\frac{1}{q}$ is the risk-free rate, firms are paying $\frac{q}{1 - \tau^c \tau^b} > q$, implies the interest rate that firms are paying is less than risk-free rate.

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Constrained firms' problem

Constrained firms' bond decision is implied by binding collateral constraints, i.e., $B^c(k,b,\psi,\varepsilon) = \theta K^c(k,b,\psi,\varepsilon)$, and the capital decision $K^c(k,b,\psi,\varepsilon)$ has to be determined recursively.

$$J(k,b,\psi,\varepsilon;\mu) = \max\left\{J^H(k,b,\psi,\varepsilon;\mu), J^L(k,b,\psi,\varepsilon;\mu), J^N(k,b,\psi,\varepsilon;\mu)\right\},$$

and J^H, J_L and J_N are defined as

Constrained firms' problem: invest higher than threshold

$$J^H(k,b,\psi,\varepsilon;\mu) = \max_{k'\in\Omega_H(k,b,\psi,\varepsilon)} \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^{\varepsilon}V^0(k',b_H^2(k'),\psi',\varepsilon_j;\mu'),$$

subject to

$$b_H(k') = -\frac{1}{q}\Big((1-\tau^c)\pi(k,\varepsilon) - b + \tau^c\delta^\psi\psi - (1-\tau^c\omega\xi)(k'-(1-\delta)k)\Big),$$

$$\psi' = (1-\delta^\psi)\psi + (1-\xi)(k'-(1-\delta)k),$$

The choice sets for H-type firms' problem are defined by

$$\Omega_H(k,b,\psi,\varepsilon) = \left[\max\left\{(1-\delta)k+\bar{I}, \min\left\{\bar{k}_H(k,b,\psi,\varepsilon),\bar{k}\right\}\right\}, \min\left\{\bar{k}_H(k,b,\psi,\varepsilon),\bar{k}\right\}\right],$$

Maximum affordable capital: $\bar{k}_H = \frac{(1-\tau^c)\pi(k,\varepsilon)+\tau^c\delta^\psi\psi-b+(1-\tau^c\omega\xi)(1-\delta)k}{1-\tau^c\omega\xi-q\theta}$

Constrained firms' problem: invest lower than threshold

$$J^L(k,b,\psi,\varepsilon;\mu) = \max_{k'\in\Omega_L(k,b,\psi,\varepsilon)} \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} V^0(k', b_L^2(k'), \psi', \varepsilon_j; \mu'),$$

subject to

$$b_L(k') = \frac{1}{q}\Big(-(1-\tau^c)\pi(k,\varepsilon) + b - \tau^c\delta^\psi\psi + (1-\tau^c\omega)(k' - (1-\delta)k)\Big),$$

$$\psi' = (1-\delta^\psi)\psi.$$

Choice set: $\Omega_L(k,b,\psi,\varepsilon) = \Big[0, \max\Big\{0, \min\Big\{(1-\delta)k + \bar{I}, \bar{k}_L(k,b,\psi,\varepsilon)\Big\}\Big\}\Big]$,

Maximum affordable capital: $\bar{k}_L = \frac{(1-\tau^c)\pi(k,\varepsilon)+\tau^c\delta^\psi\psi - b + (1-\tau^c\omega)(1-\delta)k}{1-\tau^c\omega - q\theta}$.

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When taxable income is negative for constrained firms

$$J^N(k,b,\psi,\varepsilon;\mu) = \max_{k' \in \Omega^N(k,b)} \beta \sum_{j=1}^{N_\varepsilon} \pi^\varepsilon_{ij} V^0(k', b_N(k'), \psi', \varepsilon_j; \mu')$$

subject to

$$b_N(k') = -\frac{1}{q}\left(z\varepsilon f(k,n) - wn - b - (k' - (1-\delta)k)\right)$$

$$\psi' = (1-\delta^\psi)\psi + (1-\xi)\omega(k' - (1-\delta)k)$$

$$\Omega^N(k,b,\varepsilon) = \left[\min\left\{\max\left\{\bar{k}, 0\right\}, \bar{k}_N(k,b,\varepsilon)\right\}, \bar{k}_N(k,b,\varepsilon)\right]$$

$$\bar{k}_N(k,b,\varepsilon) = \frac{z\varepsilon f(k,n) - wn - b + (1-\delta)k}{1-q\theta}$$

When taxable income is nonpositive

- In principle, IRS will not give tax subsidy if taxable income is negative.
- User cost of capital for firms with nonpositive taxable income is not affected by deduction.
- Solving for $\mathcal{I} \geq 0$ gives the upper threshold for capital decision that pays corporate tax:

$$k' \leq \bar{k} \equiv \frac{z\varepsilon f(k,n) - wn - \delta^{\psi}\psi}{\xi\omega} + (1-\delta)k,$$

Assume $F(k,n) = k^{\alpha}n^{\nu}$, I solve for $\bar{k} = (1-\delta)k + \bar{I}$ and get,

$$\tilde{k} \equiv \left(\frac{\delta^{\psi}\psi + \xi\omega\bar{I}}{A(w)z^{\frac{1}{1-\nu}}\varepsilon^{\frac{1}{1-\nu}}}\right)^{\frac{1-\nu}{\alpha}}$$

Firms that invest lower than threshold

$$v^L(k, b, \psi, \varepsilon_i; \mu) = \max_{D,k',b',n} D + \sum_{j=1}^{N_\varepsilon} \pi^{\varepsilon}_{ij} Q(\mu) v^0(k', b', \psi', \varepsilon_j; \mu'), \tag{1}$$

subject to

$$0 \leq D = (1-\tau^c)(z\varepsilon F(k,n) - wn) - b$$
$$+ qb' - (1-\tau^c\omega)(k' - (1-\delta)k) + \tau^c\delta^\psi\psi. \tag{Dividend}$$
$$k' \leq (1-\delta)k + \bar{I} \text{ and } k > \hat{k} \tag{Choice Sets}$$
$$b' \leq \theta k' \tag{Collateral}$$
$$\psi' = (1-\delta^\psi)\psi \tag{Tax Benefit LoM}$$
$$\mu' = \Gamma(\mu) \tag{Distribution LoM}$$

Firms not paying corporate tax

$$v^N(k, b, \psi, \varepsilon_i; \mu) = \max_{D,k',b',n} D + \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} Q(\mu) v^0(k', b', \psi', \varepsilon_j; \mu'), \tag{2}$$

subject to

$$0 \leq D = z\varepsilon F(k, n) - wn - b + qb' - (k' - (1-\delta)k) \qquad \text{(Dividend)}$$

$$k' \geq \max(\bar{k}, 0) \qquad \text{(Choice Sets)}$$

$$b' \leq \theta k' \qquad \text{(Collateral)}$$

$$\psi' = (1-\delta^{\psi})\psi + (1 - \mathcal{J}(k', k))\omega(k' - (1-\delta)k) \qquad \text{(Tax Benefit LoM)}$$

$$\mu' = \Gamma(\mu) \qquad \text{(Distribution LoM)}$$

Household

In each period, representative households maximize their lifetime utility by choosing consumption, c, labor supply, n^h, future firm shareholding, λ', and future bond holding, a':

$$V^h(\lambda, a; \mu) = \max_{c, n^h, a', \lambda'} \left\{ u(c, 1-n^h) + \beta V^h(\lambda', a'; \mu') \right\}$$

$$\text{s.t.} \quad c + q(\mu)a' + \int \rho_1(k', b', \psi', \varepsilon'; \mu)\lambda'(d[k' \times b' \times \psi' \times \varepsilon']) \leq (1-\tau^n)w(\mu)n^h, \quad (3)$$

$$+ a + \int \rho_0(k, b, \psi, \varepsilon; \mu)\lambda(d[k \times b \times \psi \times \varepsilon]) + R - T$$

where $\rho_0(k, b, \psi, \varepsilon)$ is the dividend-inclusive price of the current share, $\rho_1(k', b', \psi', \varepsilon')$ is the ex-dividend price of the future share, τ^n is payroll tax, R is the steady state government lump-sum rebates to households, and T is lump-sum tax to fund policy changes.

Clearing Prices

From household problem we get three optimality conditions:

- After-tax wage fully compensate MRS between leisure and consumption:

$$w(\mu) = \frac{1}{(1-\tau^n)} \frac{D_2 u(c, 1-n^h)}{D_1 u(c, 1-n^h)}$$

- As there's no agg. shock, SDF equals discounting factor equals to bond prices

$$Q(\mu) = \beta \frac{D_1 u(c, 1-n^h)}{D_1 u(c, 1-n^h)} = \beta = q$$

- With $u(c, 1-n^h) = \log c + \varphi(1-n^h)$,

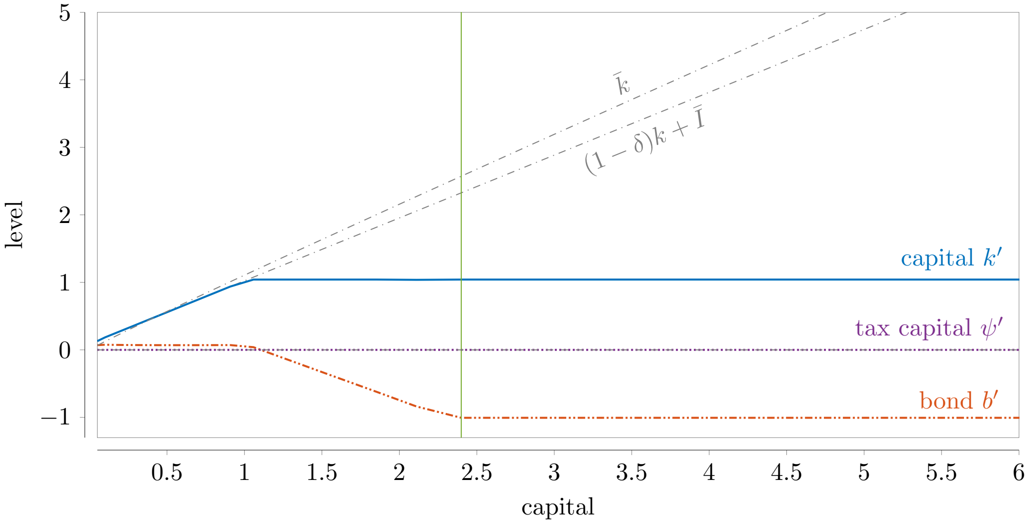
$$w(\mu) = \frac{\varphi c}{(1-\tau^n)} = \frac{\varphi}{(1-\tau^n)p}$$

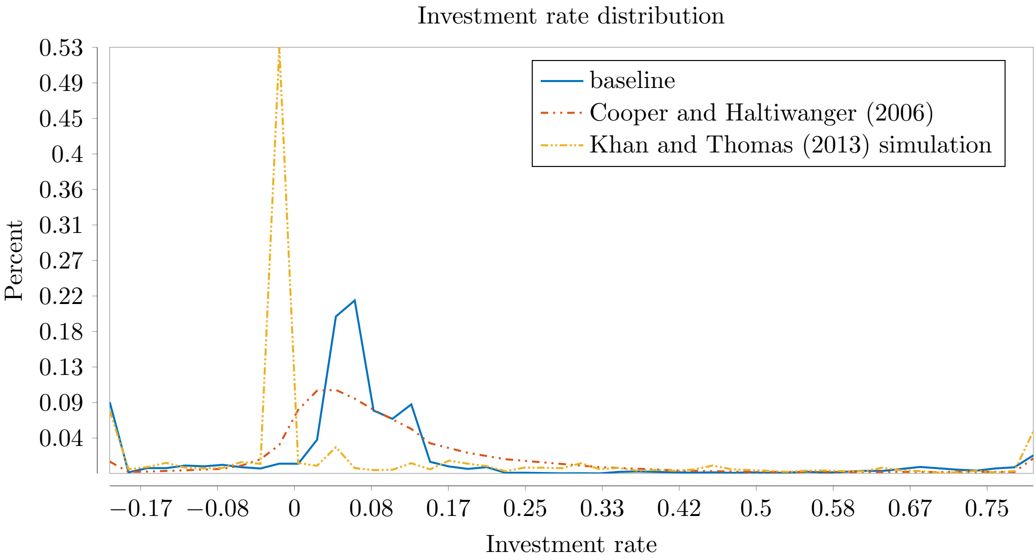
Parameters

	Parameter	Value	Reason
Calibrated parameters			
Discount rate	β	0.96	4% real interest rate
Capital share	α	0.3	private capital-output ratio
Labor share	ν	0.6	labor share
Labor tax rate	τ^n	0.25	government spending-output ratio
Preference for leisure	φ	2.05	one-third of time endowment
Capital depreciation rate	δ	0.069	average investment-equipment ratio
Collateralizability	θ	0.54	debt-to-capital ratio
Credit crunch	θ_l	0.3942	26% decrease in debt
Persistence of ε	ρ_ε	0.6	investment distribution moments
Standard deviation of ε	$\sigma_{\eta_\varepsilon}$	0.113	investment distribution moments
Equipment-capital ratio	ω	0.6	investment distribution moments
Exogenous parameters			
fraction of entrants capital endowment	χ	0.1	10% of aggregate capital
exogenous exit rate	π_d	0.1	10% entry and exit
Corporate tax rate	τ^c	0.21	US Tax schedule after TCJA
Tax benefit depreciation rate	δ^ψ	0.138	$\delta^\psi = 2\delta$ (Double-declining balance)
Bonus depreciation rate in baseline	ξ	0.5	2015 bonus rate
Section 179 threshold	$\bar{I}$	0.092	2015 threshold model counterpart

Calibration

Unproductive firm: similar to standard model ($\varepsilon = 0.7847$)




Investment rate distribution
Percent
0.53
0.49
0.45
0.4
0.36
0.31
0.27
0.22
0.18
0.13
0.09
0.04
baseline
Cooper and Haltiwanger (2006)
Khan and Thomas (2013) simulation
−0.17
−0.08
0
0.08
0.17
0.25
0.33
0.42
0.5
0.58
0.67
0.75
Investment rate

Steady State Comparison

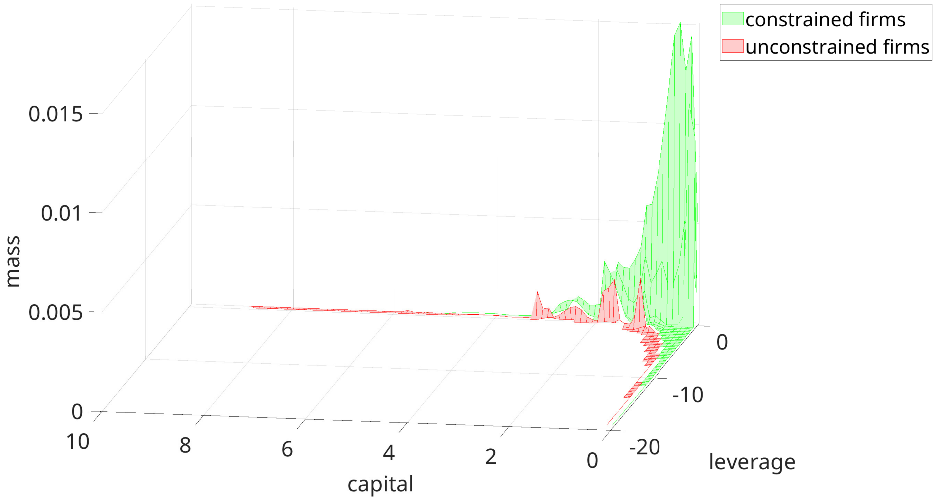
	Description	baseline	S179	bonus	both
$\tilde{T}/Y$	cost of policy / baseline output	-	0.30	0.31	0.42
Y	aggregate output	100 (0.54)	101.61	101.06	102.00
C	aggregate consumption	100 (0.36)	101.55	100.92	101.91
K	aggregate capital	100 (1.10)	104.22	103.21	105.30
I	aggregate investment	100 (0.08)	104.22	103.21	105.30
N	aggregate labor	100 (0.33)	100.06	100.13	100.09
$B > 0$	aggregate debt	100 (0.41)	106.35	113.01	112.48
R	corporate tax revenue	100 (0.03)	94.25	94.08	91.89
$\hat{z}$	measured TFP	100 (1.02)	100.32	100.02	100.38
$dY/\tilde{T}$		-	5.40	3.44	4.74
$dC/\tilde{T}$		-	3.42	1.98	2.98
$dI/\tilde{T}$		-	1.98	1.46	1.76

Notes: output, capital, debt, labor, consumption, government spending, measured TFP are expressed as fractions of baseline value.

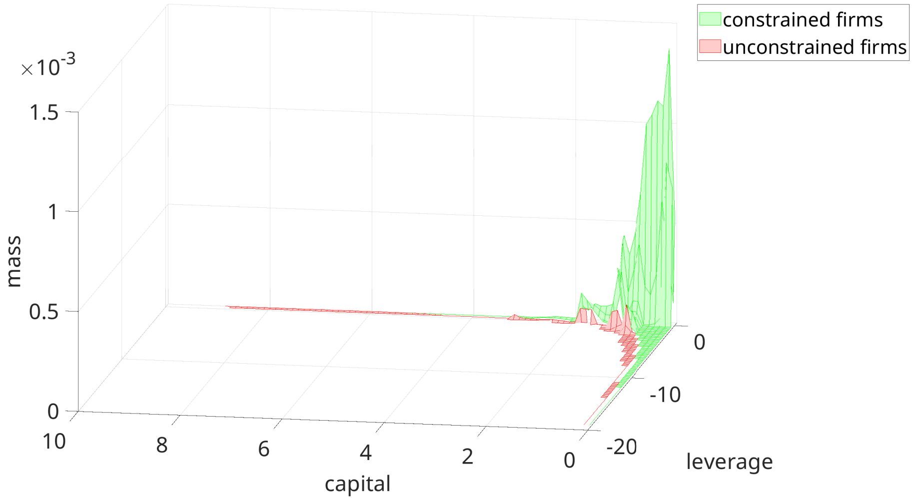
Steady State Comparison (Cont.)

	Description	baseline	S179	bonus	both
Prices					
p	marginal utility of consumption	100 (2.80)	98.47	99.08	98.13
w	wage	100 (0.97)	101.55	100.92	101.91
Distribution					
μ_{unc}	unconstrained firm mass	0.080	0.093	0.099	0.129
μ_{con}	constrained firm mass	0.920	0.907	0.901	0.871
$\mu_{\text{unc}}K$	capital: unconstrained	100 (2.70)	94.31	99.78	92.51
$\mu_{\text{con}}K$	capital: constrained	100 (0.96)	104.36	100.39	100.03
$\mu_{\text{unc}}I$	investment: unconstrained	100 (0.01)	170.53	7.04	102.47
$\mu_{\text{con}}I$	investment: constrained	100 (0.18)	102.29	106.01	105.38
Financial Variables					
D	dividend	100 (0.03)	102.08	110.14	115.64
$\mu V(\cdot)$	average firm value	100 (3.41)	98.02	94.13	95.35
μc	user cost of capital	100 (0.14)	86.26	97.44	85.45
τ^*	effective corporate tax rate	100 (0.10)	92.43	94.08	91.68

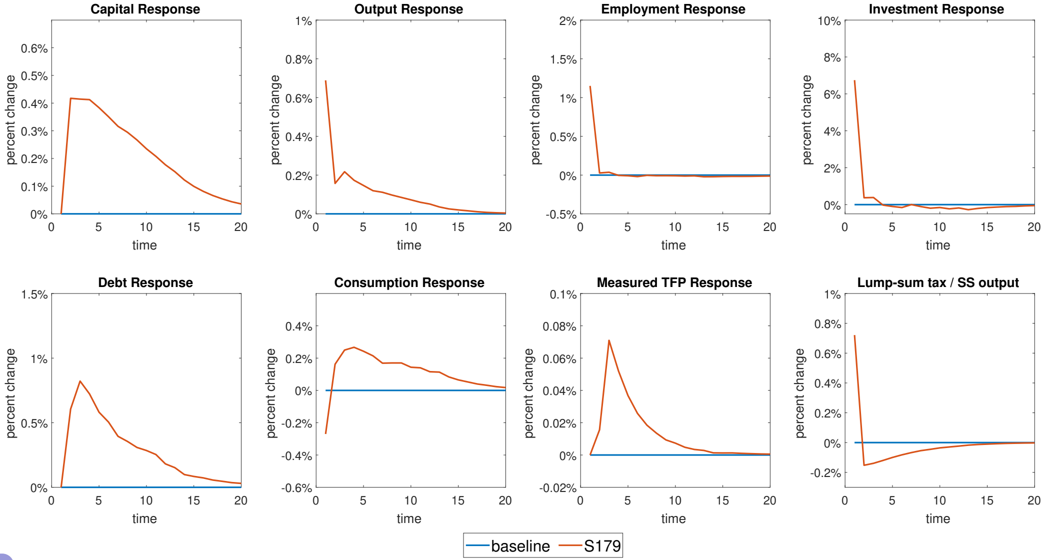
Distribution: median productivity



Distribution: minimum productivity



TFP shock: percentage deviation from baseline model



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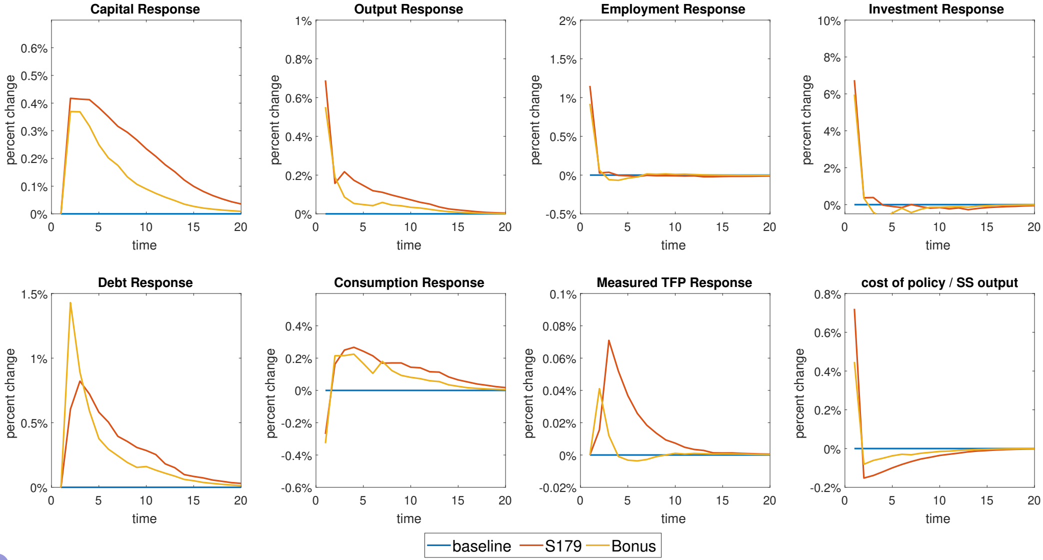
TFP shock: percentage deviation from baseline model



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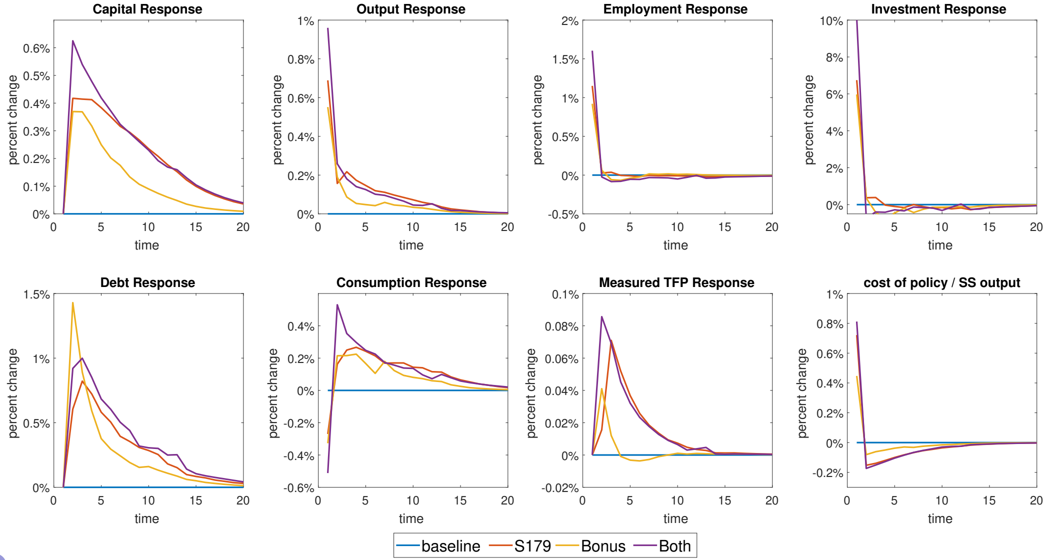
TFP shock: percentage deviation from baseline model



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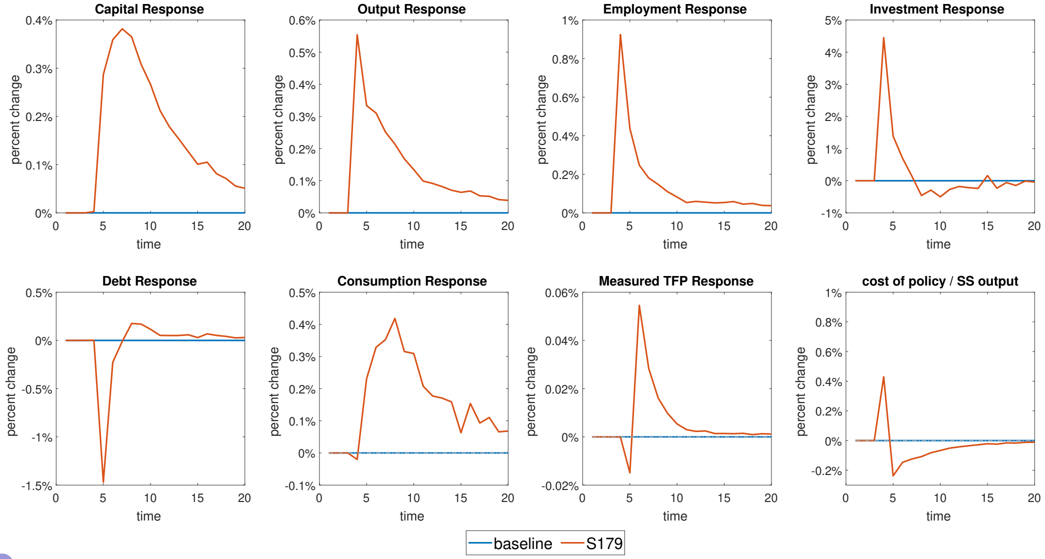
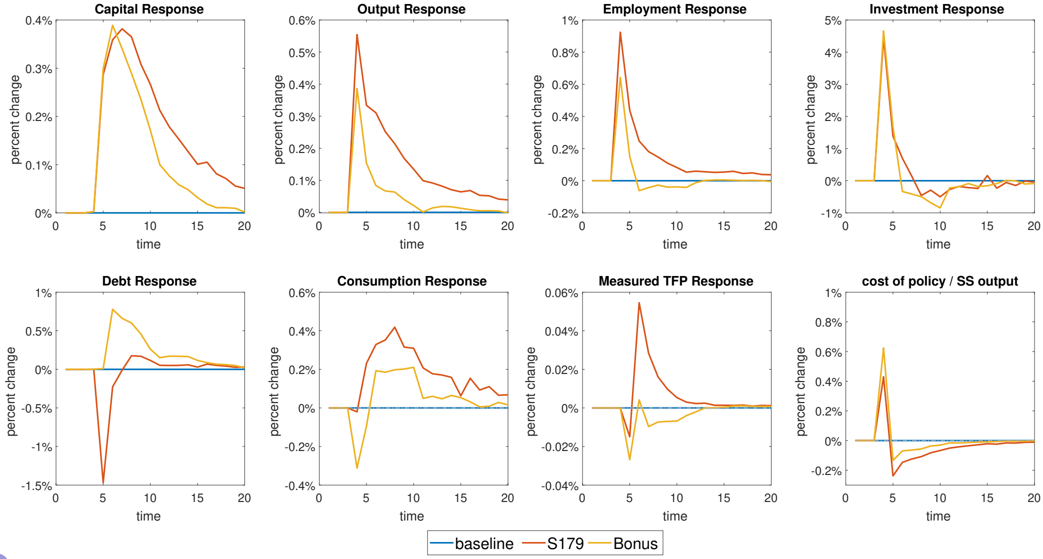
Credit shock: percentage deviation from baseline model



Credit shock: percentage deviation from baseline model



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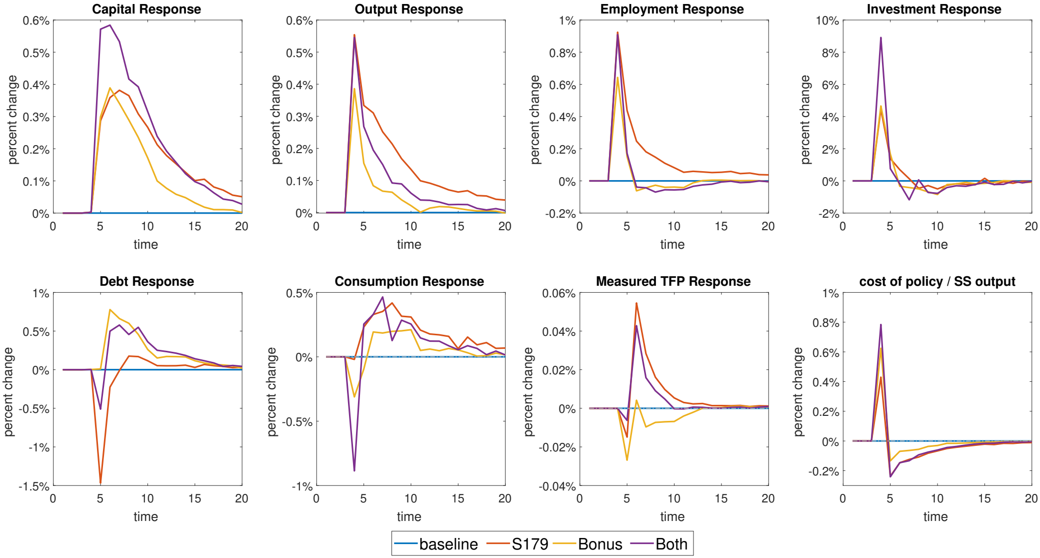
Credit shock: percentage deviation from baseline model



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