Aggregate Implication of Corporate Taxation over Business Cycle

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Macro Workshop

Outline

- Introduction
- Model
- Calibration
- Long-run effects of corporate tax deductions
- Transitional dynamics of corporate tax deductions
- Application: policy evaluation

What are the macro effects of corporate tax deductions?

Fact: (i) Corporate tax deductions have estimated cost of 86B yet impact remains debatable

(The Joint Committee on Taxation (2017), Chodorow-Reich, Zidar and Zwick (2024b))

(ii) Large (16.9%) and heterogeneous ($\epsilon \in [-0.5, -3.2]$) investment response Response

(Zwick and Mahon (2017), Ohrn (2018, 2019))

Model: $\underbrace{\text{Heterogeneous firms}}_{\text{size-dependent response}} + \underbrace{\text{Financial friction}}_{\text{create role for deductions}} + \underbrace{\text{Corporate tax deductions}}_{\text{(S,s) policy}}$

Calibrate: match key moments in US economy and establishment-level investment data

Validation: (i) $\underbrace{\text{investment rate distribution}}_{\text{Cooper and Haltiwanger (2006)}}$, (ii) $\underbrace{\text{heterogeneous investment response to policy}}_{\text{Zwick and Mahon (2017)}}$

Applications: equilibrium effects on policies in 2017 TCJA

- expanding S179 deductions, expanding bonus depreciation rate, cutting statutory tax rate

Policy examples

Preview of findings and key mechanisms

With each policy cost 0.3% of baseline GDP,

- expanding S179 raises GDP by 1.6% and is $\sim 50\%$ more effective than bonus rate
- cutting corporate tax rate is the least effective policies among all
- Implementing both depreciation deductions leads to 20% decreases in efficiency (Ohrn (2019))

Micro level: tax wedges distort firms' investment based on their financial conditions

- tax wedge limits credit-rationed firms capital accumulation by taxing flow returns
- GE effects ($w \downarrow$) induce large and resourceful firms to carry excess amounts of capital

Macro level: tax payers' money should go to firms who suffer the most in **misallocation**

- Targeting motivates self-selection $\Rightarrow$ productive firms will invest while others won't

Literature

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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 $\mathcal{I}(k', k, \psi)$
- Taxable capital ψ depreciates at rate δ^ψ to represent normal depreciation schedule
- Policies are limited to equipment $\Rightarrow$ on average ω fraction of investment is equipment

Corporate tax structure

Both current and past investment is deductible from non-negative 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.

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

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

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

choice state space

Budget constraints and Discrete Choice

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

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

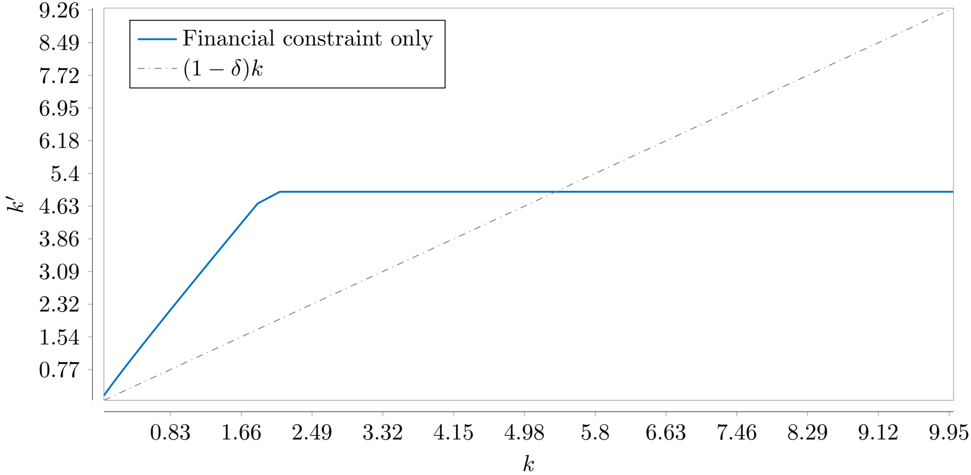
$$
v(k,b,\psi,\varepsilon;\mu) = \max \left\{ v^H(k,b,\psi,\varepsilon;\mu), v^L(k,b,\psi,\varepsilon;\mu), v^N(k,b,\psi,\varepsilon;\mu) \right\}
$$

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

Distortion created by tax wedge

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

capital decision rule at median productivity with zero debt and taxable capital



Distortion created by tax wedge

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

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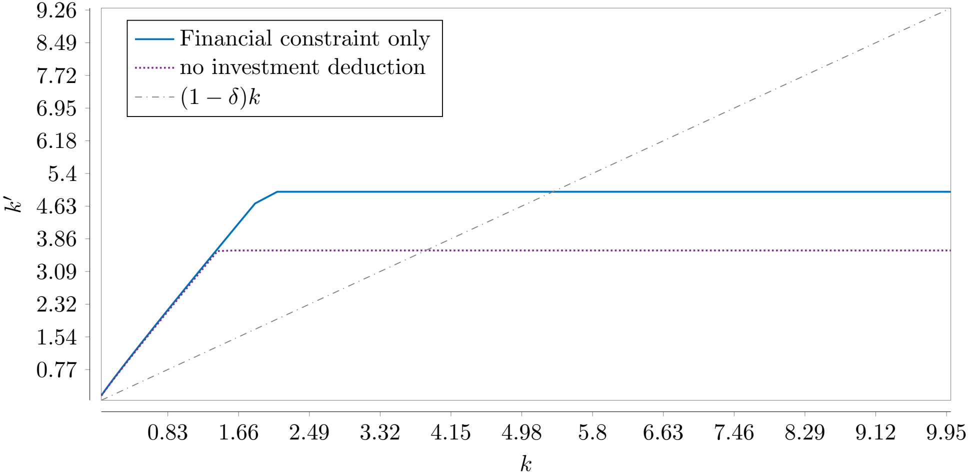

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$$D = (1-\tau^c)(z\varepsilon F(k,n) - wn) - b + qb' - (1-\tau^c\mathcal{J}(k',k)\omega)(k'-(1-\delta)k) + \tau^c\delta^\psi\psi$$

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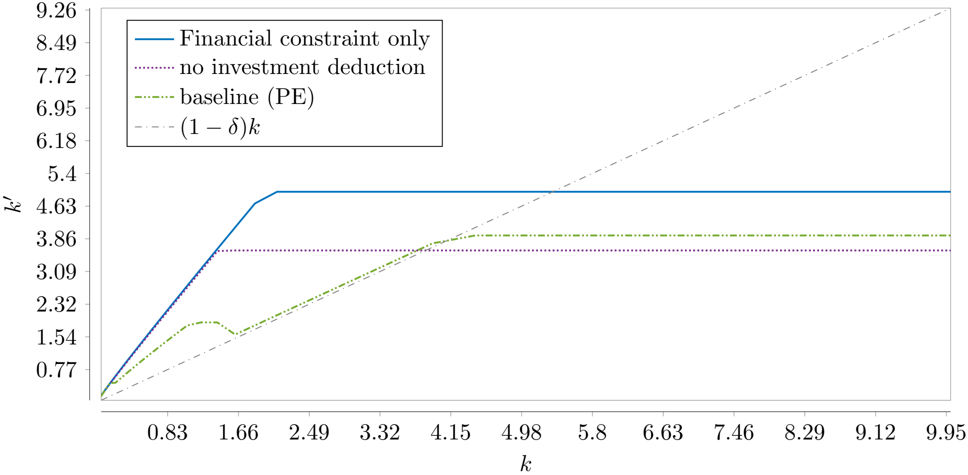

Distortion created by tax wedge

$$D = (1-\tau^c)(z\varepsilon F(k,n) - wn) - b + qb' - (1 - \tau^c \mathcal{J}(k',k)\omega)(k' - (1-\delta)k) + \tau^c \delta^\psi \psi$$

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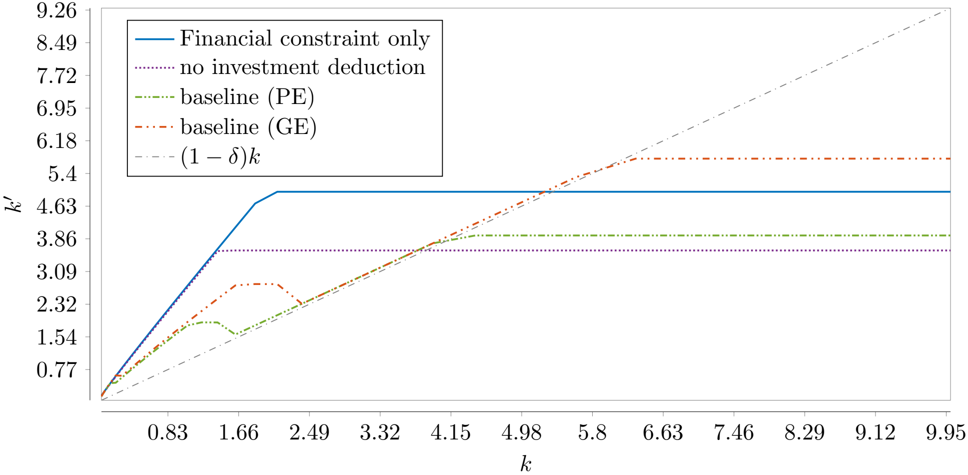

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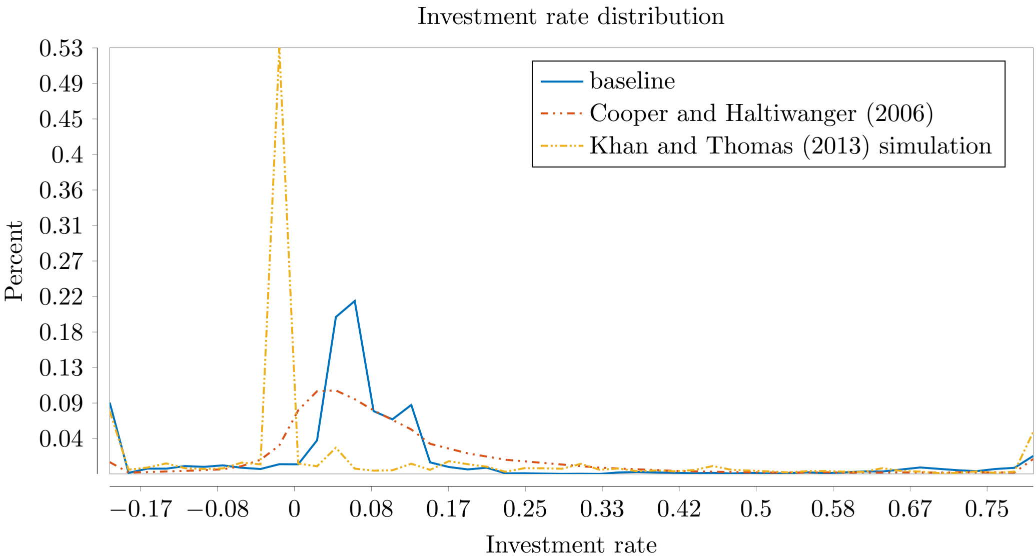
Calibrated Moments

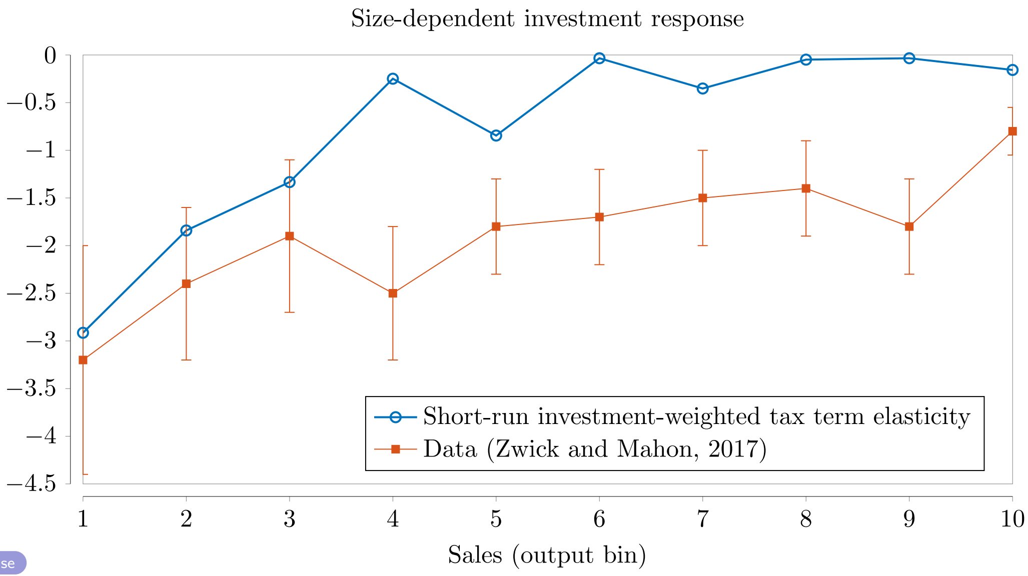
Parameter	Target		Model
$\beta = 0.96$	real interest rate	$= 0.04$	0.04
$\alpha = 0.3$	private capital-output ratio	$= 2.3$	2.03
$\nu = 0.6$	labor share	$= 0.6$	0.6
$\tau^n = 0.25$	government spending-output ratio	$= 0.21$	0.201
$\delta = 0.069$	average investment-capital ratio	$= 0.069$	0.069
$\varphi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

Functional Form Exogenous parameters investment rate distribution

Model validation: investment rate distribution for unconstrained firms

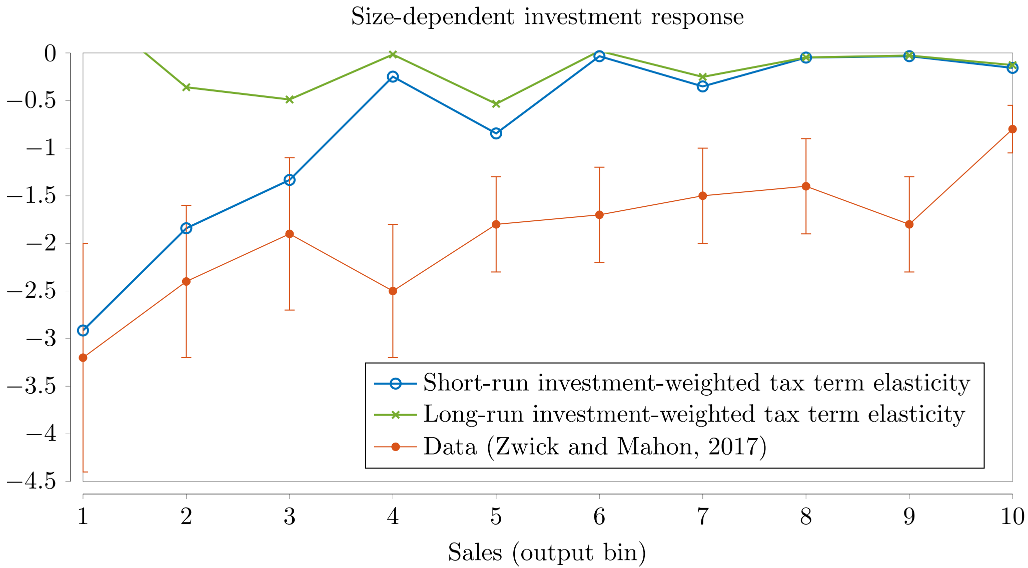


Model validation: heterogeneous investment response in the short-run



Response

Model prediction: not much heterogeneity in long-run investment response



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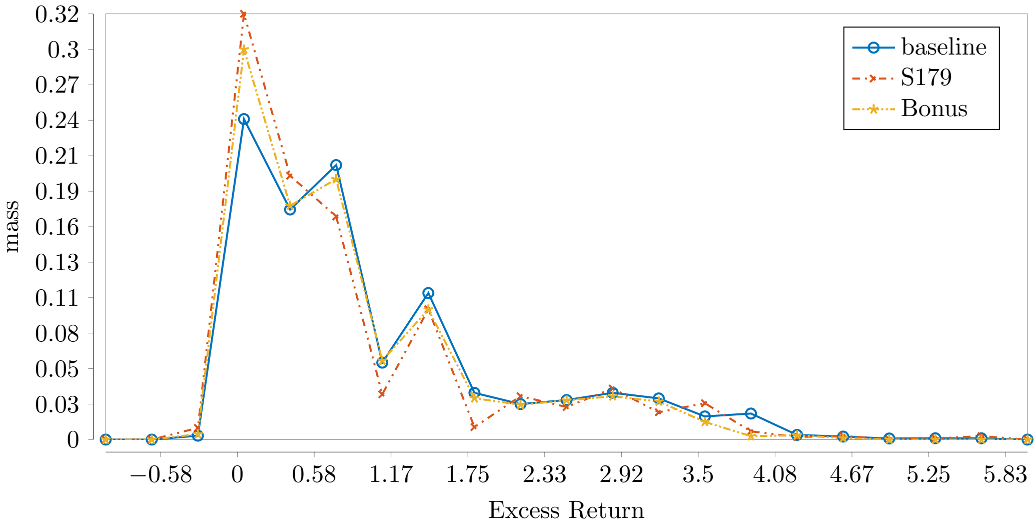
Aggregate outcomes as percentage of baseline

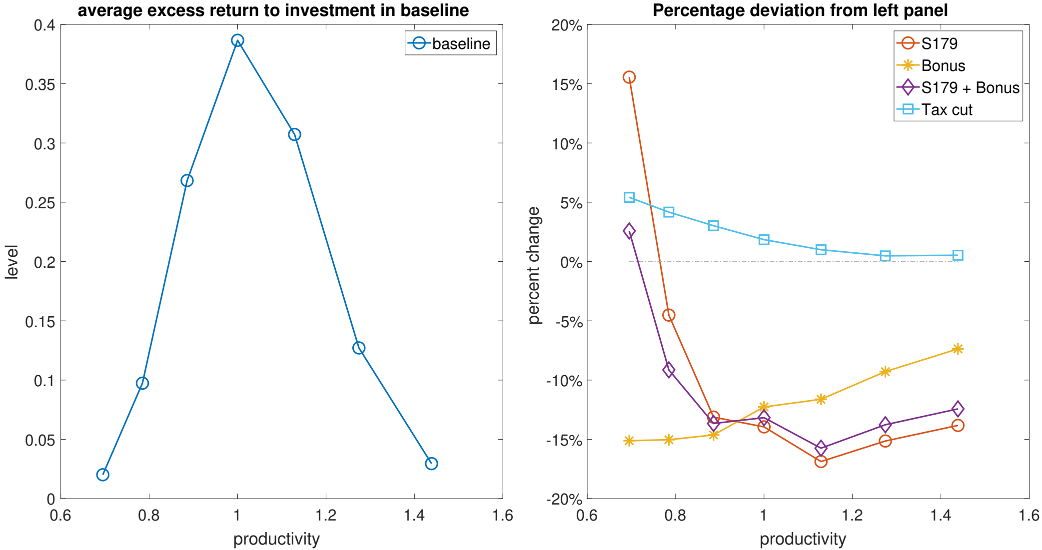
Variable	S179	Bonus	S179 + Bonus	Tax cut
Output	1.61%	1.06%	1.31%	0.64%
Consumption	1.55%	0.92%	1.27%	0.56%
Labor	0.06%	0.13%	0.04%	0.08%
Capital	4.22%	3.21%	3.39%	1.95%
Investment	4.22%	3.21%	3.39%	1.95%
Measured TFP	0.32%	0.03%	0.28%	0.01%

- Each policy costs 0.3% of baseline GDP and delivers the same government spending $\bar{G}$
- In S179 + Bonus, policy tools are 82% of the level in S179 and Bonus

Distribution of Excess Return



Expanding S179 reduces investment wedge for productive firms



excess return

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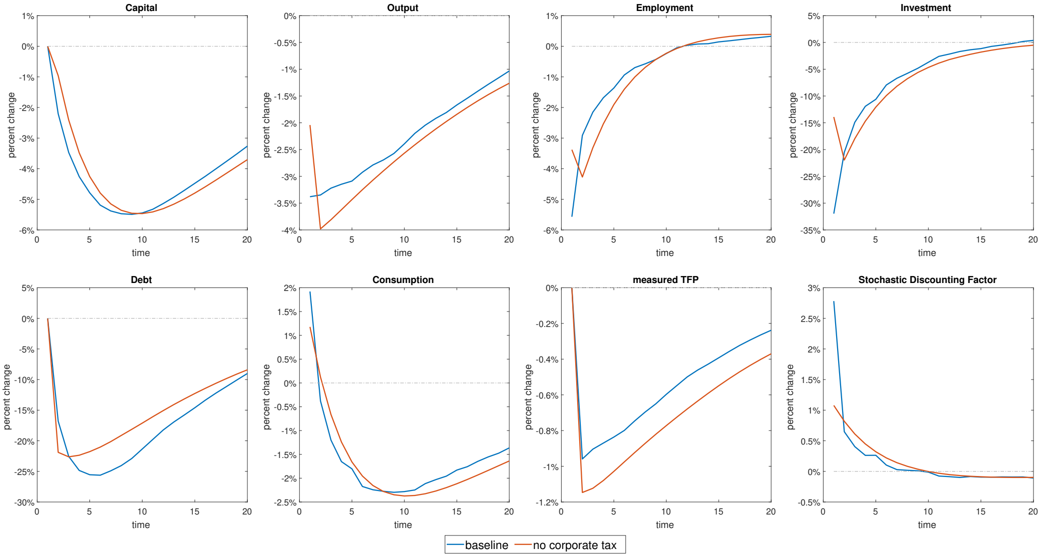
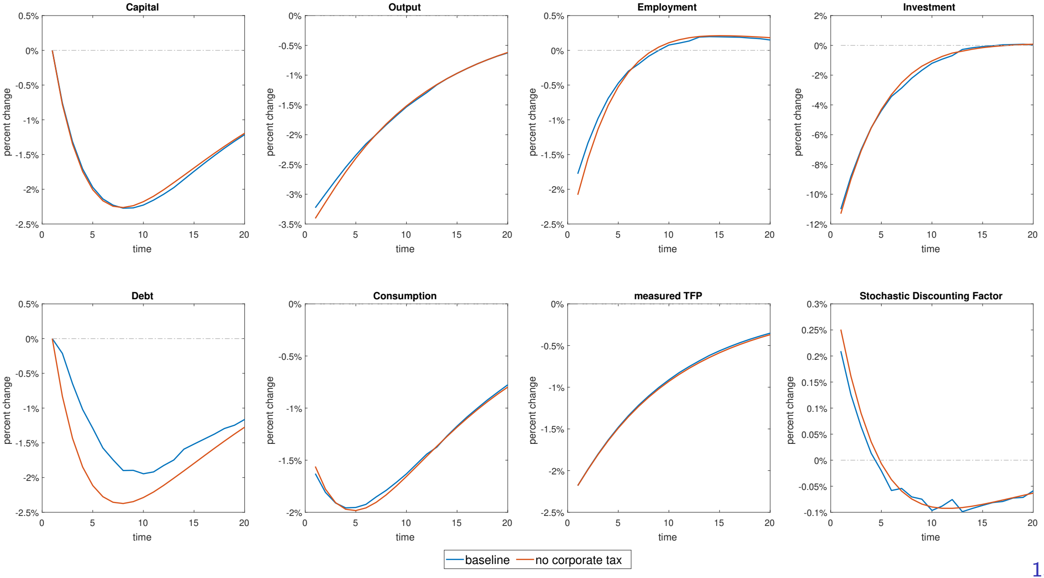
Corporate tax deductions mitigate the response to a negative credit shock



Almost no role of corporate taxation following a TFP shock



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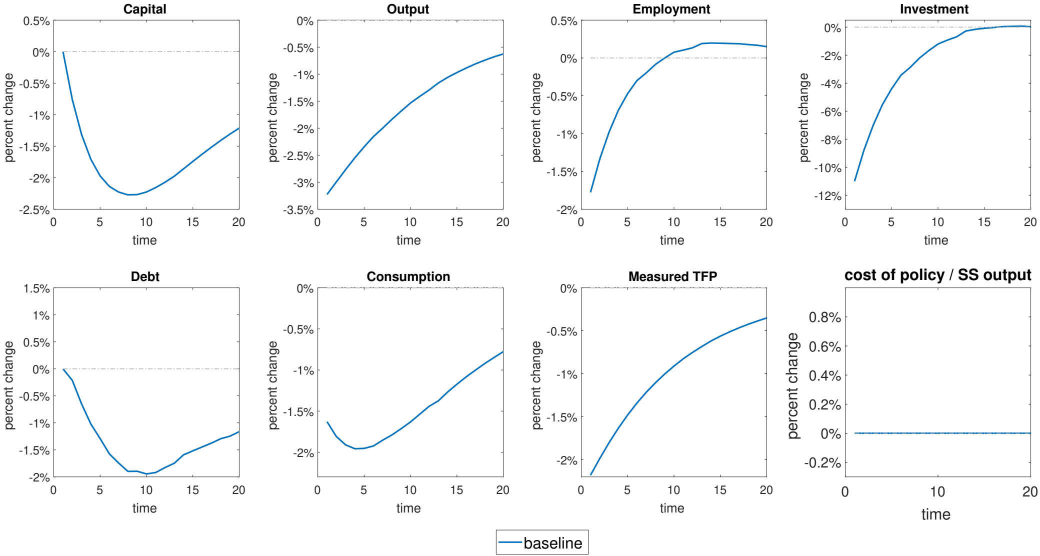
IRF: negative TFP shocks with scale 2.18% and persistence 0.909



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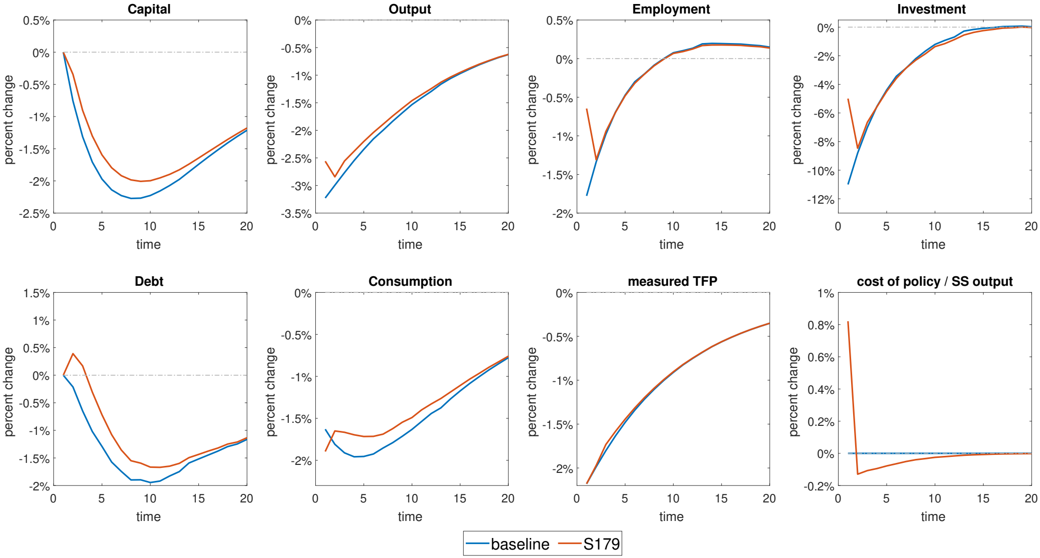

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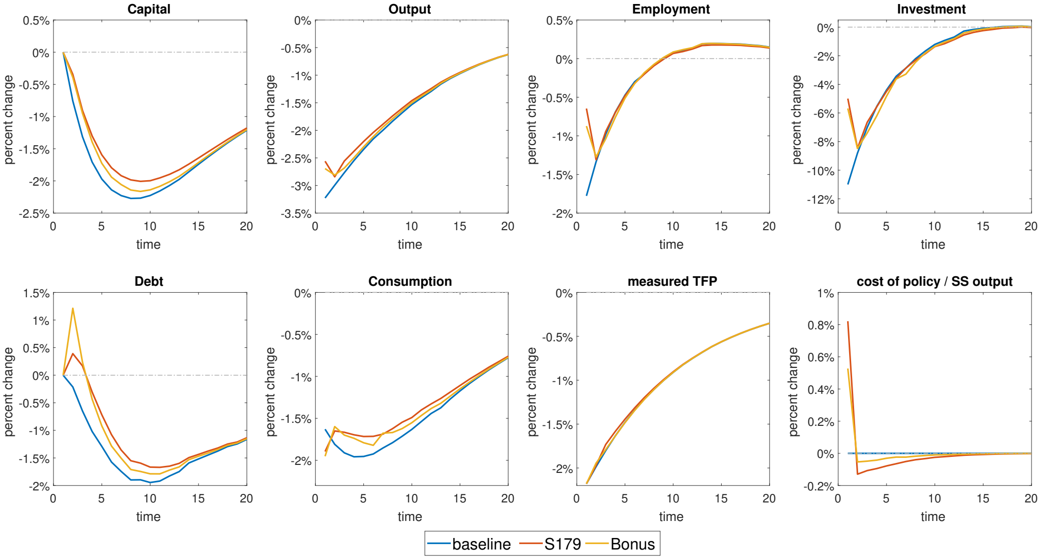

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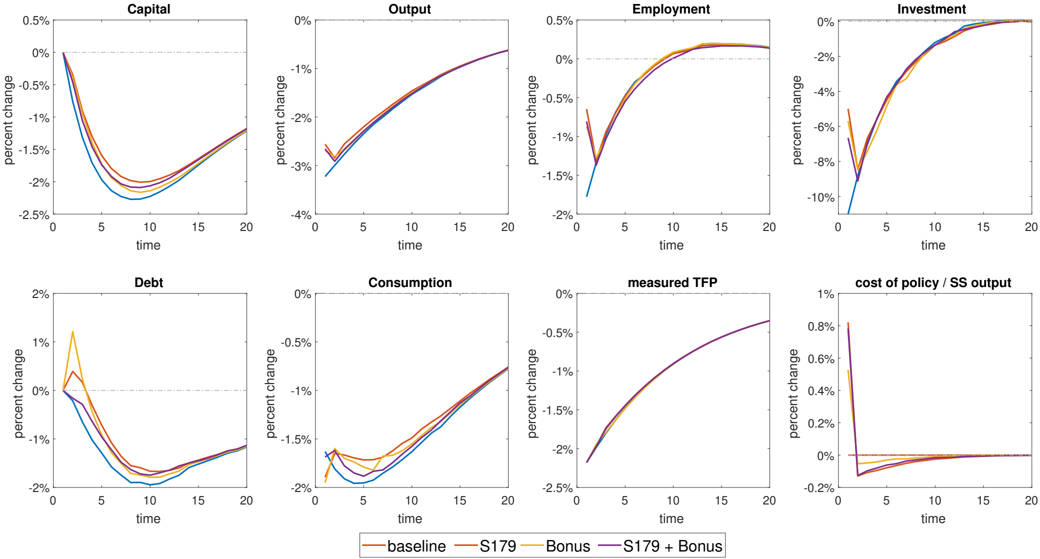
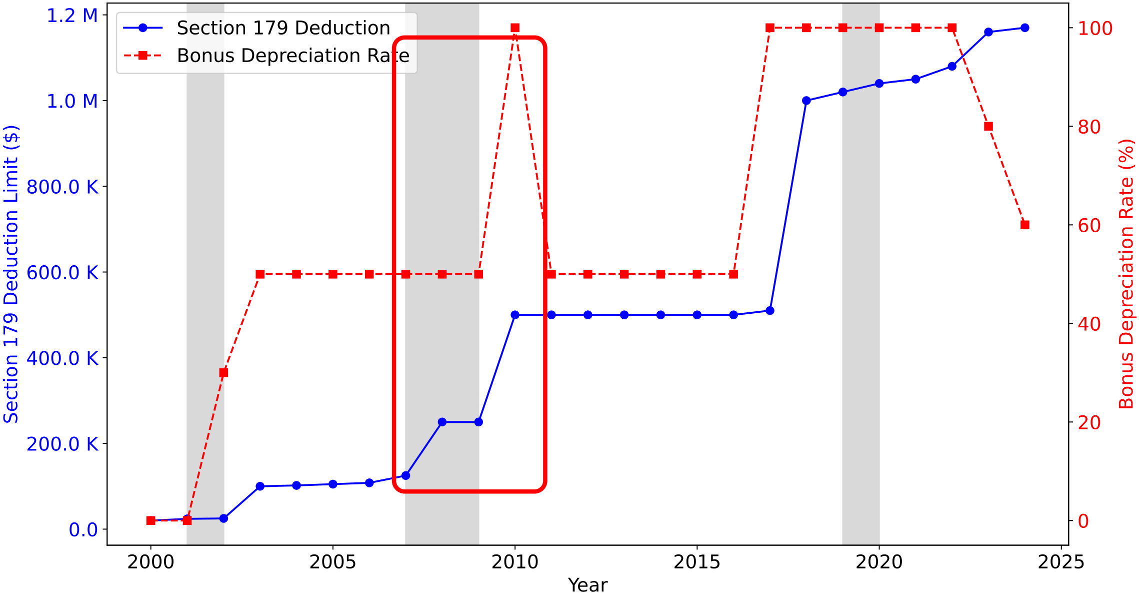
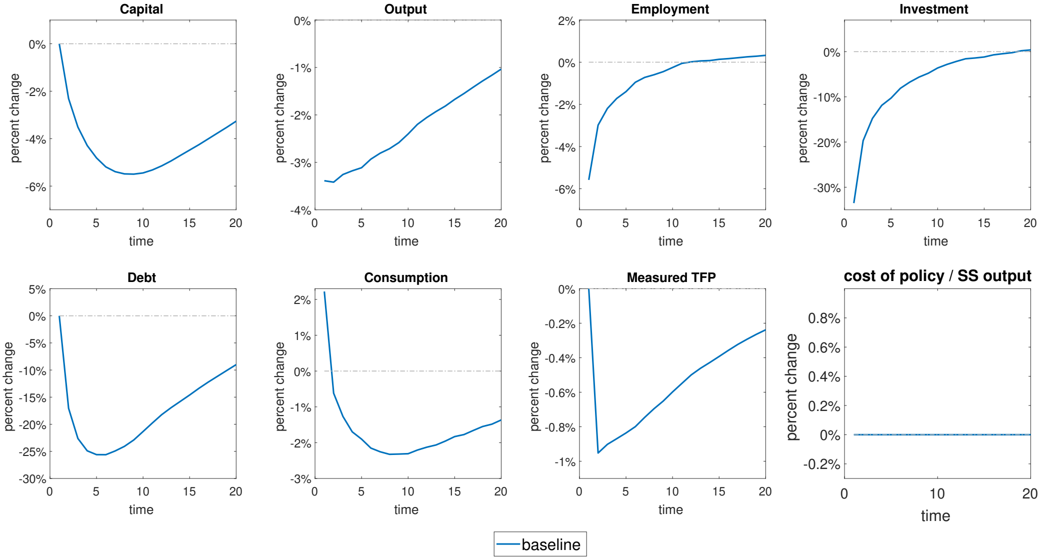
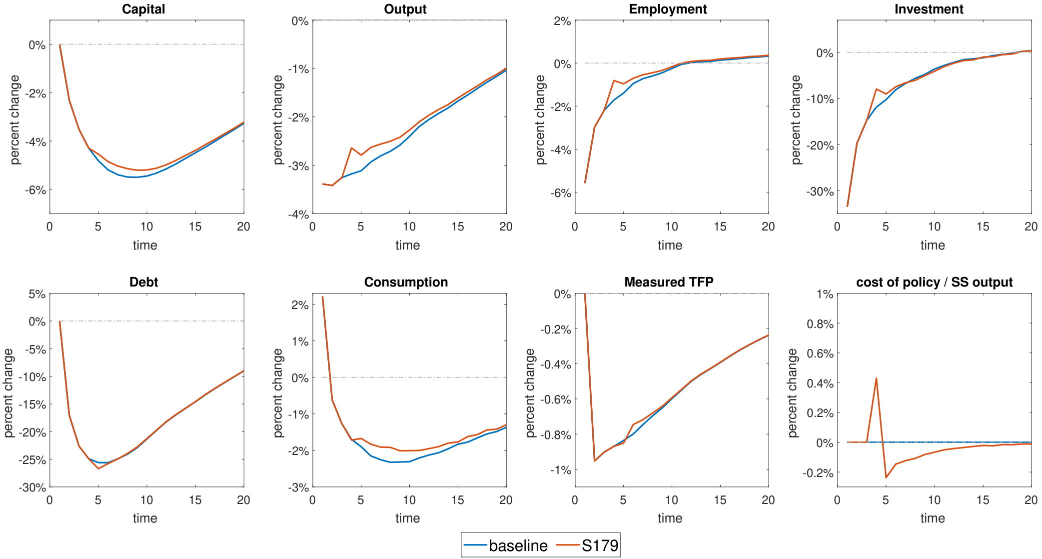



Section 179 Deduction
Bonus Depreciation Rate
Section 179 Deduction Limit ($)
Bonus Depreciation Rate (%)
Year
1.2 M
1.0 M
800.0 K
600.0 K
400.0 K
200.0 K
0.0
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025

IRF: negative credit shocks with scale 27% and persistence 0.909



IRF: negative credit shocks with scale 27% and persistence 0.909



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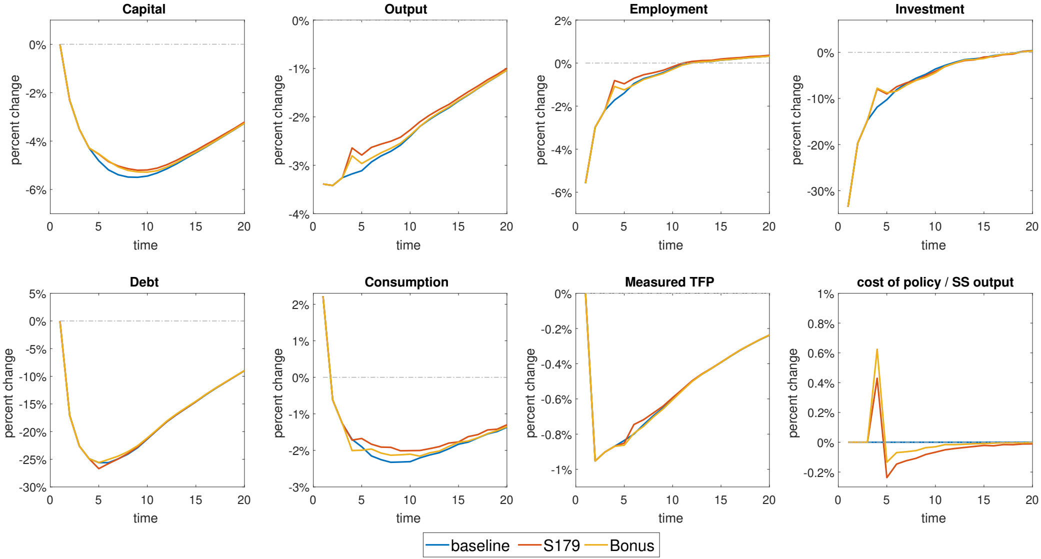

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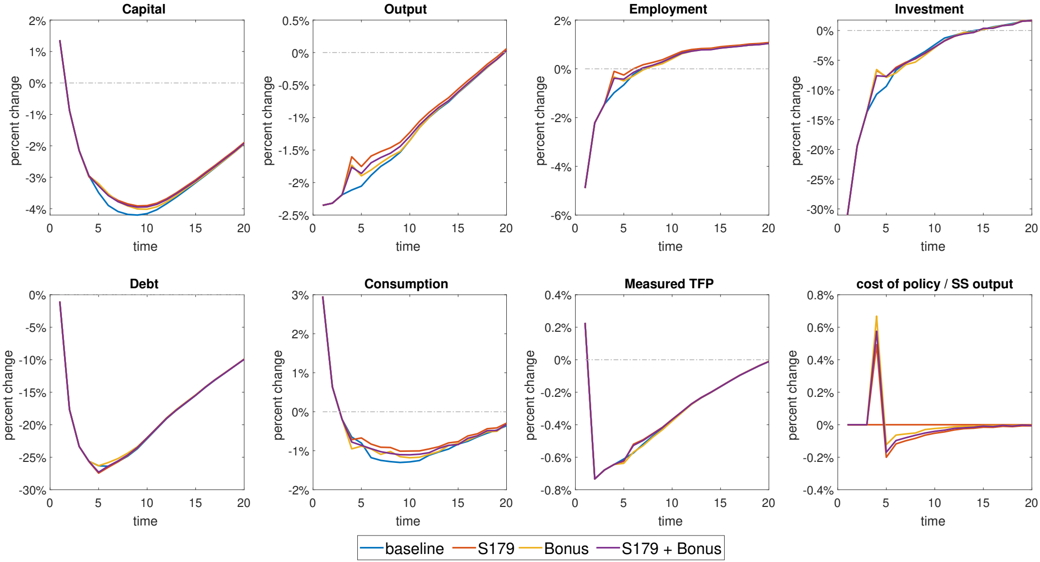

Conclusions

- 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 50% less effective than S179 as it motivates dividend payment
    - Cutting statutory tax rate is the least effective
- What's next:
    - Permanent change in policies
    - Policy effectiveness under aggregate uncertainty
    - Endogenizing financial frictions: does deduction policy reduce the incidence of firm default?

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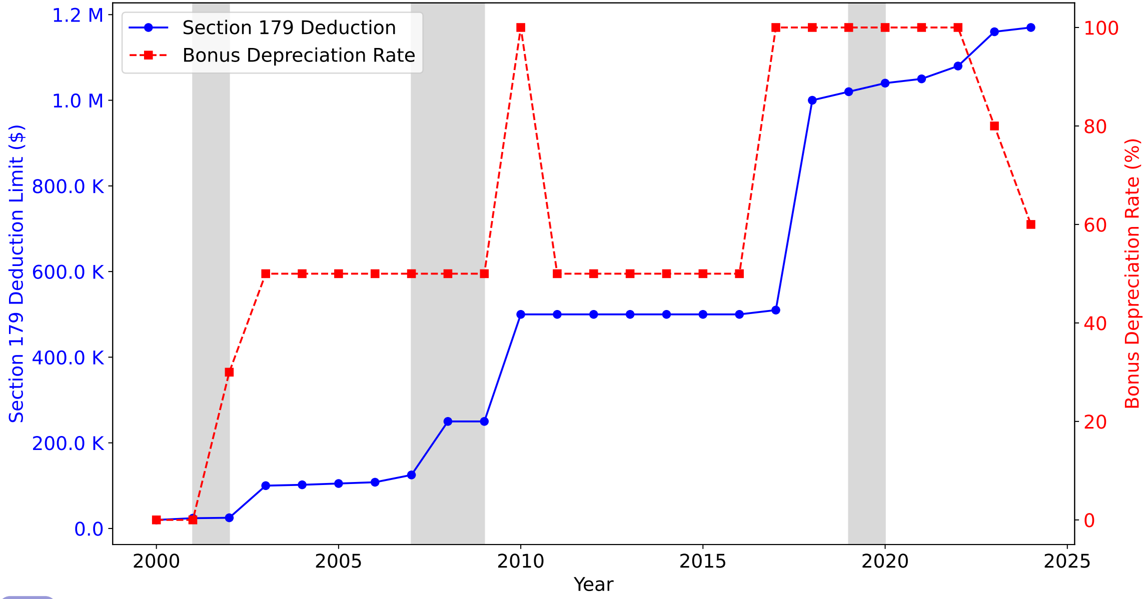
Outline

- Empirical Literatures
- Model Appendix


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

Back

Literature

- Large empirical literature on responsiveness of investment to tax credit
  - Public firm 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), Chodorow-Reich, Smith, Zidar and Zwick (2024a)

  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 fiscal policies and determines their aggregate effects

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

Corporate taxation in the US

- 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 / 100% Bonus
0	$\$1000 \times 20.00\%$	\$200	$\xrightarrow[+800\times 0.5]{}$	\$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	$\xrightarrow[\times 0.5]{}$	\$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

Example: Modified Accelerated Cost Recovery System (MARCS)

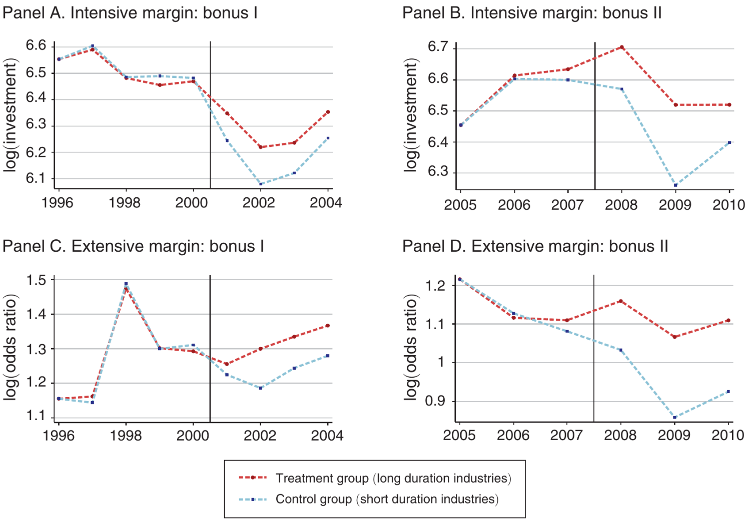
Shawn bought and placed in service a used pickup for $\$15,000$ on March 5,1998 . The pickup has a 5 year class life. His depreciation deduction for each year is computed in the following table.

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



Back

Conforming states enjoys 18% of investment boosts

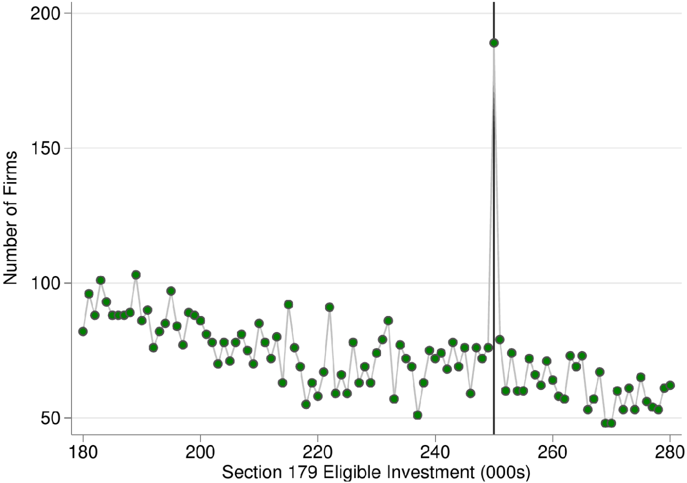
Table: Investment Impacts of State Bonus and State 179

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

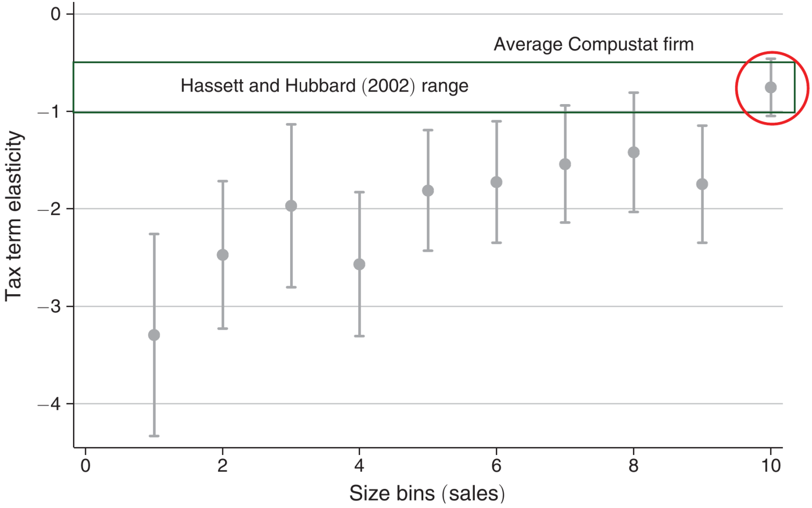


Heterogeneity in investment response

Table: Heterogeneity by Ex Ante Constraints

	Sales		Div payer?		Lagged cash	
	Small	Big	No	Yes	Low	High
$z_{N,t}$	6.29 (1.21)	3.22 (0.76)	5.98 (0.88)	3.67 (0.97)	7.21 (1.38)	2.76 (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

Outline

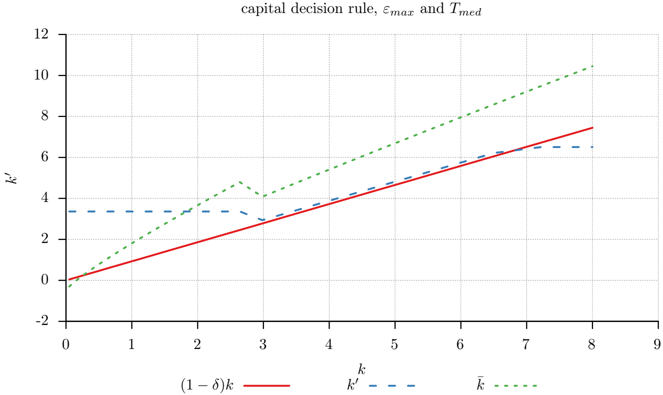
- Empirical Literatures
- Model Appendix

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

Back

Unconstrained firms' problem (Cont.)

Given these transformation, firms' problem can be rewritten as

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

Back

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:

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

Back

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, $K^w(k,\psi,\varepsilon)$,

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

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.

Back

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

Back

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

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

When taxable income is negative for constrained firms

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

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 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

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

Firms that invest lower than threshold

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

subject to

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

Back

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.

Equilibrium

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

Back

Household Optimality Conditions

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

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

With $u(c, 1-n^h) = \log c + \varphi(1-n^h)$, implied Frisch elasticity is ∞,

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

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

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

Frisch elasticity of labor supply

Let $u(c, L) = \log c + \varphi \log L$, the Lagrangian is

$$\max_L \log c + \varphi \log L + \lambda \left[w(1 - L) - c \right]$$

Thus

$$[L] : \frac{\varphi}{L} = \lambda w \Rightarrow L = \frac{\varphi}{\lambda w}, \frac{\partial L}{\partial w} = -\frac{\varphi}{\lambda w^2} = -\frac{L}{w}$$

and therefore

$$\eta^\lambda = \frac{\partial L}{\partial w} \frac{w}{L} = -1$$

Algorithm

I use Broyden's method to solve system of prices and policy tool equations.

For baseline model, I choose p and w to solve $p = \frac{1}{c}$ and $n^h = N$ to calibrate a fixed $\bar{G}$.

For all experiments, I choose p, w, and τ^n to solve $p = \frac{1}{c}$, $n^h = N$, and $\tau^n w n^h + R = \bar{G}$.

Exogenous Parameters

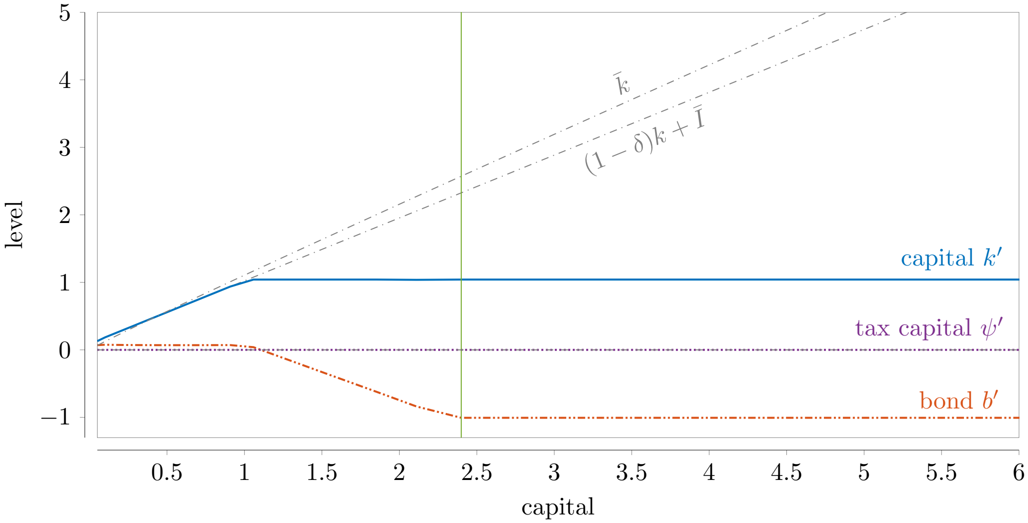
	Parameter	Value	Reason
Exogenous parameters			
fraction of entrants capital endowment	χ	0.1	10% of aggregate capital
exogenous exit rate	π_d	0.1	10% entry and exit
Corporate tax rate	τ^c	0.21	US Tax schedule after TCJA
Tax benefit depreciation rate	δ^ψ	0.138	$\delta^\psi = 2\delta$ (Double-declining balance)

Calibration

Frequency and Functional Form

- Model frequency: annual
- Household utility function: $u(c, n^h) = \log c + \varphi(1 - n^h)$
- Production function: $F(k, n) = k^\alpha n^\nu$
- Initial capital for entrants: $k_0 = \chi \int k\tilde{\mu}(d[k \times b \times \psi \times \varepsilon])$
- Initial bond and taxable capital: $b_0 = 0$ and $\psi_0 = 0$
- Idiosyncratic productivity shock: $\log \varepsilon' = \rho_\varepsilon \log \varepsilon + \eta'_\varepsilon$, $\eta_\varepsilon \sim N(0, \sigma_\varepsilon^2)$
  - 7-state Markov chain discretized using Tauchen algorithm

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



Steady State Comparison

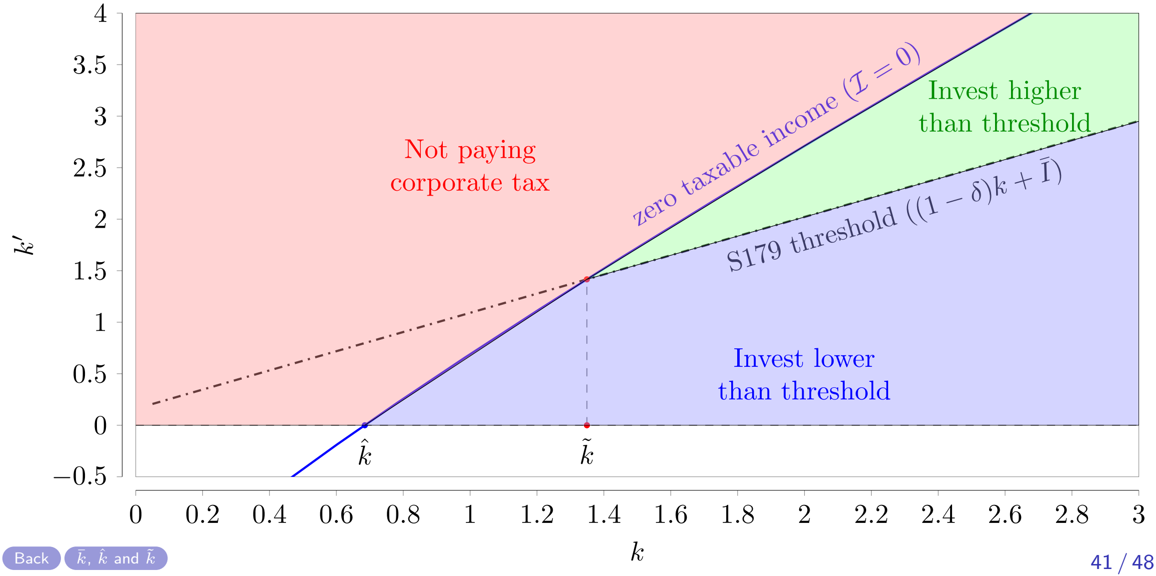
	Description	baseline	S179	bonus	both
$\tilde{T}/Y$	cost of policy / baseline output	-	0.30	0.31	0.42
Y	aggregate output	100 (0.54)	101.61	101.06	102.00
C	aggregate consumption	100 (0.36)	101.55	100.92	101.91
K	aggregate capital	100 (1.10)	104.22	103.21	105.30
I	aggregate investment	100 (0.08)	104.22	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.)

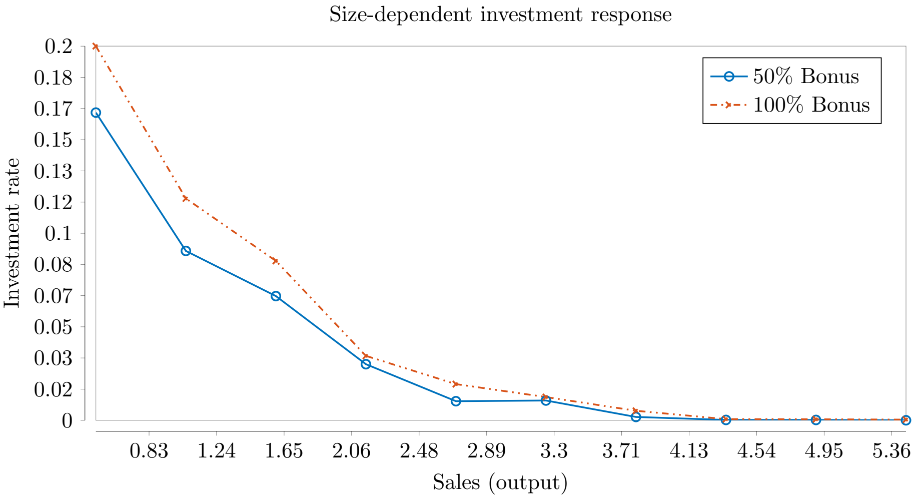
	Description	baseline	S179	bonus	both
Prices					
p	marginal utility of consumption	100 (2.80)	98.47	99.08	98.13
w	wage	100 (0.97)	101.55	100.92	101.91
Distribution					
μ_{unc}	unconstrained firm mass	0.080	0.093	0.099	0.129
μ_{con}	constrained firm mass	0.920	0.907	0.901	0.871
$\mu_{\text{unc}}K$	capital: 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

Capital choice state space



Investment Response to raising bonus depreciation

Tax term: $\frac{1-\tau^c\omega\xi}{1-\tau^c}$; Elasticity: $\frac{\%\Delta\text{Investment at bin}}{\%\Delta\text{tax term}}$



Back

Private excess return on capital

N-type firms:

$$\beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} \left[\frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial k'} + \frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial \psi'} \frac{\partial \psi'}{\partial k'} \right] - 1$$

H-type firms:

$$\beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} \left[\frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial k'} + \frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial \psi'} \frac{\partial \psi'}{\partial k'} \right] - (1 - \tau^c \omega \xi)$$

L-type firms:

$$\beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} \left[\frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial k'} + \frac{\partial V^0(k', b', \psi', \varepsilon_j; \mu)}{\partial \psi'} \frac{\partial \psi'}{\partial k'} \right] - (1 - \tau^c \omega)$$

Back

Approximating the derivatives of the value functions

I use RHS and LHS secant to approximate the derivatives of the value functions.

Let $i_\varepsilon = 1, \ldots, N(\varepsilon)$, $i_b = 1, \ldots, N(b)$, $i_k = 1, \ldots, N(k)$ and $i_\psi = 1, \ldots, N(\psi)$.

RHS secant at $(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$, $i_k = 1, \ldots, N(k) - 1$ is

$$s_r(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = \frac{V^0(k_{i_k+1}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) - V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})}{k_{i_k+1} - k_{i_k}}$$

LHS secant at $(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$, $i_k = 2, \ldots, N(k)$ is

$$s_l(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = \frac{V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) - V^0(k_{i_k-1}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})}{k_{i_k} - k_{i_k-1}}$$

Approximating the derivatives of the value functions (Cont.)

When $i_k = 2, \ldots, N(k) - 1$,

$$D_k V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = 0.5 s_r(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) + 0.5 s_l(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$$

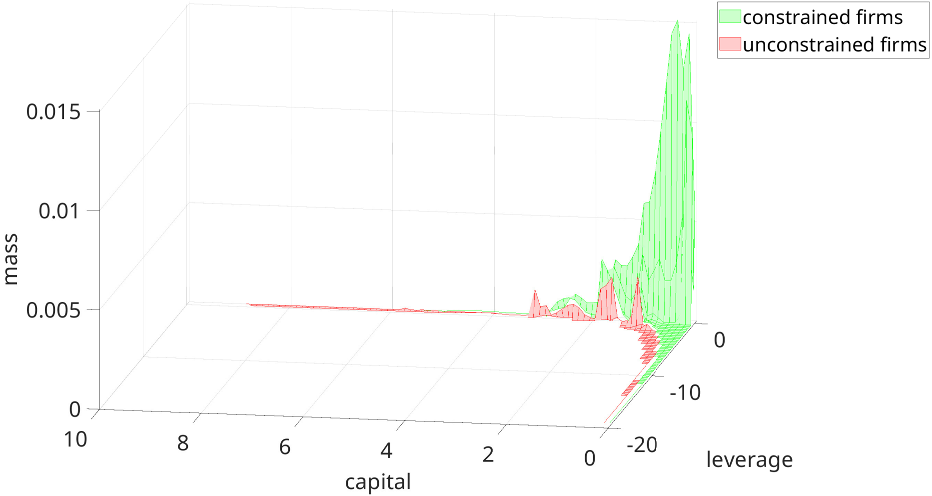
When $i_k = 1$,

$$D_k V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = s_r(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$$

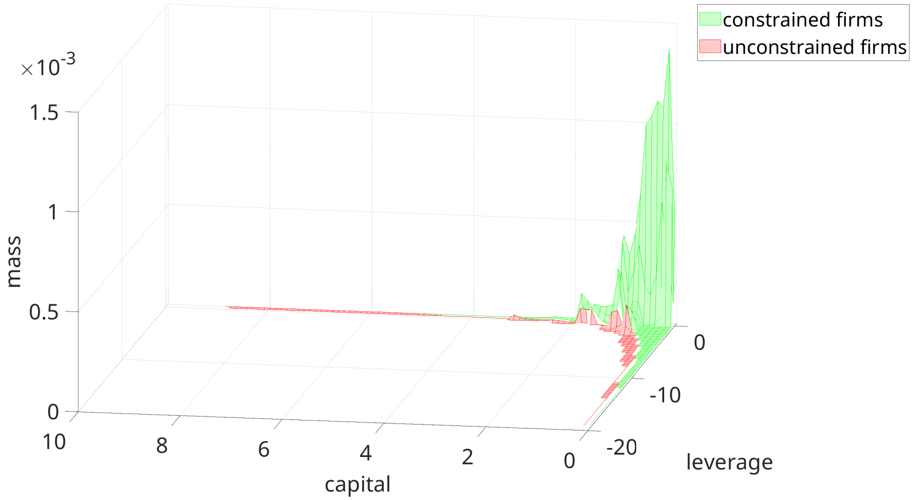
When $i_k = N(k)$,

$$D_k V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = s_l(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$$

Distribution: median productivity

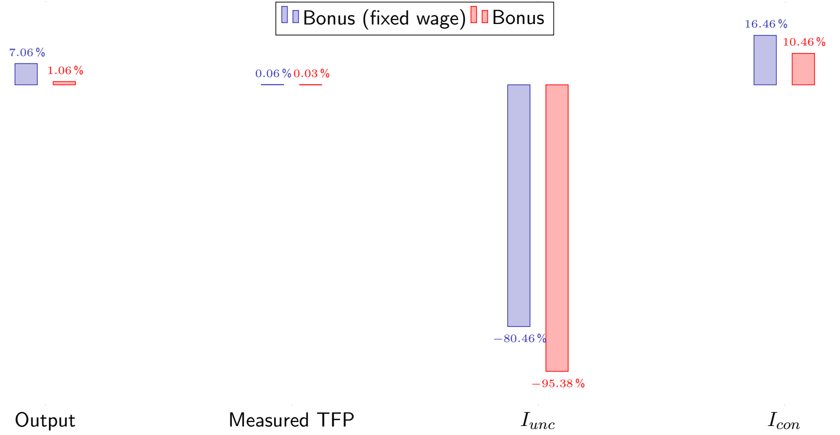


Distribution: minimum productivity



Decompose the wage effects

Fix wage at the baseline level and resolve the steady state



back