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# Aggregate Implications of Corporate Taxation over the Business Cycle



# Introduction

1 Introduction

2 Model

3 Long-run effects

4 Short-run dynamics

5 Application: policy evaluation

# What are the macro effects of corporate tax deductions?

**Fact** large deductions (100-150B), investment responses are large and heterogeneous

(The Joint Committee on Taxation (2017), Chodorow-Reich, Zidar and Zwick (2024b), Zwick and Mahon (2017), Ohn (2018, 2019))

**Model** hetero. firms + financial frictions + corporate taxes + investment deduction

**Mechanism** deductions lower user cost of capital and decrease needs for funding

**Validation** (i) deduction policies in matching investment rate distribution

(Cooper and Haltiwanger (2006))

(ii) qualitative pattern of hetero. investment response to policy

(Zwick and Mahon (2017))

**Application** GE effects on investment deductions as counter-cyclical policies

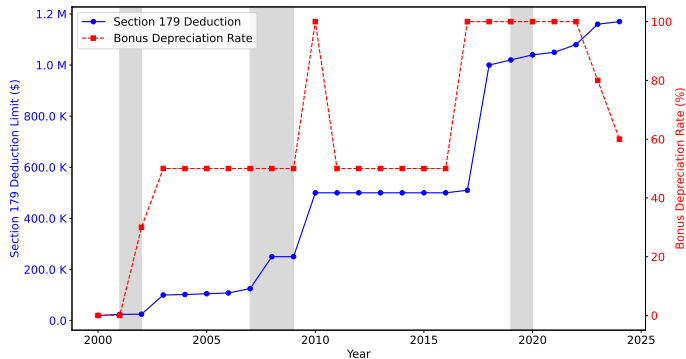
➤ against different shocks (TFP v.s. credit); v.s. other stimulus policies (TCJA)

**Result** Deduction policy that targets **small firms** generates larger boost in aggregates

➤ Large firms utilize saved funding to **pay dividend**; small firms **raise investment**

# Two policies that accelerates investment deductions

- Firms' taxable income is deductible by eligible investment that follows deduction schedule
- **Section 179 expensing**: allow firms' inv. lower than a threshold to deduct entire cost
- **Bonus depreciation**: allow all firms to deduct a bonus fraction, the rest is carried forward





# Model

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**Household:** supplies labor, pays labor tax, lends risk-free loans, and owns the firms

**Government:** collect taxes to fund exogenous government spending

**Firms:** states  $(k, b, \psi, \varepsilon)$

- Deductible stock  $\psi$  carries unrealized tax deductions forward to the next period (schedule)
- DRS production; persistent idiosyncratic productivity  $\varepsilon$ ; i.i.d. exit shock  $\pi_d$
- Capital  $k$  accumulation is hindered by collateral constraints  $b' \leq \theta k'$  and tax wedges
- Taxable income  $\mathcal{I}(\cdot)$  is nonnegative and deductible by investment expenditure

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

- › Gov won't issue tax rebate when taxable income is negative  $\Rightarrow$  zero lower bound
- ›  $\mathcal{J}(k', k)$ : indicator function for investment deduction policies

$$\mathcal{J}(k', k) = \begin{cases} \omega & \text{if } k' - (1 - \delta)k \leq \bar{I} \\ \xi\omega & \text{if } k' - (1 - \delta)k > \bar{I} \end{cases}$$

- ›  $\bar{I}$ : Section 179 threshold (targeted policy)
- ›  $\xi \in [0, 1]$ : bonus depreciation (untargeted policy)
- ›  $\omega$ : fraction of eligible investment to total investment

› choice state space

# How corporate tax burden affect budget

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

If  $\mathcal{I}(k', k, \psi, \varepsilon) > 0$ ,

(Barro and Furman (2018), Chodorow-Reich, Smith, Zidar and Zwick (2024a))

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

More generous deduction policies ( $\mathcal{J}(k', k) \uparrow$ ), higher dividend payment

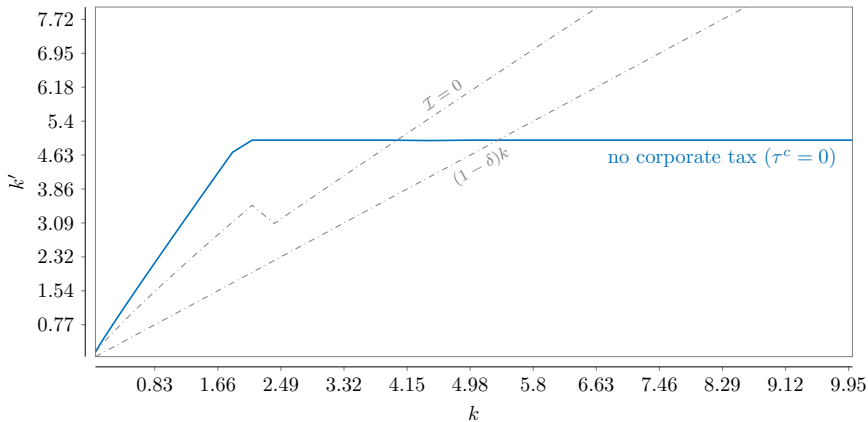
If  $\mathcal{I}(k', k, \psi, \varepsilon) \leq 0$ ,

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



$$D = \frac{(z\varepsilon F(k, n) - wn) - b + qb' - I}{I}$$

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

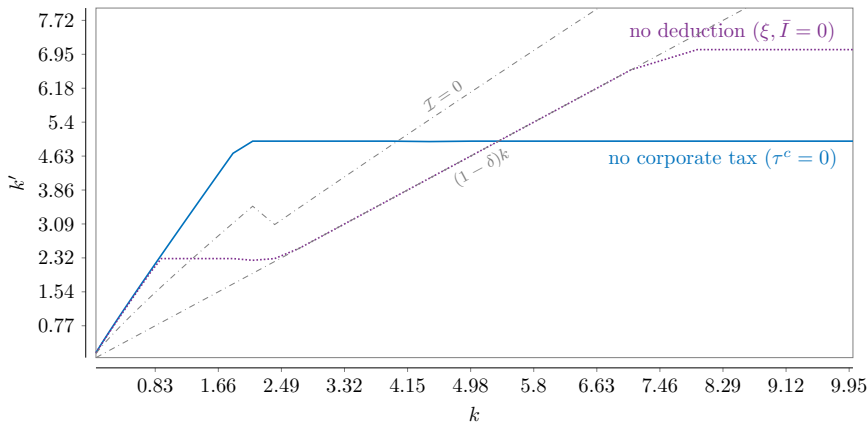


# Distortion created by tax wedge

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

$$I \mid_{I \geq 0} - (1 - \tau^c \omega) I \mid_{I < 0}$$

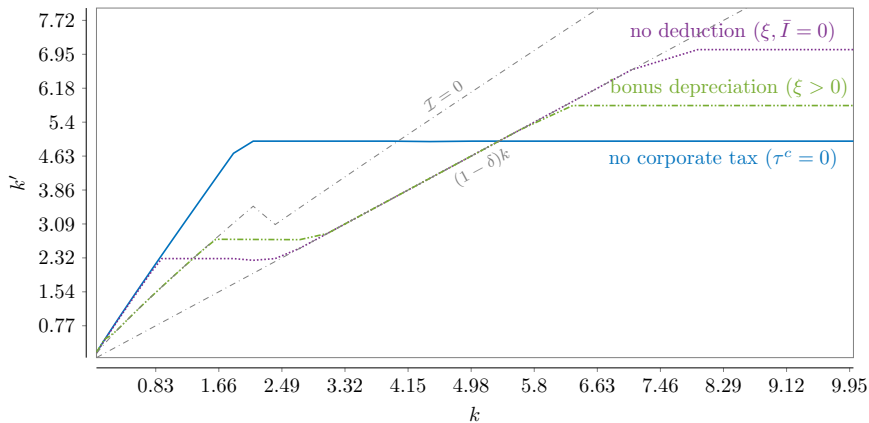
capital decision rule at median productivity with zero debt and taxable capital



# Distortion created by tax wedge

$$D = (1 - \tau^c)(z\varepsilon F(k, n) - wn) - b + qb' - (1 - \tau^c \mathcal{J}(k', k))I \mid_{I \geq 0} - (1 - \tau^c \omega)I \mid_{I < 0} + \tau^c \delta \psi \psi$$

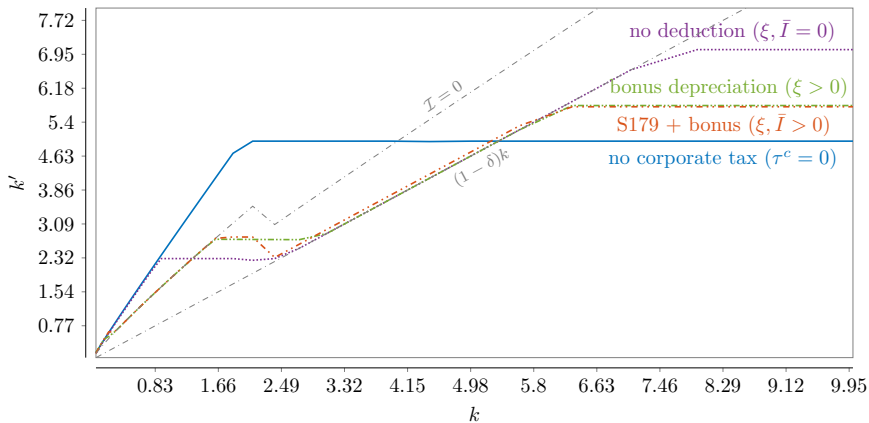
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# Distortion created by tax wedge

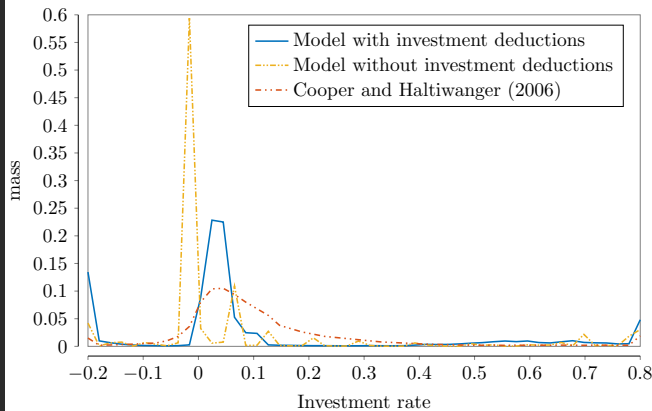
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capital decision rule at median productivity with zero debt and taxable capital



# Model validation: investment rate distribution for large firms

Investment rate distribution

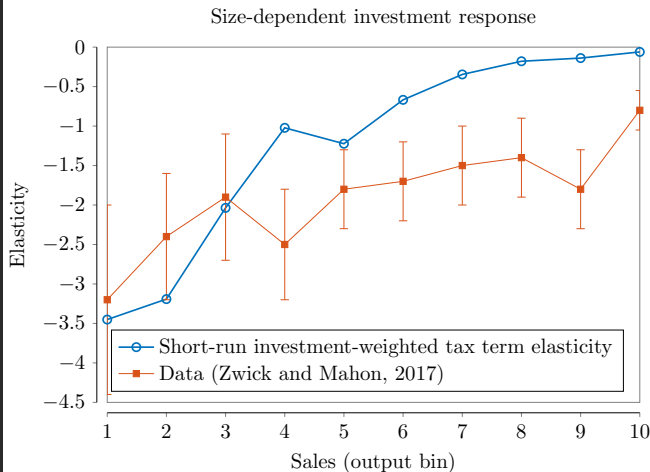


- Simulate 50,000 **unconstrained** firms for 100 periods
- Take the last 17 periods and plot investment rate distribution for firm  $\times$  periods
- Model with investment deduction tightly match the investment rate distribution

► Back

► Role of deductible stock

# Model validation: heterogeneous investment response in the short-run



- Simulate 50,000 firms for 100 periods
- Drop credit parameter  $\theta$  by 27% at date 79 and boost bonus rate at date 80
- Aggregate tax term elasticity from date 79 to date 80:  $-1.23$
- Zwick and Mahon (2017):  $-1.6$

▶ without fin friction

▶ GE

▶ Response



# Long-run effects

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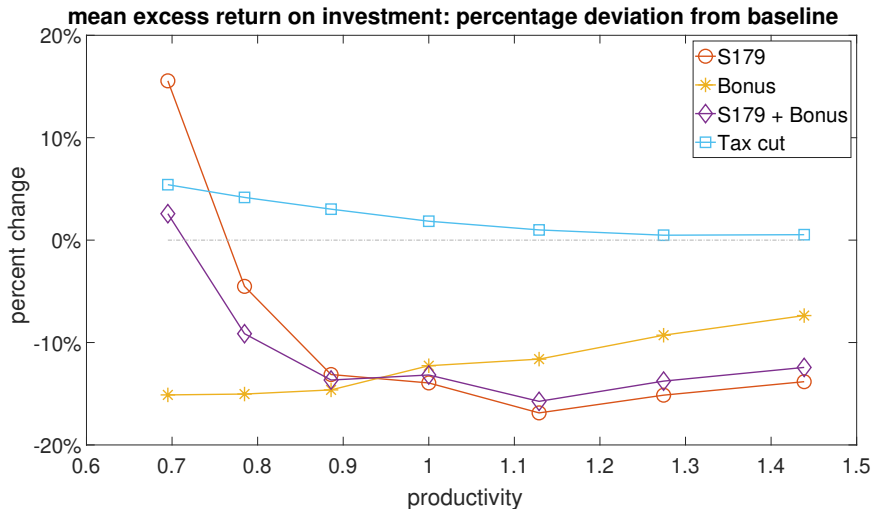
## Aggregate outcomes as percentage deviation of baseline

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%
Dividend	2.08%	10.14%	2.99%	-2.09%

- 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
- Untargeted nature of bonus induces dividend payment: recall  $D \propto \mathcal{J}(k', k)$ 
  - » unconstrained firms: user cost of capital drops, easier to achieve target capital



# Expanding S179 reduces investment wedge for productive firms





# Short-run dynamics

1 Introduction

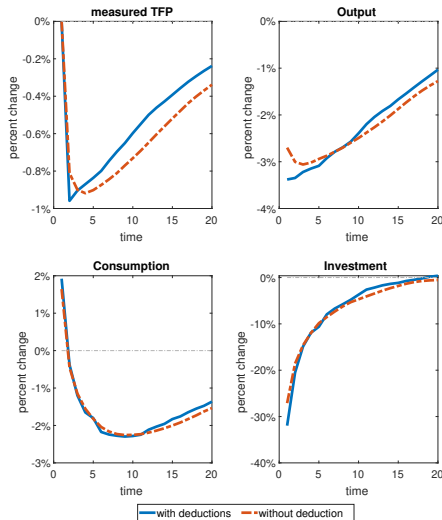
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# Corporate tax deductions leads to faster recoveries after credit shocks



**Exercise** Two economy, w/ and w/o deductions

**Shock** 27% initial drop in credit,  $\rho = 0.909$   
lead to 26% drop in debt

**Control** Hold  $\{G\}_{t=0}^T$  fixed

**Summary**

	w/ deduct	w/o deduct
Half life: $\hat{z}$	12 period	16 period
Trough: $\hat{z}$	-0.95%	-0.91%
Half life: $y$	14 period	16 period
Trough: $y$	-3.38%	-3.05%

# Application: policy evaluation

1 Introduction

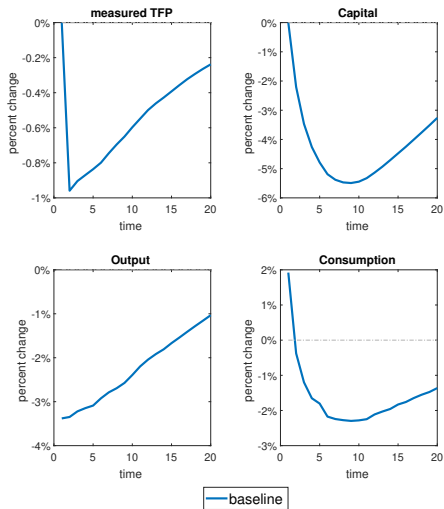
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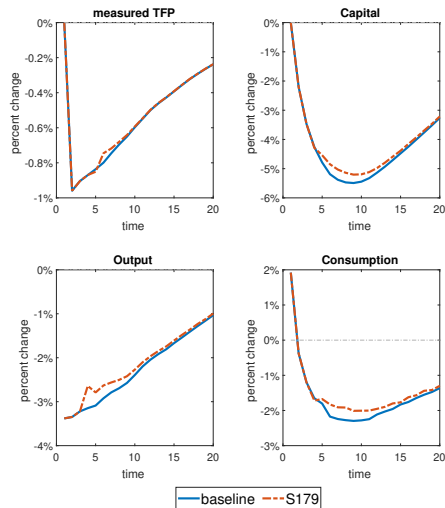
# Comparison of temporary investment tax deductions under credit shocks



**Shock** 27% initial drop in credit,  $\rho = 0.909$   
lead to 26% drop in debt

► Detail

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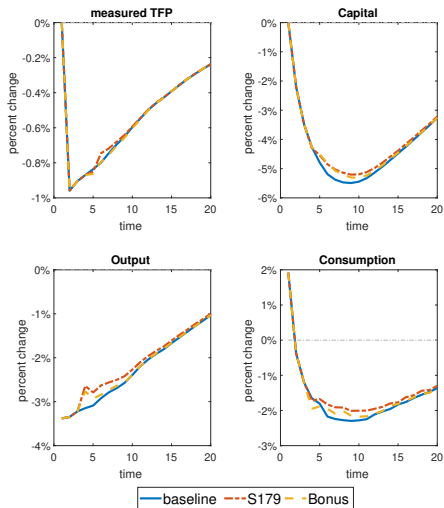
**Policy** implement in date 4, unexpected by HH

**S179** boost  $\hat{z}$  by 0.05% at date 6

	$Y$	$C$	$K$
trough $\downarrow$	0.51%	0.28%	0.29%

► Detail

# Comparison of temporary investment tax deductions under credit shocks



**Shock** 27% initial drop in credit,  $\rho = 0.909$   
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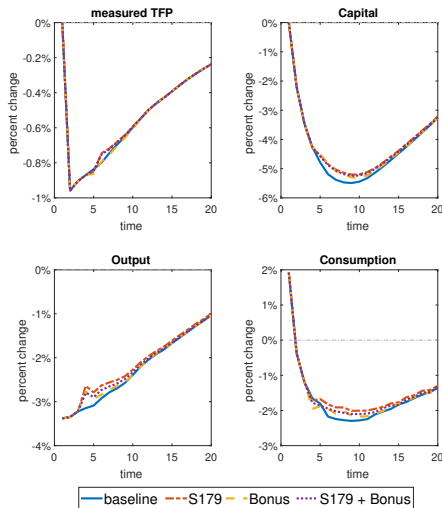
	$Y$	$C$	$K$
trough $\downarrow$	0.51%	0.28%	0.29%

**Bonus** boost  $\hat{z}$  by 0.005% at date 6

	$Y$	$C$	$K$
trough $\downarrow$	0.38%	0.14%	0.19%

► Detail

# Comparison of temporary investment tax deductions under credit shocks



**Shock** 27% initial drop in credit,  $\rho = 0.909$   
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**Policy** implement in date 4, unexpected by HH

**S179** boost  $\hat{z}$  by 0.05% at date 6

	Y	C	K
trough ↓	0.51%	0.28%	0.29%

**Bonus** boost  $\hat{z}$  by 0.005% at date 6

	Y	C	K
trough ↓	0.38%	0.14%	0.19%

**S179 + Bonus** boost  $\hat{z}$  by 0.04% at date 6

	Y	C	K
trough ↓	0.35%	0.19%	0.25%

► Detail



- 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 30% 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?



Thank you!

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- 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), Ohn (2018), Ohn (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 that accounts for distribution effects of shocks
  - Khan and Thomas (2013), House (2014), Koby and Wolf (2020), Winberry (2021)

New - utilize the technique and expands the analysis to counter-cyclical fiscal policies

# Corporate tax deductions in the US

- 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	$\Rightarrow +800 \times 0.5$	\$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	$\Rightarrow \times 0.5$	\$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.

MACRS Percentage 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

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%

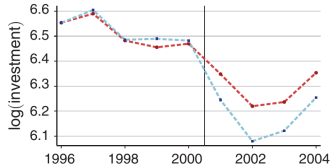
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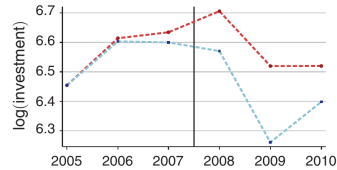
# Long-duration industries respond more to bonus depreciation

Source: Zwick and Mahon (2017)

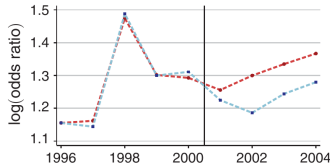
Panel A. Intensive margin: bonus I



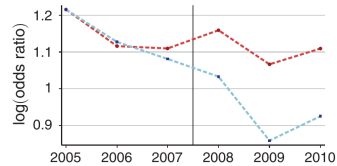
Panel B. Intensive margin: bonus II



Panel C. Extensive margin: bonus I



Panel D. Extensive margin: bonus II



--- Treatment group (long duration industries)  
--- Control group (short duration industries)

# Conforming states enjoys 18% of investment boosts

Source: Ohrn (2019)

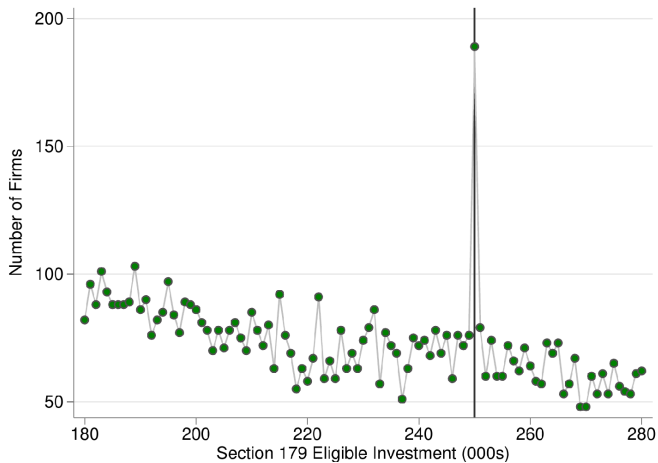
Table: Investment Impacts of State Bonus and State 179

Dependent Var: Specification	Ln CapEx			
	(1)	(2)	(3)	(4)
State Bonus	0.038 (0.036)		0.031 (0.037)	0.174** (0.073)
State 179		0.013 (0.009)	0.012 (0.009)	0.020** (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 \*.

# Firm distribution in 2008-2009

Source: Zwick and Mahon (2017)



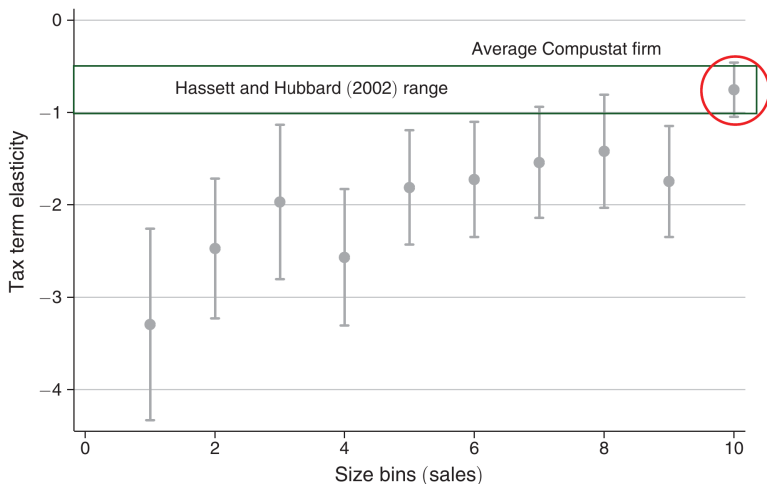
# Heterogeneity in investment response

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

Source: Zwick and Mahon (2017)



In 2015,

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

▶ Back

# 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,

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

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

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



# Unconstrained 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

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

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

$$B^w(k, \psi, \varepsilon) = \min_{\varepsilon_j} \left( \tilde{B}(K^w(k, \psi, \varepsilon_i), \psi', \varepsilon_j) \right)$$

$$\tilde{B}(k, \psi, \varepsilon_i) = \frac{1}{1 - \tau^c \tau^b} \left( (1 - \tau^c) \pi(k, \varepsilon_i) + \tau^c \delta^\psi \psi \right. \\ \left. - (1 - \tau^c \omega \mathcal{J}(K^w(k, \psi, \varepsilon_i) - (1 - \delta)k)) (K^w(k, \psi, \varepsilon_i) - (1 - \delta)k) \right. \\ \left. + q \min \{B^w(k, \psi, \varepsilon_i), \theta K^w(k, \psi, \varepsilon_i)\} \right),$$

I set interest deductability  $\tau^b = 0$  as minimum saving policy cannot converge with positive  $\tau^b$ . 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' 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.

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

and  $J^H$ ,  $J^L$  and  $J^N$  are defined as [► Back](#)

## 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

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

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

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

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

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

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

► Back

## 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

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

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

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

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

## 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:

$$k' \leq \bar{k} \equiv \min \left( \frac{z\varepsilon f(k, n) - wn - \delta^\psi \psi}{\xi\omega} + (1 - \delta)k, \mathbf{K}_{max} \right),$$

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

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

► Back

# 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

$$0 \leq D = (1 - \tau^c)(z\varepsilon F(k, n) - wn) - b + qb' - (1 - \tau^c \xi \omega)(k' - (1 - \delta)k) + \tau^c \delta^\psi \psi. \quad (\text{Dividend})$$

$$k' \in ((1 - \delta)k + \bar{I}, \bar{k}) \text{ and } k > \tilde{k} \quad (\text{Choice Sets})$$

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

$$\psi' = (1 - \delta^\psi)\psi + (\omega - \omega \xi)(k' - (1 - \delta)k) \quad (\text{deductible stock LoM})$$

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

► Back

►  $v^L(k, b, \psi, \varepsilon; \mu): \xi = 1$

►  $v^N(k, b, \psi, \varepsilon; \mu): \tau^c = 0$

► Household

► Equilibrium



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

subject to

$$0 \leq D = (1 - \tau^c)(z\varepsilon F(k, n) - wn) - b + qb' - (1 - \tau^c\omega)(k' - (1 - \delta)k) + \tau^c\delta^\psi\psi. \quad (\text{Dividend})$$

$$k' \leq (1 - \delta)k + \bar{I} \text{ and } k > \hat{k} \quad (\text{Choice Sets})$$

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

$$\psi' = (1 - \delta^\psi)\psi \quad (\text{Tax Benefit LoM})$$

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

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

subject to

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

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

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

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

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

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

$$\begin{aligned}
 V^h(\lambda, a; \mu) = & \max_{c, n^h, a', \lambda'} \left\{ u(c, 1 - n^h) + \beta V^h(\lambda', a'; \mu') \right\} \\
 \text{s.t. } & c + q(\mu)a' + \int \rho_1(k', b', \psi', \varepsilon'; \mu) \lambda' (d[k' \times b' \times \psi' \times \varepsilon']) \leq (1 - \tau^n) w(\mu) n^h, \\
 & + a + \int \rho_0(k, b, \psi, \varepsilon; \mu) \lambda (d[k \times b \times \psi \times \varepsilon]) + R - T
 \end{aligned} \tag{3}$$

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,  $\tau^n$  is payroll tax,  $R$  is the steady state government lump-sum rebates to households, and  $T$  is lump-sum tax to fund policy changes.

Market clear :  $Y = C + [(1 - \pi_d) (K' - (1 - \delta)K) - \pi_d(1 - \delta)K] + \pi_d k_0 + \bar{G}$

Output :  $Y = \int z\varepsilon F(k, n(k, \varepsilon)) d\mu$

Capital :  $K = \int k d\mu$

Labor :  $N^h = N$ , where  $N = \int n(k, \varepsilon) d\mu$

Deductible stocks :  $\Psi = \int \psi(k, \psi, \varepsilon) d\mu$

Debt :  $B = \int b d\mu$

Corp. revenue :  $R = \tau^c \int \max (z\varepsilon F(k, n) - wn - \mathcal{J}(k', k)(K' - (1 - \delta)k) - \delta^\psi \psi, 0) d\mu$

Gov. Budget :  $\bar{G} = \tau^n w N^h + R + T$

- 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  $\infty$ ,

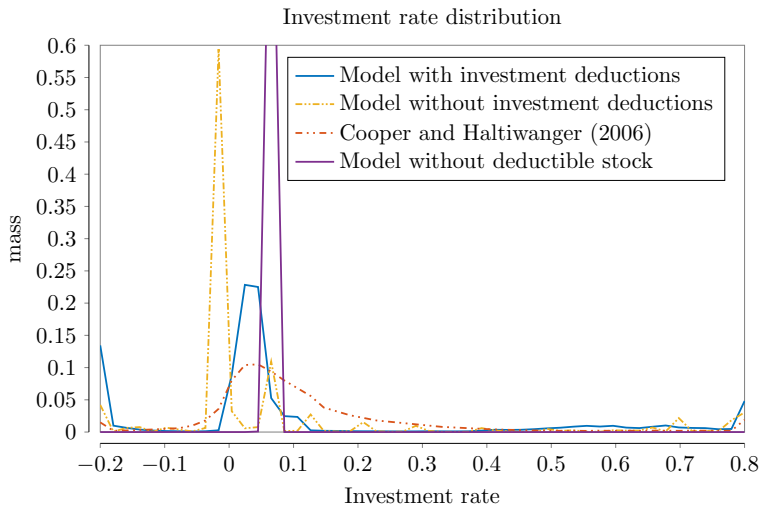
$$w(\mu) = \frac{\varphi c}{(1 - \tau^n)}$$

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

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

	Parameter	Value	Reason
<i>Exogenous parameters</i>			
fraction of entrants capital endowment	$\chi$	0.1	10% of aggregate capital
exogenous exit rate	$\pi_d$	0.1	10% entry and exit
Corporate tax rate	$\tau^c$	0.21	US Tax schedule after TCJA
Deductible stock depreciation rate	$\delta^\psi$	0.138	$\delta^\psi = 2\delta$ (Double-declining balance)

◀ Calibration

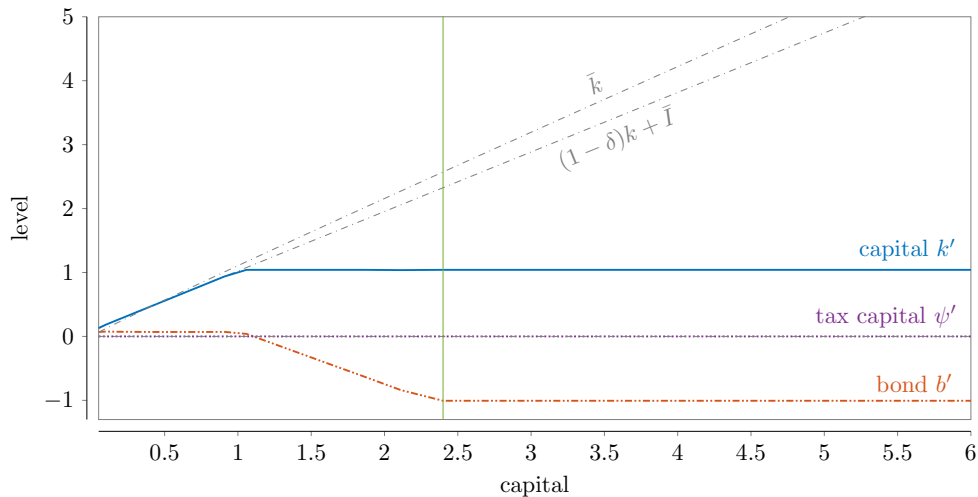


- › Model frequency: annual
- › Household utility function:  $u(c, n^h) = \log c + \varphi(1 - n^h)$
- › Production function:  $F(k, n) = k^\alpha n^\nu$
- › Initial capital for entrants:  $k_0 = \chi \int k \tilde{\mu}(d[k \times b \times \psi \times \varepsilon])$
- › Initial bond and taxable capital:  $b_0 = 0$  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

▶ Back



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

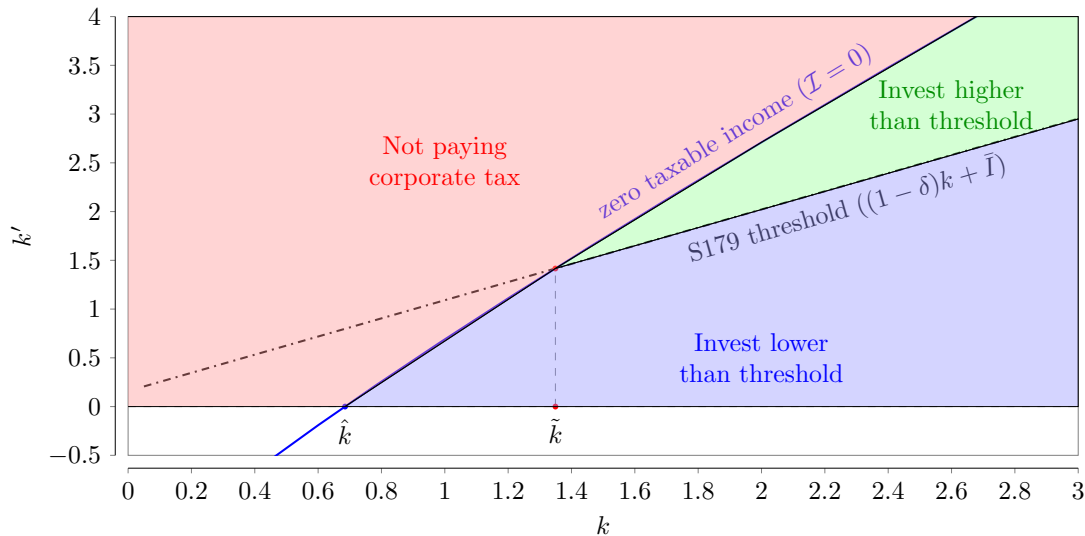


## Steady State Comparison (Cont.)

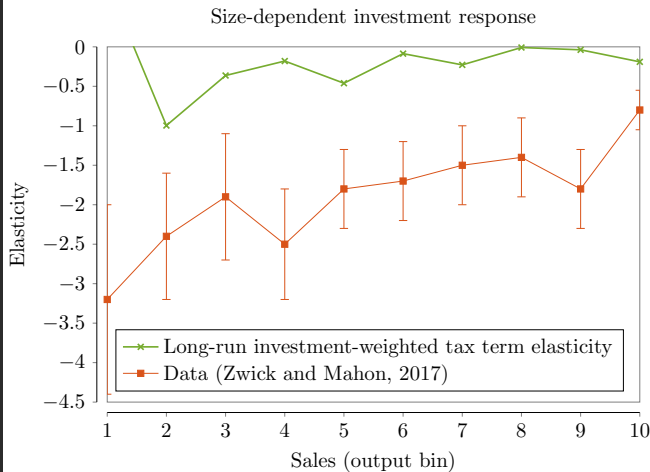
	Description	baseline	S179	bonus	both
<i>Prices</i>					
$p$	marginal utility of consumption	100 (2.80)	98.47	99.08	98.13
$w$	wage	100 (0.97)	101.55	100.92	101.91
<i>Distribution</i>					
$\mu_{\text{unc}}$	unconstrained firm mass	0.080	0.093	0.099	0.129
$\mu_{\text{con}}$	constrained firm mass	0.920	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
<i>Financial Variables</i>					
$D$	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
$\mu c$	user cost of capital	100 (0.14)	86.26	97.44	85.45
$\tau^*$	effective corporate tax rate	100 (0.10)	92.43	94.08	91.68

► Aggregates

# Capital choice state space

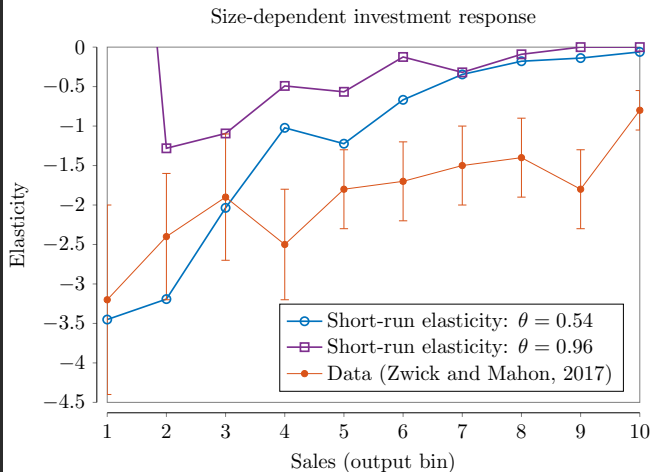


# Model prediction: not much heterogeneity in long-run investment response



- Include the GE effects
- aggregate elasticity:  $-0.17$

# Investment elasticity without financial friction



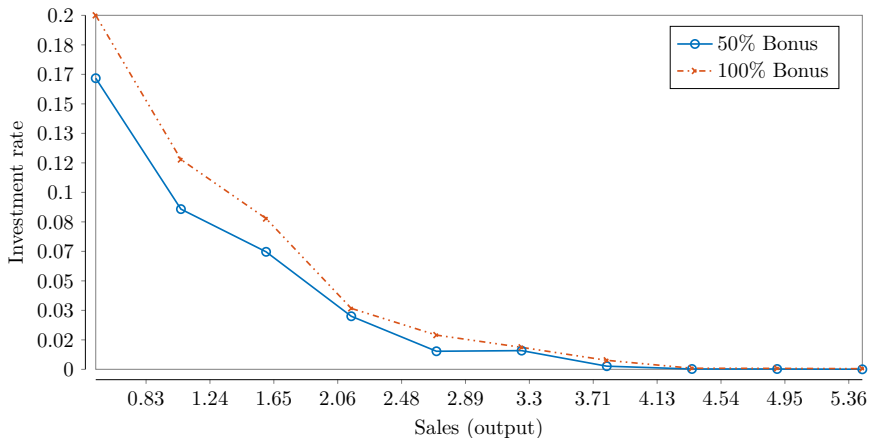
- When  $\theta \rightarrow \frac{1}{q}$ , the collateral constraints are not binding
- Aggregate tax term elasticity: 0.29

◀ Back

# Investment Response to raising bonus depreciation

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

Size-dependent investment response



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:

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

# Approximating the derivatives of the value functions

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

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

RHS secant at  $(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$ ,  $i_k = 1, \dots, N(k) - 1$  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  $(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$ ,  $i_k = 2, \dots, N(k)$  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  $i_k = 2, \dots, N(k) - 1$ ,

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

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  $i_k = N(k)$ ,

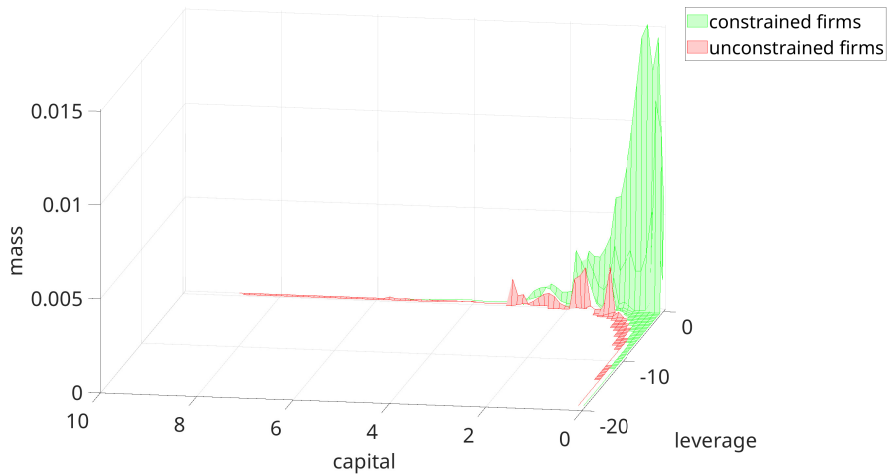
$$D_k V^0(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon}) = s_l(k_{i_k}, b_{i_b}, \psi_{i_\psi}, \varepsilon_{i_\varepsilon})$$

# Calibrated Moments for Baseline Model

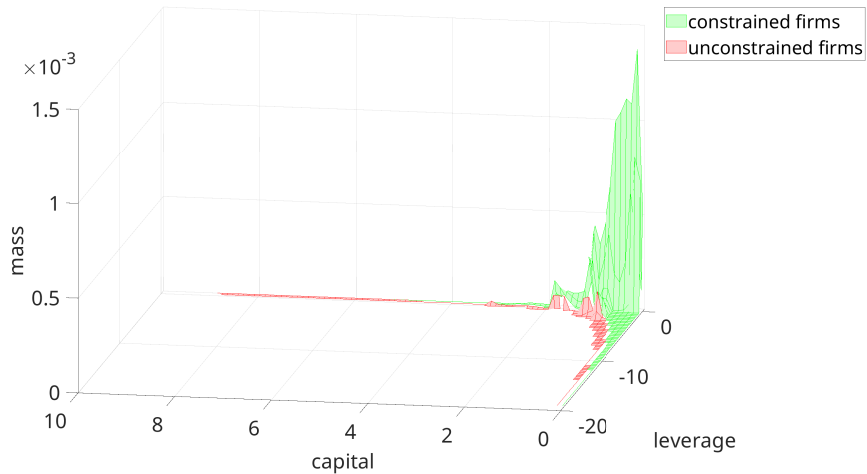
Parameter	Target		Model
$\beta = 0.96$	real interest rate	$= 0.04$	0.04
$\alpha = 0.3$	private capital-output ratio	$= 2.3$	2.03
$\nu = 0.6$	labor share	$= 0.6$	0.6
$\tau^n = 0.25$	government spending-output ratio	$= 0.21$	0.201
$\delta = 0.069$	average investment-capital ratio	$= 0.069$	0.069
$\varphi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

[◀ Back](#)
[► Functional Form](#)
[► Exogenous parameters](#)
[► Investment rate distribution](#)

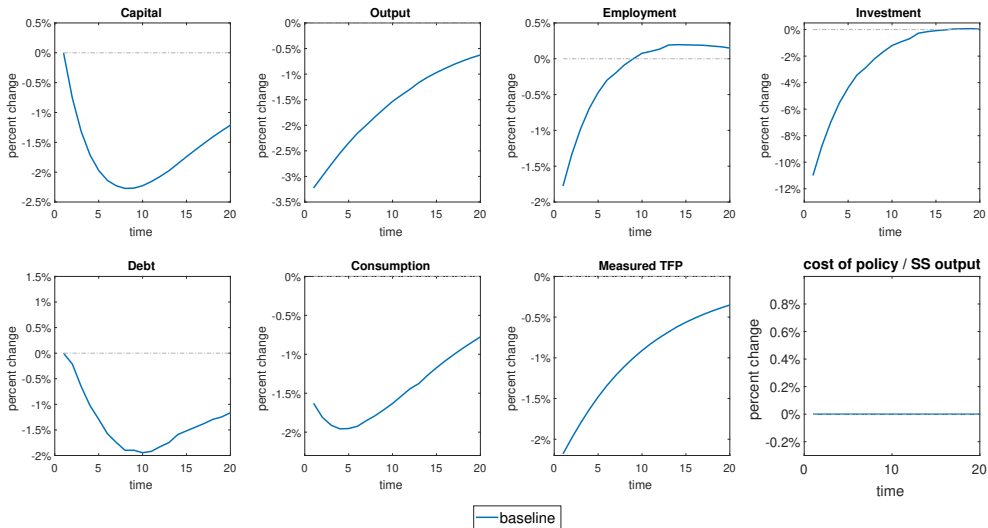
## Distribution: median productivity



## Distribution: minimum productivity

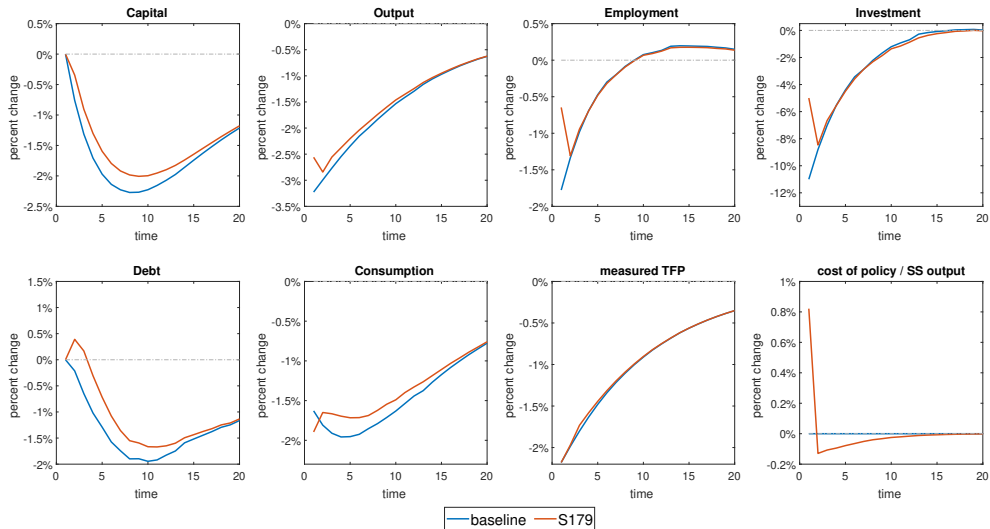


# IRF: negative TFP shocks with scale 2.18% and persistence 0.909



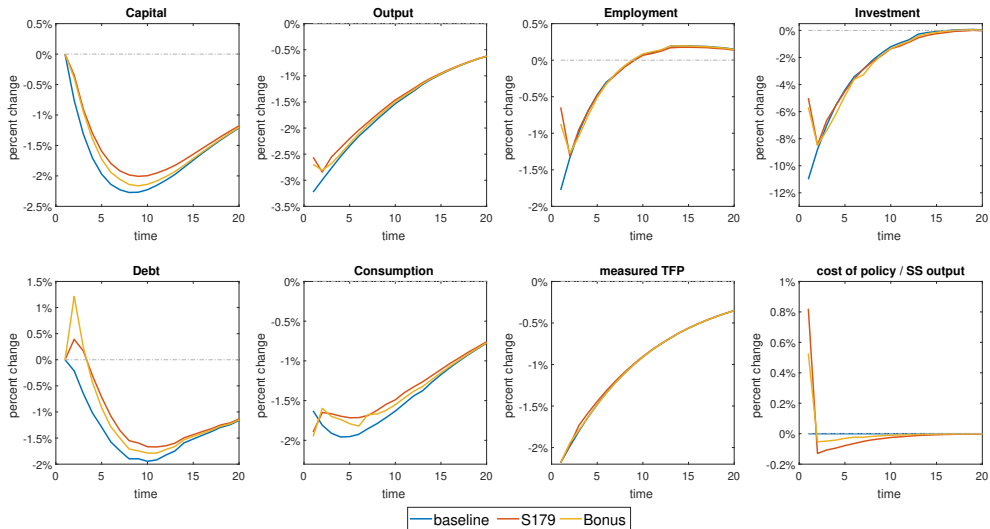
► Percentage deviation from baseline

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



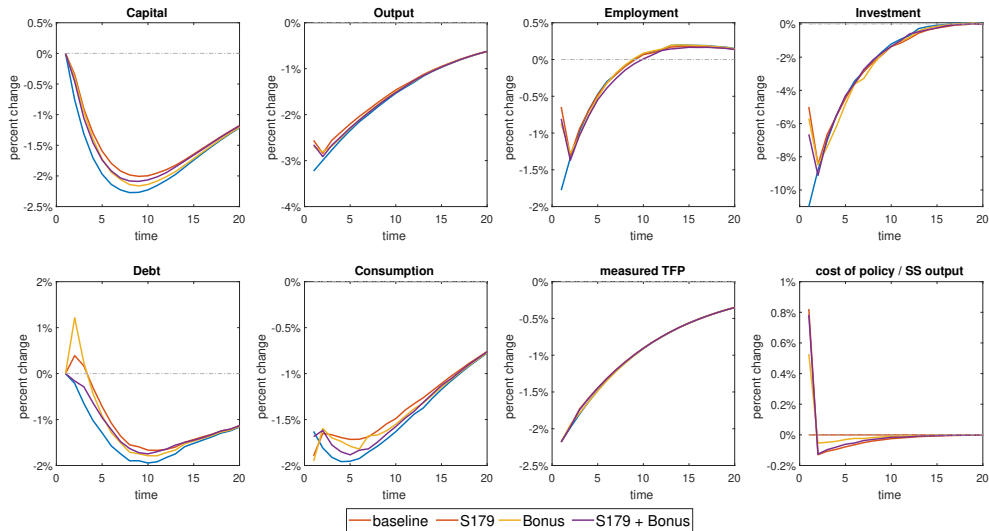
► Percentage deviation from baseline

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



► Percentage deviation from baseline

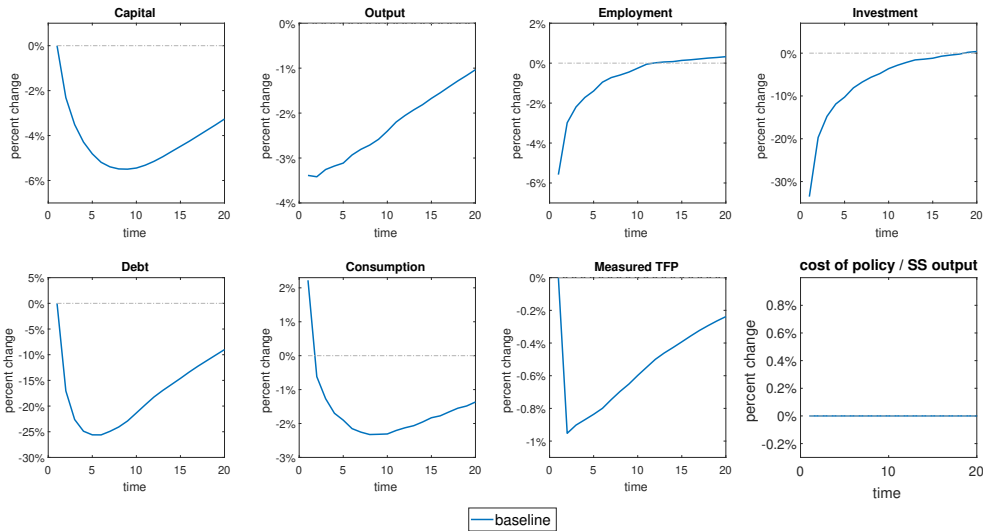
# IRF: negative TFP shocks with scale 2.18% and persistence 0.909



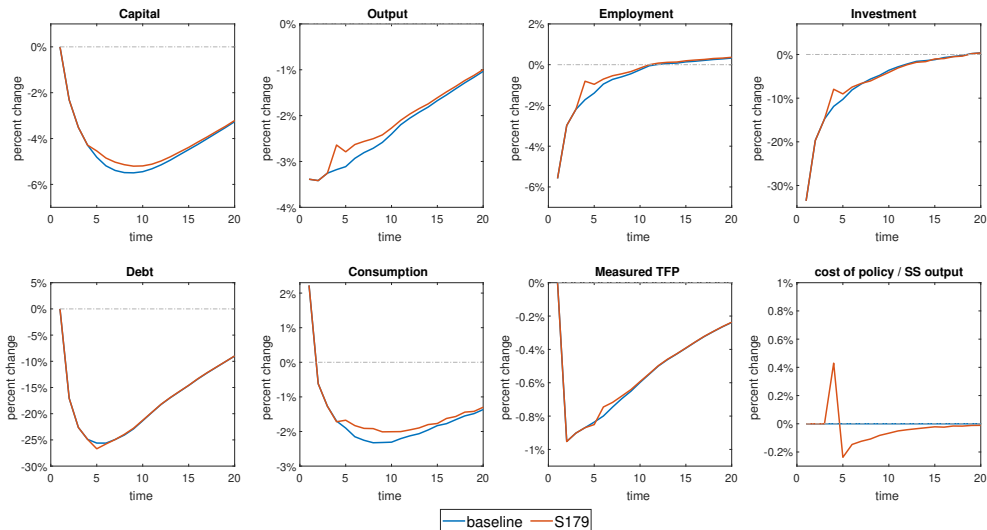
► Percentage deviation from baseline



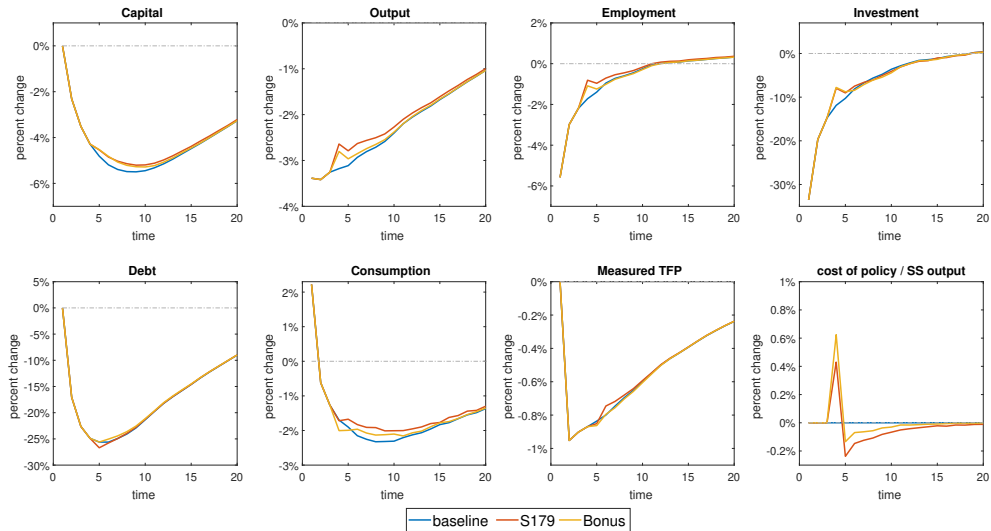
# IRF: negative credit shocks with scale 27% and persistence 0.909



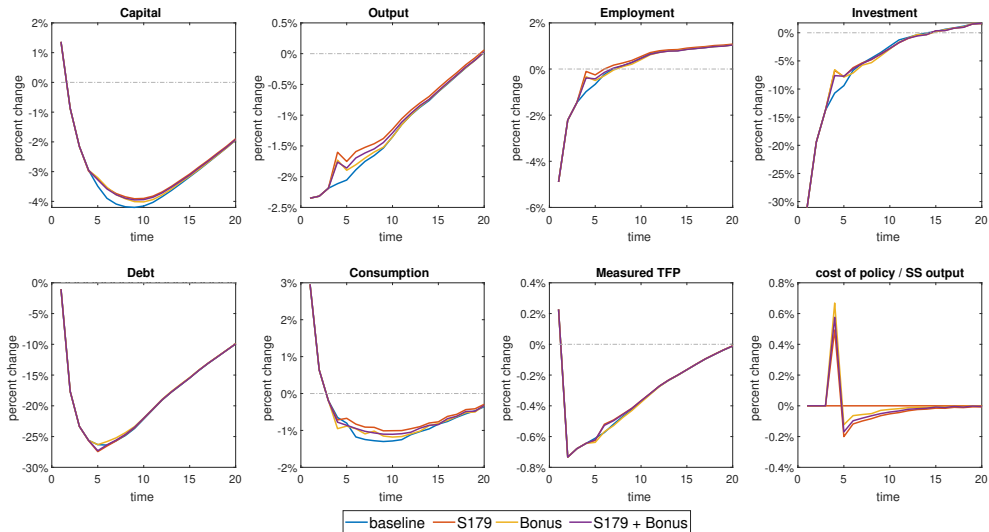
# IRF: negative credit shocks with scale 27% and persistence 0.909



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



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



# Almost no role of corporate taxation following a TFP shock

