Stabilization vs. Growth

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Motivation

- Advanced economies operate with some form of **soft credit** [Kornai, 1980]
  - Ex-post interventions that support firms in distress
  - Lending arrangements: evergreening (Japan 90s), restructuring (Chapter 11)
  - Fiscal interventions: business support, guarantee programs (COVID-19 recession)

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- **Question**: what are the effects of soft credit in a model of fluctuations & growth?
- **Challenges**:
  - Typical macro models not designed to study this trade-off
  - Requires framework with business cycles + firm heterogeneity + endogenous growth

This paper: overview

1. **Develop a novel general equilibrium model with key features**:
   - Aggregate fluctuations with tractable firm heterogeneity
   - Defaultable firm debt + endogenous firm exit
   - Endogenous productivity growth with innovation externalities

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2. **Parametrize the model w/ mix of calibration & direct estimation**
   - Benchmark: US economy $\simeq$ soft credit regime w/ evergreening
   - Key parameters estimated using firm-level data:

     (i) learning from peers, (ii) R&D cost curvature

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3. **Compare alternative economies**
   - Soft credit (evergreening, restructuring, credit guarantees) vs. <u>hard credit</u>
   - Study effects on growth, volatility, welfare
   - How does optimal policy differ under commitment vs. discretion?

This paper: main findings

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- Weakens selection, lowers average productivity $\Rightarrow$ raises cost of innovation
- General equilibrium: more firms survive, wages $\uparrow$, profits & investment $\downarrow$

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Effects of eliminating evergreening in the U.S.:

- GDP growth $\uparrow$ (2%$\rightarrow$2.39%); std. dev. GDP growth $\uparrow$ (2.03$\rightarrow$2.81)
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Why does soft credit arise?

- Policymaker with commitment $\Rightarrow$ eliminate soft credit
- Discretion: value short-run stabilization at the expense of long-run growth

Literature

1. The soft budget constraint: Kornai (1980, 1986); Dewatripont & Maskin (1995); Kornai, Maskin, and Roland (2003)
    - Microfound the SBC in a model of business cycles and endogenous growth
2. Innovation, finance & growth: Howitt and Levine (2018); Celik (2023); Ottonello and Winberry (2024); Aghion, Bergeaud, Dewatripont & Matt (2025)
    - Interactions between financial frictions and endogenous innovation; business cycles & endogenous growth
3. Cleansing effects of recessions: Caballero and Hammour (1994), Barlevy (2003), Ouyang (2009)
    - New mechanism for the cleansing effect of recessions + features that can mute this mechanism
4. Technology spillovers: Hall (2011); Bloom, Schankerman and Van Reenen (2013); Monge-Naranjo (2019); Atkeson and Burstein (2019), Akcigit, Hanley and Stantcheva (2022)
    - Complementary estimates for spillovers of R&D investment across firms
5. Welfare costs of business cycles: Lucas (1987, 2003)
    - Policymaker without commitment may value stabilization over long-run growth

Roadmap

Model

Calibration and estimation

Quantitative results

Welfare and policy

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Model structure

- Time is discrete and infinite $t = 0, 1, 2, \ldots$
- Demographics:
  - **Firms:** unit mass, intra-period heterogeneity via idiosyncratic shock ε
  - **Lenders:** unit mass, risk-neutral, matched one-to-one with firms
  - **Household**: representative, supplies labor and deposits, owns all claims ▸ details

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- Key Features:
  1. Aggregate shocks $\Rightarrow$ business cycles
  2. Endogenous innovation (R&D) $\Rightarrow$ long-run growth
  3. Institutional arrangements in lender-borrower relationships:
     - hard credit: repay or default/exit
     - soft credit: some firms may benefit from ex-post interventions

Firms: technology and productivity

Production (decreasing returns):

$$y = a^{1-\eta}(\zeta k)^{\alpha} n^{\eta}, \quad a = z \cdot \varepsilon$$

- $\zeta =$ AR(1) capital quality shocks [e.g., Brunnermeier & Sannikov, 2014]
- $z =$ fundamental productivity (same for all firms in eq.)
- $\varepsilon \sim F[0, \infty)$ is idiosyncratic productivity, i.i.d. across time and firms

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Innovation (choice of z'):

$$\text{R\&D costs} = \phi \left(\frac{z'}{z^{1-\rho}(a^*)^{\rho}} \right)^{\kappa}, \qquad a^* = Z \times \mathbb{E}[\varepsilon | \text{incumbent}]$$

- ρ: learning spillovers from average productivity a^* [Monge-Naranjo, 2019]
- κ: curvature of R&D costs / innovation elasticity [Greenwood, Han, and Sánchez, 2022]

Firms: financial frictions

Debt instruments:

1. Intraperiod debt (working capital): firm borrows ℓ, repays $(1+i)\ell$ within period

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$$b' \leq \theta k'$$

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Limited liability and default:

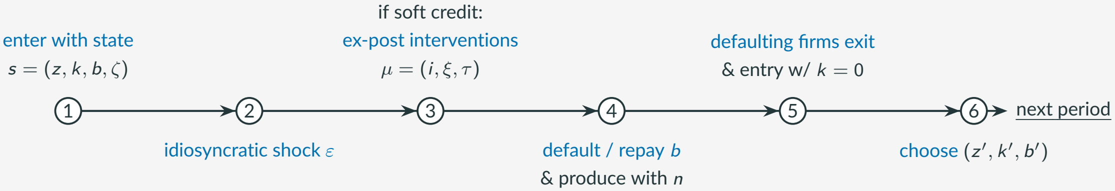
- Default at the start of the period, after shocks, before production
- In default, lender recovers

$$(1-\lambda)\zeta k$$

Timeline within a period

1. enter with state $s = (z, k, b, \zeta)$
2. idiosyncratic shock ε
3. if soft credit: ex-post interventions $\mu = (i, \xi, \tau)$
4. default / repay b & produce with n
5. defaulting firms exit & entry w/ $k = 0$
6. choose (z', k', b') → next period

Timeline within a period



Ex-post soft credit interventions $\mu \rightarrow$ conditional on (s, ε):

- Evergreening: lenders may extend cheaper intraperiod credit $i \geq i^{reg}$
- Restructuring: lenders may write off fraction $\xi \leq \xi^{reg}$ of existing debt b
- Credit guarantees: government may issue targeted loan guarantee $\tau \leq \tau^{reg}$

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Model structure: intra-period heterogeneity via ε + intertemporal aggregation

- Dynamic choices (z', k', b') remain identical across firms

Firm problem

1. **Enter period with $s \equiv (z, k, b, \zeta)$, observe ε and $\mu = (i, \xi, \tau)$, choose default iff:**

$$V_0(s, \varepsilon; \mu) < 0 \Leftrightarrow \varepsilon < \bar{\varepsilon}(s; \mu)$$

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2. **If repay, pay fixed cost ν, hire labor n, borrow ℓ, produce $\rightarrow$ payout:**

$$V_0(s, \varepsilon; \mu) = \max_{n,\ell} (z\varepsilon)^{1-\eta}(\zeta k)^{\alpha} n^{\eta} - wn + \ell - (1 + i)\ell - \nu - b(1 - \xi) + (1 - \delta)\zeta k + \tau + V_1(s)$$

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3. **Exiting firms replaced with entrants; all firms choose (z', k', b'):**

$$V_1(s) = \max_{z',k',b'} -\phi \left(\frac{z'}{z^{1-\rho}(a^*)^{\rho}} \right)^{\kappa} - k' + qb' + \mathbb{E}[M \cdot \max\{0, V_0(s', \varepsilon'; \mu')\}]$$

$$\text{s.t.} \quad b' \leq \theta k'$$

Lenders: dynamic problem

- Each firm maintains a relationship with a risk-neutral lender
- Lender chooses deposits d' and price of debt q s.t. funding constraint

$$W_1(s) = \max_{q,d'} \mathbb{E}_{\zeta',\varepsilon'}\{M \cdot [W_0(z'(s;q), k'(s;q), b'(s;q), \zeta', \varepsilon') - d']\} \quad \text{s.t.} \quad qb'(s;q) \leq Q^d d'$$

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- **Free entry**: zero expected profits

$$W_1(s) = 0 \Rightarrow q = \frac{\mathbb{E}[M \cdot W_0(z'(s;q), k'(s;q), b'(s;q), \zeta', \varepsilon')]}{b'(s;q)}$$

- Ex-post profits/losses are rebated lump-sum to household

Lenders: intraperiod problem

- Lenders raise resources at linear cost ω to fund intraperiod lending
- Hard credit: lend at $i = \omega \rightarrow$ threat of new lenders creates upper bound

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- Hard credit: lend at $i = \omega \rightarrow$ threat of new lenders creates upper bound
- Evergreening: internalize effects of i on default decision

$$W_0(s,\varepsilon) = \max_{i \geq i^{reg}} \underbrace{\mathbf{1}[\varepsilon \geq \bar{\varepsilon}(s;i)]}_{\text{no default}} \underbrace{\{b + (i-\omega)wn(s,\varepsilon;i)\}}_{\text{lend, continue}}$$

$$+ \underbrace{\mathbf{1}[\varepsilon < \bar{\varepsilon}(s;i)]}_{\text{default}} \underbrace{(1-\lambda)\zeta k}_{\text{recovery}}$$

Intraperiod equilibrium: hard vs. soft credit

▸ evergreening details

Hard Credit: no ex-post support allowed

$$i^{reg} = \omega$$

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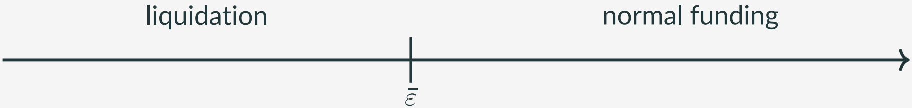

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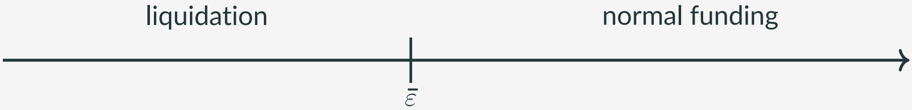

Soft Credit: interventions occur after shock ε is observed

$$i(s, \varepsilon) \in [i^{reg}, \omega]$$

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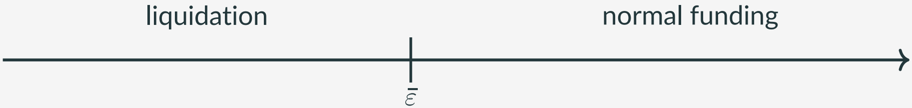

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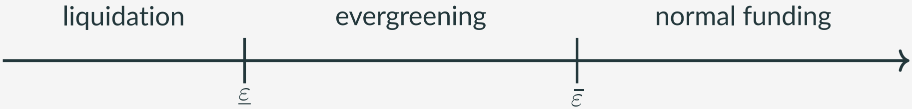

Soft credit and growth: three transmission channels

eq. definition
balanced growth path

$$\underbrace{\frac{z'}{z}}_{\text{prod. growth}} = \underbrace{\left[\frac{(\varepsilon^*)^{\rho\kappa}}{\kappa\tilde{\phi}}\right]^{\frac{(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}}}_{\text{innovation costs}} \times \underbrace{\left\{\mathbb{E}\left[M \cdot \int_{\bar{\varepsilon}(s')}^{\infty} \frac{\partial V_0}{\partial z'}\, \mathrm{d}F(\varepsilon')\right]\right\}^{\frac{(1-\alpha)}{\kappa(1-\alpha)-(1-\eta)}}}_{\text{innovation benefits}}$$

(1) Spillovers:

Soft credit keeps low-ε firms alive, $\varepsilon^* \downarrow \Rightarrow$ higher innovation costs

(2) Congestion: More firms $\Rightarrow$ labor demand $\uparrow \Rightarrow$ wages $\uparrow \Rightarrow$ profits $\downarrow$

(3) Debt overhang: Larger "rescue" zone $\Rightarrow$ private innovation benefits $\downarrow$

Soft credit $\longrightarrow$ Innovation becomes more expensive & Payoffs get smaller $\longrightarrow$ Slower growth

Roadmap

Model

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- **Proceed in three steps**:
  1. External calibration of standard parameters ▸ details
  2. Direct estimation of parameters related to R&D cost and externality using micro data (κ, ρ)
  3. Internal calibration of remaining parameters to match moments of the U.S. economy
     - exit rate, rel. prod. of exiters, credit spreads, profit rates, GDP growth (avg., autocorr., vol.) ▸ details

Estimating the R&D Cost Function

Model R&D Cost Function for firm i in industry s:

$$\mathrm{R\&D}_{i,s,t} = \phi_t \left(\frac{z_{i,s,t+1}}{z_{i,s,t}^{1-\rho} \left(a_{i,s,t}^{*}\right)^{\rho}} \right)^{\kappa},$$

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Objects in the data:

- $z_{i,s,t}$: firm productivity
- $a^*_{i,s,t}$: peer productivity (industry s excluding i)
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Take logs and re-arrange:

$$\log z_{i,s,t+1} - \log z_{i,s,t} = \frac{1}{\kappa} \left(\log \mathrm{R\&D}_{i,s,t} - \log \phi_t\right) + \rho \log \left(\frac{a^*_{i,s,t}}{z_{i,s,t}} \right)$$

Parameters to be identified: $1/\kappa$ and ρ

Empirical specification & identification

▸ TFP Estimation ▸ Details & Robustness

Empirical specification uses predetermined productivity terms & time FEs

$$\log z_{i,s,t+1} - \log z_{i,s,t-1} = \mu_t + \beta_1 \log \mathrm{R\&D}_{i,s,t} + \beta_2 \log \left(\frac{a^*_{i,s,t-1}}{z_{i,s,t-1}} \right) + u_{i,s,t}$$

- **Endogeneity concern**: $\mathrm{R\&D}$ correlated with unobservables (e.g. expected growth)

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- **First stage**: higher credits $\Rightarrow$ higher reported firm R&D; F-stat $\approx$ 15–20

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- **Endogeneity concern**: $\mathrm{R\&D}$ correlated with unobservables (e.g. expected growth)
- IV approach: state-level R&D tax credits [Wilson, 2009; Bloom et al., 2013]
- **First stage**: higher credits $\Rightarrow$ higher reported firm R&D; F-stat $\approx$ 15–20
- **Data:** annual Compustat, sample: 1982–2023; obtain firm-level TFP estimates

Results: $\hat{\beta}_1 = 0.33^{***}$, $\hat{\beta}_2 = 0.30^{***} \Rightarrow \hat{\kappa} \approx 1/\hat{\beta}_1 \approx 3, \quad \hat{\rho} \approx 0.30$

- Magnitude: 1% more R&D or 1% larger peer gap $\Rightarrow$ 0.3% higher prod. growth
- Robustness: baseline lies near middle of range $\beta_1 \in [0.22, 0.51]$, $\beta_2 \in [0.23, 0.41]$

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Impact of soft credit on balanced growth path

PD ε policy functions

Moment	Hard Credit	Evergreening	Restructure	Guarantee
Share of subsidized firms, %	0.00	5.00	5.00	5.00
Exit rate, %	8.86	4.91	4.92	4.96
Wage				
Average iid productivity, ε^*				
GDP growth				
std. dev. GDP growth				
$corr(\text{R\&D}, Y)$				

Hard credit: firms in distress receive no support $\Rightarrow$ more exit

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Wage	**0.73**	**0.78**	**0.78**	**0.78**
Average iid productivity, ε^*	**1.05**	**1.03**	**1.03**	**1.03**
GDP growth				
std. dev. GDP growth				
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Hard credit: lower equilibrium wages, better selection $\varepsilon^* \uparrow$

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Average iid productivity, ε^*	1.05	1.03	1.03	1.03
GDP growth	**2.39**	**2.00**	**2.05**	**2.06**
std. dev. GDP growth	**2.81**	**2.03**	**2.27**	**2.25**
$corr(\mathrm{R\&D}, Y)$				

Hard credit: stronger growth, more volatile GDP

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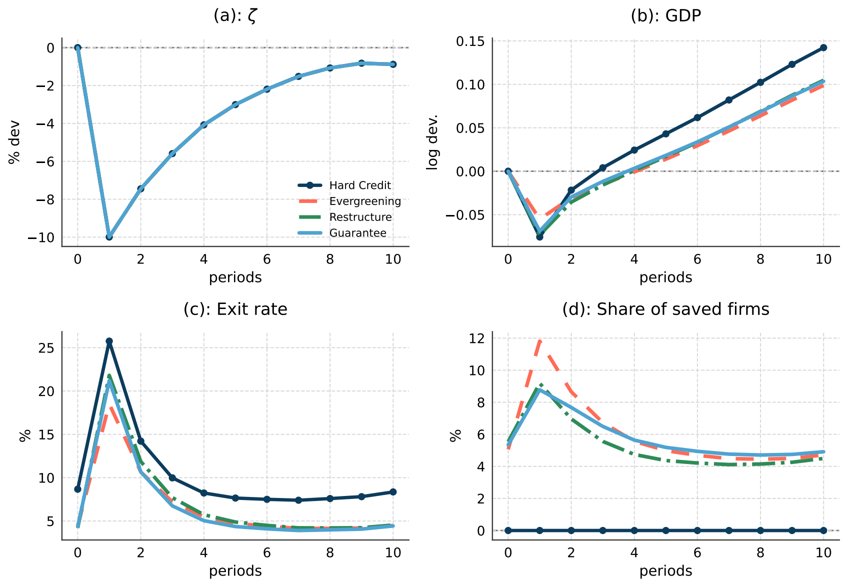
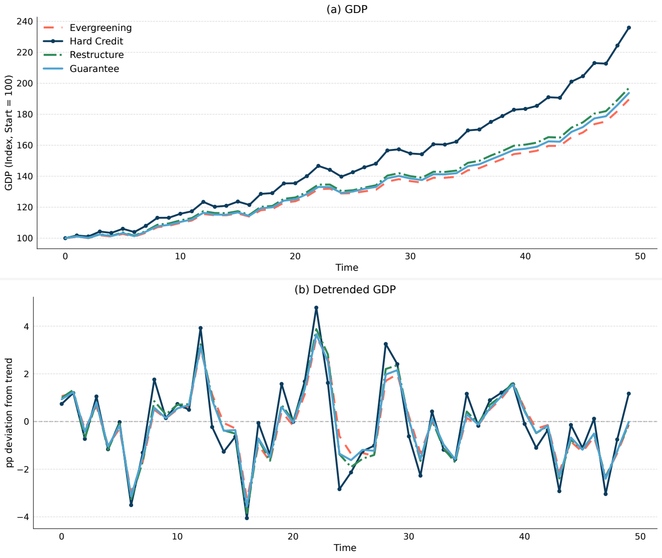
corr$(\mathrm{R\&D}, Y)$	**0.69**	**0.90**	**0.85**	**0.90**

Hard credit: R&D investment is less cyclical

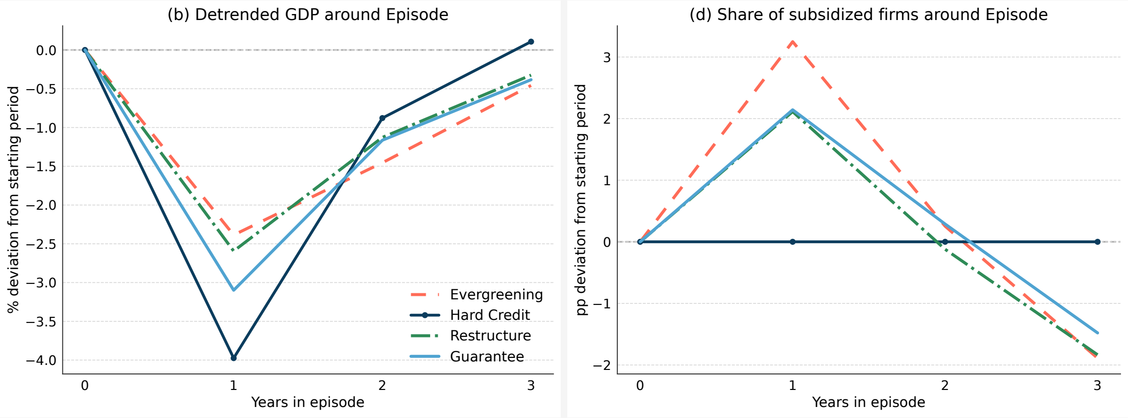
IRF to capital quality shock: soft credit economies more resilient



Hard credit: faster growth, more volatile business cycle



Average recession episodes



Model robustness

- No learning externalities, $\rho = 0$ results
- Learning externalities over different moments of the distribution (p75, p90)
- Higher discount factor, $\beta \uparrow$
- Higher risk aversion, $\sigma \uparrow$

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Quantitative results

Welfare and policy

Measuring welfare

- Expected PDV of flow utility for rep. household in economy k ▸ details

$$\mathcal{U}^k = \mathbb{E} \sum_{t=0}^{\infty} \beta^t u(X_t^k)$$

- X is the consumption-labor composite good in King, Plosser & Rebelo (1988) preferences

$$X_t^k = \underbrace{x_t^k}_{\text{cyclical part}} \times \underbrace{(z_t^k)^{\frac{1-\eta}{1-\alpha}}}_{\text{stochastic trend}}, \qquad z_t^k = \prod_{s=0}^{t-1} G_{z,s}^k$$

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- Second-order approximation of welfare:

$$\mathcal{U}^k \simeq \mathcal{U}^k_{\text{mean}} + \mathcal{U}^k_{\text{vol}}$$

- Further approximate volatility component as:

$$\mathcal{U}^k_{\text{vol}} = \mathcal{U}^k_{\text{vol,cyclical}} + \mathcal{U}^k_{\text{vol,trend}} + \mathcal{U}^k_{\text{vol,cov}}$$

Welfare effects of soft credit

details on welfare comparison | transitional dynamics

CEV of moving from Hard Credit to...	Evergreening	Restructuring	Guarantee
CEV, total	**-3.13**	**-2.47**	**-2.32**
CEV, mean			
CEV, volatility			
CEV, cyclical volatility			
CEV, trend volatility			
CEV, volatility from $\mathrm{Cov}(x, z)$			

$CEV < 0 \Rightarrow$ **welfare higher in Hard Credit economy**

Welfare effects of soft credit

details on welfare comparison transitional dynamics

CEV of moving from Hard Credit to...	Evergreening	Restructuring	Guarantee
CEV, total	-3.13	-2.47	-2.32
CEV, mean	**-2.37**	**-1.82**	**-1.62**
CEV, volatility			
CEV, cyclical volatility			
CEV, trend volatility			
CEV, volatility from $\mathrm{Cov}(x, z)$			

Mean component $< 0 \Rightarrow$ growth effect dominates

Welfare effects of soft credit

▸ details on welfare comparison ▸ transitional dynamics

CEV of moving from Hard Credit to...	Evergreening	Restructuring	Guarantee
CEV, total	-3.13	-2.47	-2.32
CEV, mean	-2.37	-1.82	-1.62
CEV, volatility	**-0.76**	**-0.65**	**-0.70**
CEV, cyclical volatility			
CEV, trend volatility			
CEV, volatility from $\mathrm{Cov}(x, z)$			

Volatility component also negative $\Rightarrow$ explained by more stable stochastic trend

Welfare effects of soft credit

details on welfare comparison
transitional dynamics

CEV of moving from Hard Credit to...	Evergreening	Restructuring	Guarantee
CEV, total	-3.13	-2.47	-2.32
CEV, mean	-2.37	-1.82	-1.62
CEV, volatility	-0.76	-0.65	-0.70
CEV, cyclical volatility	**0.10**	**-0.01**	**0.09**
CEV, trend volatility	**-0.52**	**-0.31**	**-0.52**
CEV, volatility from $\mathrm{Cov}(x, z)$	**-0.28**	**-0.27**	**-0.22**

Soft credit dominates only in terms of cyclical stabilization

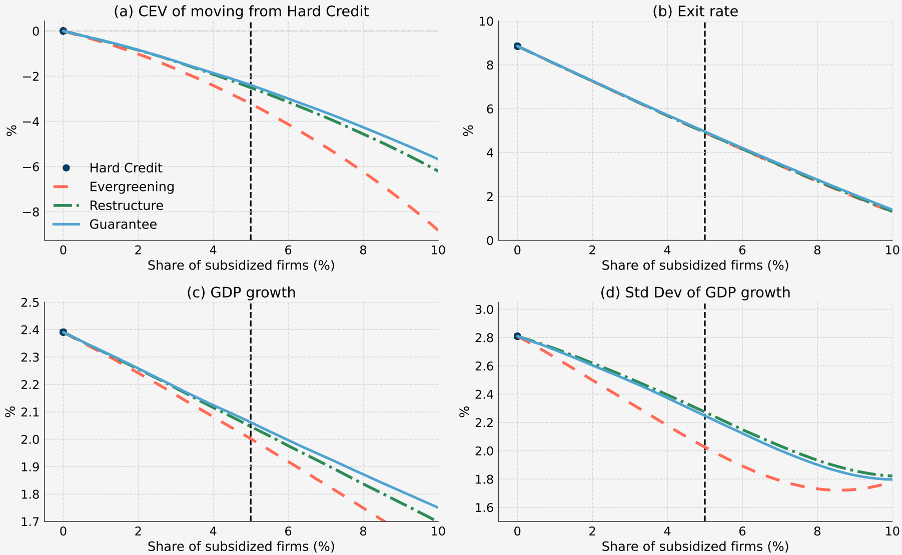
Optimal policy

- If soft credit is welfare-dominated, why is it prevalent?
- Assume the extent of soft credit i^{reg} can be chosen by a benevolent government
- Two possible implementations:

1. Commitment to a constant policy: “constant Ramsey” [Sargent, 2019]
2. Discretion

Commitment to a constant policy

Comparative statics ρ



Hard credit is always optimal!

Optimal policy without commitment

▸ details

Moment	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	7.21	7.37	7.47
Exit rate (%)	8.86	3.22	2.98	2.94
Detrended wage, $\tilde{w}$	0.73	0.80	0.80	0.80
Average iid productivity, ε^*	1.05	1.02	1.02	1.02
GDP growth				
std. dev. GDP growth				
CEV, total				

Policymaker chooses more soft credit, lower exit than baseline

Optimal policy without commitment

details

Moment	Hard Credit	Evergreening	Restructuring	Guarantee
Share of subsidized firms (%)	0.00	7.21	7.37	7.47
Exit rate (%)	8.86	3.22	2.98	2.94
Detrended wage, $\tilde{w}$	0.73	0.80	0.80	0.80
Average iid productivity, ε^*	1.05	1.02	1.02	1.02
GDP growth	**2.39**	**1.82**	**1.85**	**1.88**
std. dev. GDP growth	**2.81**	**2.03**	**2.01**	**1.99**
CEV, total				

This results in lower GDP growth, and lower volatility

Optimal policy without commitment

details

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GDP growth	2.39	1.82	1.85	1.88
std. dev. GDP growth	2.81	2.03	2.01	1.99
CEV, total		**-5.22**	**-4.59**	**-4.22**

Welfare even lower than in the baseline

Conclusion

- **Research Question**: What are the effects of ex-post interventions ("soft credit")?

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- **Approach**: Develop and calibrate tractable general equilibrium model with business cycles, firm heterogeneity, and endogenous growth.
- **Key channel**: Soft credit allows low-productivity firms to survive, $\Rightarrow$ affects productivity of other firms due to innov. externalities and GE effects.

Conclusion

- **Research Question**: What are the effects of ex-post interventions ("soft credit")?
- **Approach**: Develop and calibrate tractable general equilibrium model with business cycles, firm heterogeneity, and endogenous growth.
- **Key channel**: Soft credit allows low-productivity firms to survive,
  $\Rightarrow$ affects productivity of other firms due to innov. externalities and GE effects.
- This stabilizes the economy in the short run, but slows down long-run growth.
- "Soft credit" tends to arise when a benevolent government acts under discretion
  - Direct government intervention, i.e. credit guarantees [Kornai, Maskin & Roland, 2003]
  - Financial system architecture, i.e. evergreening [Faria-e-Castro, Paul & Sánchez, 2024]

APPENDIX

Representative Household

back

- Representative household maximizes PDV of period utility with discount factor β
- Flow utility follows King, Plosser & Rebelo (1988), required for balanced growth

$$u(X) = \frac{X^{1-\sigma}}{1-\sigma}$$

where X is a consumption-labor composite

$$X(C,N) = C\left[1 + (\sigma - 1)\chi \frac{N^{1+\varphi}}{1+\varphi}\right]^{\frac{\sigma}{1-\sigma}}$$

- Budget constraint:

$$C + Q^d D' = wN + D + \Psi - T$$

- Ψ are firm and intermediary profits
- T are lump-sum taxes: government runs balanced budget in the economy with guarantees

Intraperiod equilibrium w/. evergreening

back

Define the following objects:

1. $i^{\max}(s, \varepsilon)$: max rate for which firm does not default

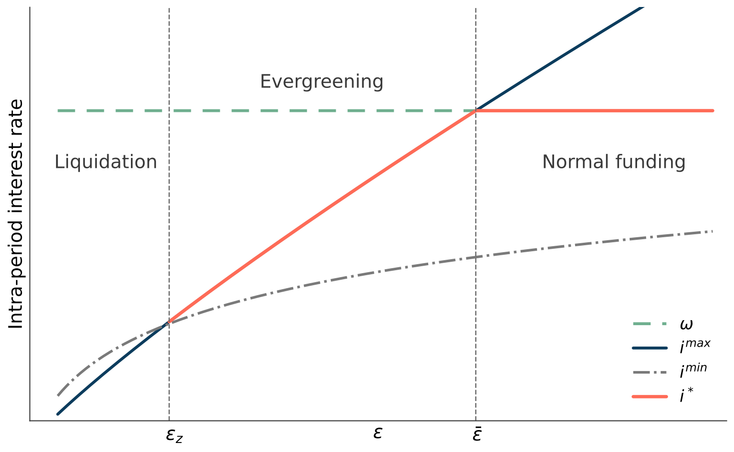
$$i^{\max}(s, \varepsilon) = \max\{i : \bar{\varepsilon}(s; i) = \varepsilon\}$$

2. $i^{\min}(s, \varepsilon)$: min rate for which lender is indifferent between lending or liquidating

$$i^{\min}(s, \varepsilon) = \min\{i : W_0(s, \varepsilon; i) = (1 - \lambda)\zeta k\}$$

Example: evergreening

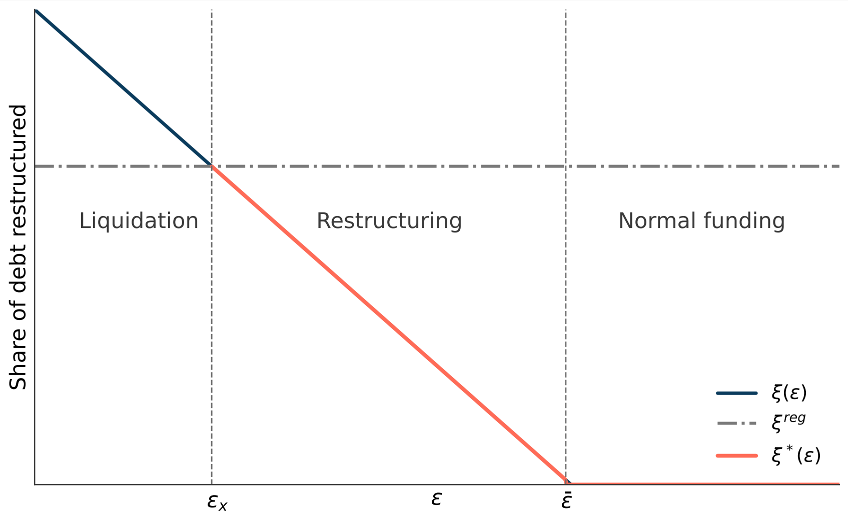
back



- **Evergreening:** lender takes losses on intraperiod loan to recover legacy b
- Subsidized interest rates $\Rightarrow$ lower WK costs $\Rightarrow$ higher labor demand for low-prod. firms

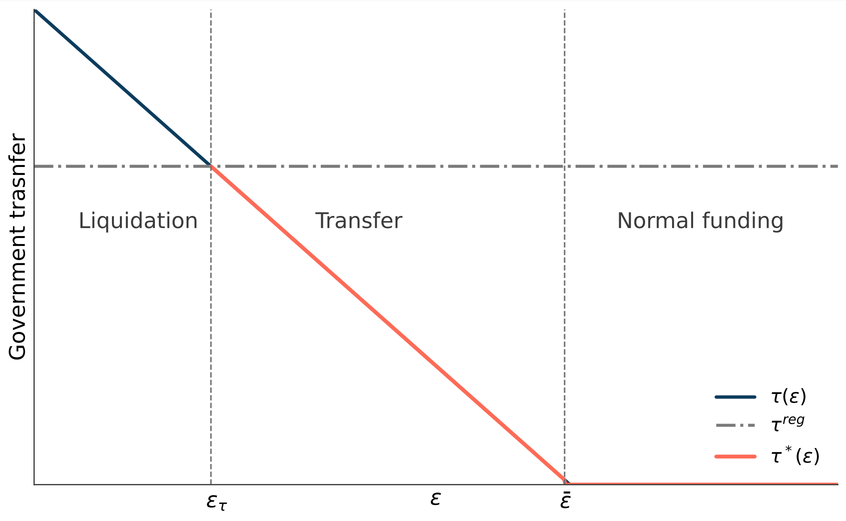
Intraperiod equilibrium with restructuring

▸ back



Intraperiod equilibrium with guarantees

back



Competitive equilibrium

back

Allocations $(C_t, N_t, D_{t+1}, z_{t+1}, k_{t+1}, b_{t+1}, n_t, \ell_t)$, prices (w_t, q_t), and thresholds $(\underline{\varepsilon}_t, \bar{\varepsilon}_t)$ such that:

1. Households
   - choose $\{C_t, N_t, D_{t+1}\}$ to maximize utility
   - subject to the budget constraint, taking prices and firm behavior as given
2. Firms
   - choose inputs (n_t, ℓ_t) and dynamic policies $(z_{t+1}, k_{t+1}, b_{t+1})$
   - maximize firm value given prices, lending terms, and thresholds
   - Symmetry: all firms follow the same policy, $s_t = S_t$
3. Lenders
   - choose contract terms and debt prices (i_t, ξ_t, q_t)
   - subject to regulation, funding constraints, and free entry
   - thresholds satisfy firms' indifference conditions
4. Markets clear
   - labor, goods, deposits, intraperiod debt, interperiod debt

Balanced growth path

back

- Economy admits a BGP with detrending factor

$$z_t^{\frac{1-\eta}{1-\alpha}}$$

- We solve for a detrended version of the model, where for each variable X_t:

$$X_t = x_t \cdot z_t^{\frac{1-\eta}{1-\alpha}}$$

- Letting $G_{z,t} \equiv z_{t+1}/z_t$, all real quantities in the economy grow at gross rate

$$G_{z,t}^{\frac{1-\eta}{1-\alpha}}$$

External calibration

back

Parameter	Description	Value	Target/Reason
β	Discount factor	0.98	Acemoglu et al., 2018
σ	Inverse EIS	2	Acemoglu et al., 2018
φ	Inv. Frisch elasticity	1	Standard
α	Capital share	$0.36 \times \psi$	Standard
η	Labor share	$0.64 \times \psi$	Standard
δ	Depreciation rate	0.08	Standard
θ	Collateral constraint	1	Debt / fixed-assets $\simeq$ 1, Y-14
λ	Loss given default	0.35	Y-14 data
ω	Lending cost	0.02	2% annual, Gilchrist & Zakrajsek, 2012

Internally calibrated parameters

back

Parameter	Description	Value	Moment	Source	Data	Model
σ_ε	Variance of prod.	0.406	TFP of exiting/continuing firms	Lee & Mukoyama (2015)	0.65	0.65
ν	Fixed cost	-0.226	Exit/default rate	Crane et al. (2022)	5.0%	4.9%
i^{reg}	Lower bound int. rate	-0.105	Credit spread	Y-14 data	2.0%	2.0%
ψ	Returns to scale	0.860	EBITDA/Value Added	Compustat	30.0%	30.0%
$\tilde{\phi}$	Level cost of R&D	0.358	GDP pc growth	U.S. data	2%	2%
ρ_ζ	Capital quality persistence	0.736	GDP growth rate, AR	U.S. data	0.16	0.16
σ_ζ	Capital quality volatility	0.035	GDP growth rate, SD	U.S. data	0.02	0.02

TFP Estimation

back

- Use annual firm data from S&P's Compustat for years 1982-2023
- Use perpetual inventory method to estimate capital stock [Ottonello & Winberry, 2020]

$$\log(\text{value added}_{i,t}) = \alpha + \beta_{1,s} \cdot \log(\text{capital}_{i,t-1}) + \beta_{2,s} \cdot \log(\text{employees}_{i,t}) + u_{i,t},$$

where we allow β_1 and β_2 to vary by industry s

- Recover the log-TFP estimates as

$$\log(TFP_{i,t}) = (\hat{\alpha} + \hat{u}_{i,t})/(1-\eta).$$

- Divide by calibrated $(1-\eta)$ to align estimates with assumed production function.

Estimates R&D Cost Function (1)

back

	(i) Baseline	(ii) Fixed Effects	(iii) TFP-Def.	(iv) Learning	(v) Capital	(vi) ACF-2015
β_1 $(= 1/\kappa)$	0.35***	0.52***	0.41***	0.53***	0.24***	0.22***
	(0.09)	(0.13)	(0.12)	(0.14)	(0.07)	(0.06)
β_2 $(= \rho)$	0.29***	0.39***	0.39***	0.39***	0.23***	0.40***
	(0.02)	(0.03)	(0.05)	(0.04)	(0.01)	(0.04)
Time FE	✓		✓	✓	✓	✓
Industry-Time FE		✓				
First-Stage F-Stat	19	18	15	16	24	15
R-squared	0.12	0.17	0.12	0.14	0.11	0.14
Observations	34,556	34,243	34,556	34,556	35,519	38,868
Number of Firms	4,847	4,823	4,847	4,847	5,380	5,010
Number of Industries	46	41	46	46	47	47

Estimates R&D Cost Function (2)

back

	(i) Baseline (IV)	(ii) Baseline (OLS)	(iii) Knowledge Stock (IV)	(iv) Knowledge Stock (OLS)	(v) R&D Intensity (IV)	(vi) R&D Intensity (OLS)
$\beta_1\ (= 1/\kappa)$	0.35***	0.04***	0.19***	0.06***	0.55***	0.00
	(0.09)	(0.00)	(0.05)	(0.01)	(0.12)	(0.03)
$\beta_2\ (= \rho)$	0.29***	0.23***	0.30***	0.27***	0.17***	0.18***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Time FE	✓	✓	✓	✓	✓	✓
First-Stage F-Stat	19		51		227	
R-squared	0.12	0.12	0.15	0.15	0.09	0.09
Observations	34,556	34,556	21,406	21,409	69,908	70,028
Number of Firms	4,847	4,847	3,471	3,472	9,045	9,057
Number of Industries	46	46	46	46	50	50

Estimates R&D Cost Function (3)

back

	(i) Baseline	(ii) h=2	(iii) h=3	(iv) LP	(v) Bootstrap
β_1 $(= 1/\kappa)$	0.35***	0.41***	0.51***	0.17***	0.36***
	(0.09)	(0.12)	(0.18)	(0.04)	(0.12)
β_2 $(= \rho)$	0.29***	0.34***	0.40***	0.33***	0.29***
	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)
Time FE	✓	✓	✓	✓	✓
First-Stage F-Stat	19	15	11	19	19
R-squared	0.12	0.14	0.13	0.1	0.12
Observations	34,556	29,033	24,641	39,238	34,556
Number of Firms	4,847	4,518	3,824	5,789	4,847
Number of Industries	46	46	46	47	46

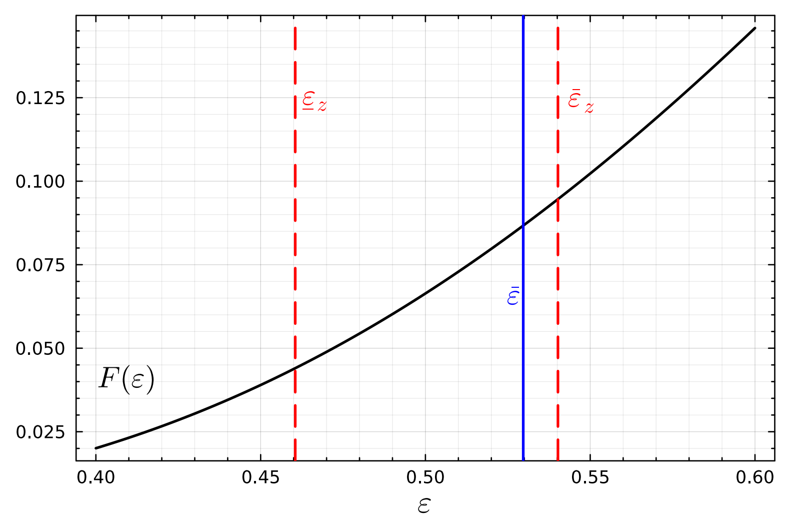
Estimates R&D Cost Function (4)

back

	(i) Baseline	(ii) P50	(iii) P75	(iv) P90	(v) Patents
β_1 $(= 1/\kappa)$	0.35***	0.49***	0.43***	0.41***	0.43***
	(0.09)	(0.13)	(0.11)	(0.11)	(0.12)
β_2 $(= \rho)$	0.29***	0.37***	0.36***	0.34***	0.30***
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Time FE	✓	✓	✓	✓	✓
First-Stage F-Stat	19	16	17	18	15
R-squared	0.12	0.14	0.14	0.13	0.13
Observations	34,556	34,556	34,556	34,556	24,136
Number of Firms	4,847	4,847	4,847	4,847	2,857
Number of Industries	46	46	46	46	42

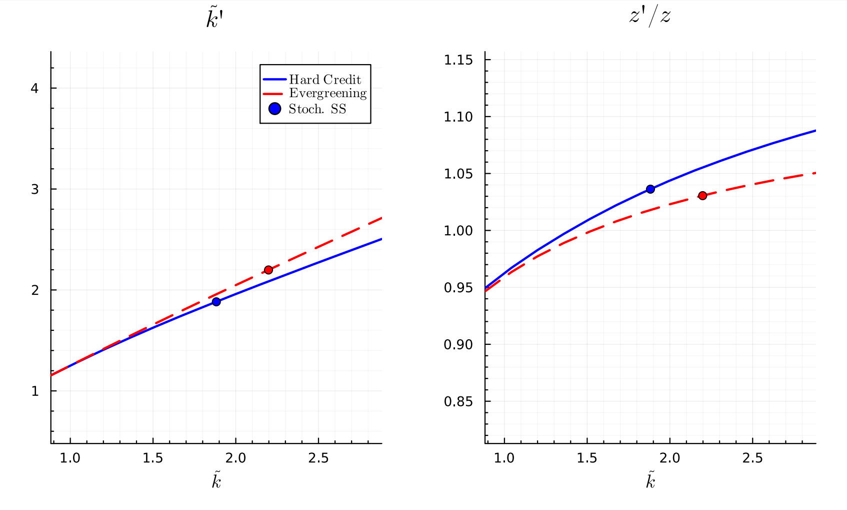
Probability distribution function of idiosyncratic productivity

back



Firm policy functions for physical capital and R&D

back



Details on Welfare Comparisons

back

- Welfare differences reported in terms of consumption-equivalent variation [Lucas, 2003]

$$CEV_{HC\to SC} = 100 \times \left[\left(\frac{\mathcal{U}^{HC}}{\mathcal{U}^{SC}} \right)^{1/(1-\sigma)} - 1 \right]$$

- Assume that all economies start out with the same set of states:

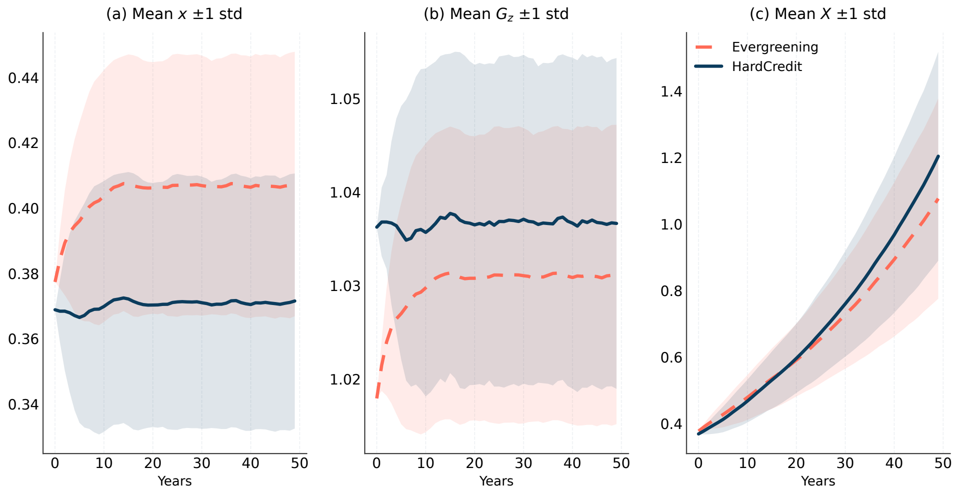
$$z_0 = 1, \qquad k_0 = k^*_{HC}, \qquad \zeta_0 = 1$$

where k^*_{HC} is the stochastic SS of the hard credit economy

- Accounts for transition dynamics

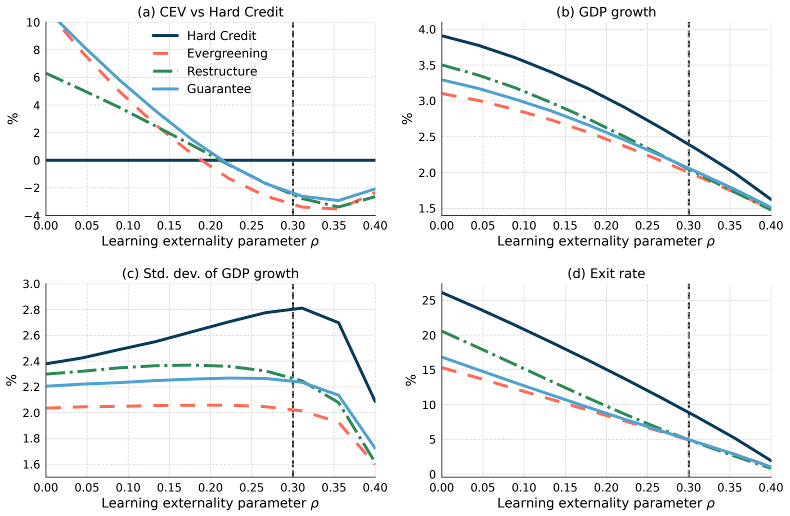
Transitional Dynamics: Hard Credit vs. Evergreening

back



Comparative statics w.r.t. ρ

back



- Welfare comparisons invert when $\rho \to 0$, but stabilization-growth trade-off remains

Optimal policy without commitment

back

Assume policymaker solves the following problem

$$\tilde{\mathcal{U}}(\tilde{k},\zeta) = \max_{\varpi^{reg}} u(\tilde{C},N) + \beta G_z^{(1-\sigma)\frac{1-\eta}{1-\alpha}} \mathbb{E}[\tilde{\mathcal{U}}(\tilde{k}',\zeta')]$$
$$\text{s.t.} \;\; (\tilde{C},N,\tilde{k}',G_z) \in \mathcal{Y}(\tilde{k},\zeta;\varpi^{reg})$$

where

- $\tilde{\mathcal{U}}$ is a recursive formulation of detrended welfare
- $\varpi^{reg} \in \{i^{reg},\xi^{reg},\tau^{reg}\}$ is the choice of policy
- $\mathcal{Y}(\tilde{k},\zeta;\varpi^{reg})$ is the set of equilibrium allocations