Real Credit Cycles

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Diagnostic Expectation (DE)

- Stochastic Process:

$$a_t = \rho a_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2) \tag{1}$$

- Diagnostic Expectation (DE, indexed by θ):

$$E_t^\theta(a_{t+1}) = \underbrace{E_t(a_{t+1})}_{RE} + \theta \left[E_t(a_{t+1}) - E_{t-1}(a_{t+1}) \right] \tag{2}$$

- DE: $\theta > 0$

$$E_t^\theta(a_{t+1}) = \rho a_t + \theta \rho \left[a_t - \rho a_{t-1} \right] = \rho a_t + \theta \rho \varepsilon_t \tag{3}$$

- Predictable Forecast Error: RE - DE

$$FE_{t+1} \equiv E_t(a_{t+1}) - E_t^\theta(a_{t+1}) = -\theta \rho \varepsilon_t \tag{4}$$

Test for DE (1)

$$FE_{t+1} \equiv E_t(a_{t+1}) - E_t^{\theta}(a_{t+1}) = -\theta\rho\varepsilon_t \quad (5)$$

- Measurement
  - FE: firm-level forecast errors (I/B/E/S)
  - ε_t: investment or debt issuance
- Hypothesis
  - RE: $\theta = 0 \rightarrow corr(FE_{t+1}, \varepsilon_t) = 0$
  - DE: $\theta > 0 \rightarrow corr(FE_{t+1}, \varepsilon_t) < 0$
- Results

	(1)	(2)	(3)	(4)
	Forecast Error$_{t+1}$			
Estimation Method:	OLS	GMM	OLS	GMM
Investment$_t$	-0.618^{***}	-1.459^{***}		
	(0.119)	(0.061)		
Debt$_t$			-0.562^{***}	-0.887^{***}
			(0.187)	(0.056)
Firm Effects		X		X

Toy Model: Bond Pricing

- Lenders
  - risk-neutral w. deep pocket
  - R = 1
- Borrowers:
  - roll over one-period bond
  - default if productivity is below a threshold A^*
  - default probability:

$$\delta_t^\theta = \Phi\left[\frac{\ln A^* - E_t^\theta(\ln A_{t+1})}{\sigma}\right] \tag{6}$$

  - interest rate:

$$\hat{R}_t = \frac{1}{1-\delta_t^\theta} \tag{7}$$

Toy Model: Bond Pricing

- Credit spread

$$s_t^\theta \equiv \hat{R}_t - 1 = \frac{\delta_t^\theta}{1-\delta_t^\theta} \tag{8}$$

  - log-linearization

$$s_t^\theta \approx s_\infty - sE_t^\theta(a_{t+1}) \tag{9}$$

  - s_∞: long-run spread

- DE

$$E_t^\theta(a_{t+1}) = \rho a_t + \theta\rho\varepsilon_t \tag{10}$$

- Credit spread under DE

$$s_t^\theta \approx (1-\rho)s_\infty + \rho s_{t-1} - s\rho(1+\theta)\varepsilon_t + s\rho^2\theta\varepsilon_{t-1} \tag{11}$$

Toy Model: Bond Pricing

- Credit Spread under RE:

$$s_t^* \approx (1-\rho)s_\infty + \rho s_{t-1} - s\rho\varepsilon_t \tag{12}$$

- DE vs RE:

$$s_t^\theta - s_t^* = \underbrace{-s\rho\theta\varepsilon_t}_{overoptimism} + \underbrace{s\rho^2\theta\varepsilon_{t-1}}_{reversal} \tag{13}$$

- DE accounts for:
  - over-optimism in good times (excess shift in credit and capital)
  - reversal after good times

Test for DE (2)

	(1)	(2)	(3)	(4)
	Forecast Error_{t+1}	Return_{t+1}	$\Delta\ \text{Spread}_{t+1}$	$\Delta\ \text{Investment}_{t+1}$
IV Stage:	First	Second	Second	Second
Forecast Error_{t+1}		0.007^{*}	-0.011^{***}	0.485^{***}
		(0.004)	(0.004)	(0.061)
Investment_t	-0.562^{***}			
	(0.105)			
Year Effects	X	X	X	X
Years	2003-2018	2003-2018	2003-2018	2003-2018
Firm-Years	2852	2852	2852	2852
First Stage F	28.94			

Figure: Forecast Error and Reversals

- Stage 1 ($\sim$ Table 1): high investment $\rightarrow$ over-optimism $\rightarrow$ low FE
- Stage 2: high investment $\rightarrow$ high future spread & low future investment

RBC Model with Diagnostic Expectation

- Firms (DE)
  - observe agg. and idios. shocks
  - choose to default or repay; if repay,
  - hire labor and capital to produce with DRS technology, using
  - external finance 1: risky debt, s.t. credit spread
  - external finance 2: equity, s.t. issuance cost
- Lenders (DE)
  - risk-neutral and competitive
- Partial Equilibrium
  - exogenous risk-free rate (R) and wage (W)
  - exogenous SDF
  - extension: GE version

Firms

- Technology: $(k, n) \to y$

$$y = Azk^{\alpha} n^{\nu}, \quad \alpha + \nu < 1 \tag{14}$$

- Capital law of motion

$$k' = i + (1 - \delta)k, \quad 0 < \delta < 1$$

s.t. quadratic adjustment costs $AC(i, k) = \frac{\eta_k}{2} \left(\frac{i}{k}\right)^2 k$

- Micro TFP follows (RE / true)

$$\log z' = \rho_z \log z + \varepsilon'_z, \quad \varepsilon'_z \sim N\left(0, \sigma_z^2\right), \quad 0 < \rho_z < 1$$

- Macro TFP follows (RE / true)

$$\log A' = \rho_A \log A + \varepsilon'_A, \quad \varepsilon'_A \sim N\left(0, \sigma_A^2\right), \quad 0 < \rho_A < 1.$$

Firms

- Micro TFP follows (DE)

$$\log z' \mid (\log z, \varepsilon_z) \sim N\left[\rho_z\left(\log z + \theta\varepsilon_z\right), \sigma_z^2\right] \tag{15}$$

- Macro TFP follows (DE)

$$\log A' \mid (\log A, \varepsilon_A) \sim N\left[\rho_A\left(\log A + \theta\varepsilon_A\right), \sigma_A^2\right] \tag{16}$$

- Exo. state variables (DE):

$$s \equiv \{\underbrace{z, A}_{s^{RE}}, \varepsilon_z, \varepsilon_A\}$$

Firms' Problem

- Dividend policy

$$d = (1-\tau)\pi - i + q^{\theta}\left(s, k', b'\right) b' - b + \tau(R + \delta k) \quad (17)$$

s.t. equity issuance cost

$$IC(d) = I(d < 0)[\underbrace{\eta_f}_{fixed} + \underbrace{\eta_d |d|}_{variable}] \quad (18)$$

hiring rule (static, DE = RE)

$$\pi = \max_n \{y - Wn - AC(i,k) - \phi\} \quad (19)$$

Firms' Problem

- Value at non-default state

$$V_{ND}^{\theta}(s,k,b) = \max_{k',b'} \left\{ d - IC(d) + \frac{1}{1+R} \mathbb{E}^{\theta} \left[V^{\theta}(s',k',b') \mid s \right] \right\} \quad (20)$$

- Value at default state

$$V_{D}^{\theta}(s) = \left\{ 0 + \frac{1}{1+R} \mathbb{E}^{\theta} \left[V(s',0,0) \mid s \right] \right\} \quad (21)$$

- Value of firm

$$V^{\theta}(s,k,b) = \max \left[V_{D}^{\theta}(s), V_{ND}^{\theta}(s,k,b) \right] \quad (22)$$

default decision: $df^{\theta}(s,k,b) = 1$ iff $V_{D}^{\theta}(s) > V_{ND}^{\theta}(s,k,b)$

- DE $\rightarrow \{df^{\theta}, k'^{\theta}, b'^{\theta}\}$

Lenders and Bond Pricing

- Recovery rate of debt

$$\mathcal{R}(k,b) = \gamma(1-\tau)\frac{(1-\delta)k}{b} \tag{23}$$

  $1-\gamma$ fraction: deadweight loss

- IR condition: bond return (DE) = risk free rate R

$$q^{\theta}\left(s,k'^{\theta},b'^{\theta}\right) = \frac{1}{1+R}\mathbb{E}^{\theta}\left[1+df^{\theta}\left(s',k'^{\theta},b'^{\theta}\right)\left(\mathcal{R}\left(k'^{\theta},b'^{\theta}\right)-1\right) \mid s\right] \tag{24}$$

- Spread relative to the risk-free rate is given by

$$S^{\theta}\left(s,k',b'\right) = \frac{1}{q^{\theta}\left(s,k',b'\right)} - (1+R) \tag{25}$$

- DE $\rightarrow \{q^{\theta}\}$

Aside: Algorithm

- Guess a default policy df^{θ}, and compute implied debt prices q^{θ} according to IR condition of lenders

  1. Given q^{θ} and df^{θ}, solve Bellman equations (DE) for $\{V^{\theta}, V_{ND}^{\theta}, V_{D}^{\theta}\}$, and for $\{k'^{\theta}, b'^{\theta}\}$ (standard discrete-state, discrete-policy dp policy iteration algorithm)
  2. Update default policies df^{θ} according to $\{V^{\theta}, V_{ND}^{\theta}, V_{D}^{\theta}\}$
  3. Compute the ergodic distribution $\mu(s, k, b)$ implied by $\{df^{\theta}, k'^{\theta}, b'^{\theta}\}$
  4. Compute the mass of states in which the guessed default policy differs from the updated default policy

- Update set of default states until convergence

Calibrated Parameters

Param.	Role	Value	Source
δ	Depreciation rate	0.100	Annual Solution
R	Risk-free rate	0.04	Annual Solution
α	Capital elasticity	0.25	Bloom et al. (2018)
ν	Labor elasticity	0.5	Bloom et al. (2018)
ρ_A	TFP autocorr.	0.95	Bloom et al. (2018)
τ	Corporate income tax	0.200	Effective rates, CBO (2017)

Estimated Parameters

Parameter	Role	DE Model	RE Model
θ	Diagnosticity	0.991(0.074)	–
ρ_z	Micro TFP autocorrelation	0.785(0.004)	0.920(0.001)
σ_z	Micro TFP volatility	0.111(0.010)	0.107(0.015)
η_k	Capital adjustment cost	3.627(0.261)	3.804(0.695)
ϕ	Fixed operating cost	0.131(0.007)	0.078(0.009)
γ	Recovery rate	0.250(0.057)	0.125(0.237)
σ_A	Macro TFP volatility	0.006(0.000)	0.009(0.002)
η_f	Equity fixed cost	0.022(0.069)	0.077(0.173)
η_d	Equity linear cost	0.094(0.018)	0.064(0.045)
σ_π	Earnings noise	0.761(0.067)	0.352(0.042)

Role of DE:

- raise perceived 'persistence' of micro-TFP shock: $\rho \rightarrow \rho(1+\theta)$
- inflate perceived 'volatility' of macro-TFP shock

Estimated Model Fit

	Moment	Data	DE Model	RE Model
Panel A: Micro Moments				
1	Cov(Δ Forecast Error_{t+1},Δ Investment_{t-1})	0.003	0.002	0.000
2	Cov(Δ Forecast Error_{t+1},Δ Debt_{t-1})	0.001	0.004	0.000
3	Std. Dev(Forecast Error_{t+1})	0.304	0.266	0.224
4	Std. Dev(Profit_t)	0.262	0.263	0.225
5	Corr(Profit_t, Investment_t)	0.257	0.114	0.090
6	Corr(Profit_t, Debt_t)	0.111	0.129	0.114
7	Corr(Profit_t, Spread_t)	−0.159	−0.024	0.087
8	Std. Dev(Investment_t)	0.067	0.052	0.035
9	Corr(Investment_t,Debt_t)	0.183	0.739	0.489
10	Corr(Investment_t,Spread_t)	−0.057	−0.054	0.083
11	Std. Dev(Debt_t)	0.056	0.134	0.066
12	Corr(Debt_t,Spread_t)	0.015	0.061	0.003
13	Std. Dev(Spread_t)	0.011	0.013	0.006
Panel B: Macro Moments				
14	$\mathbb{E}(\text{Spread}_t)$	0.029	0.028	0.030
15	$\mathbb{E}(\text{Default}_t)$	0.003	0.006	0.005
16	Std. Dev(Δ GDP_t)	0.015	0.012	0.017

- $cov(FE, \Delta Inv.)$, $cov(FE, \Delta Debt)$: DE vs RE
- $corr(Profit, Spread)$, $corr(Inv., Spread)$: DE vs RE (GE ?)

Model Mechanism: Investment Response

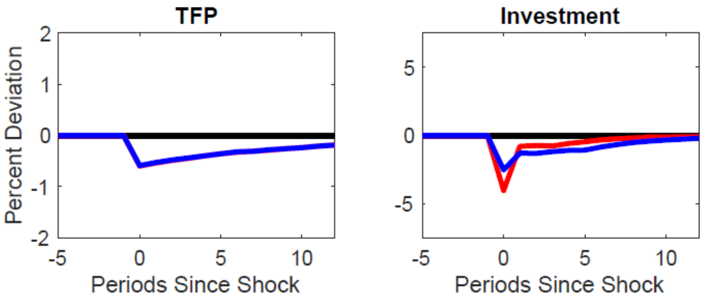
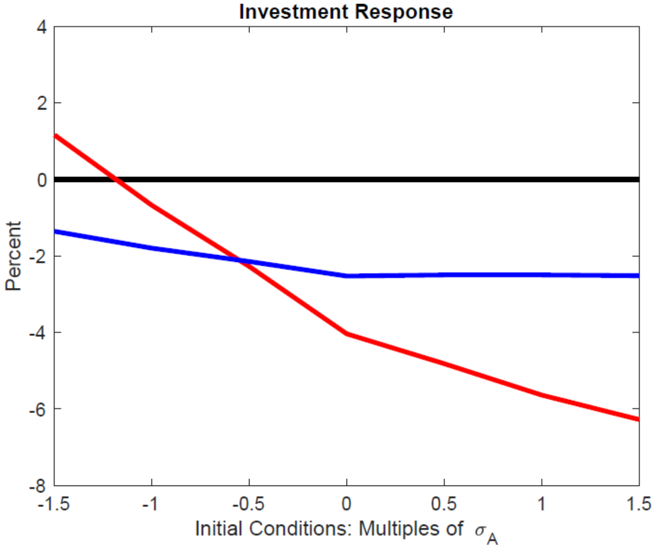


Figure: IRFs to Negative TFP Shock

Note: red line represents DE response, blue line represents RE response

Model Mechanism: State-dependent Response



Credit Supply vs Credit Demand Effect

- Good news
  - demand side: firm over-optimistic to borrow and invest
  - supply side: lenders over-optimistic to lend at lower spread
- Good news $\rightarrow$ Bad news
  - demand side: firm over-pessimistic to default and cut investment
  - supply side: lenders over-pessimistic to demand high spread
  - quantitative exercise: supply effect prominent

Credit Cycles

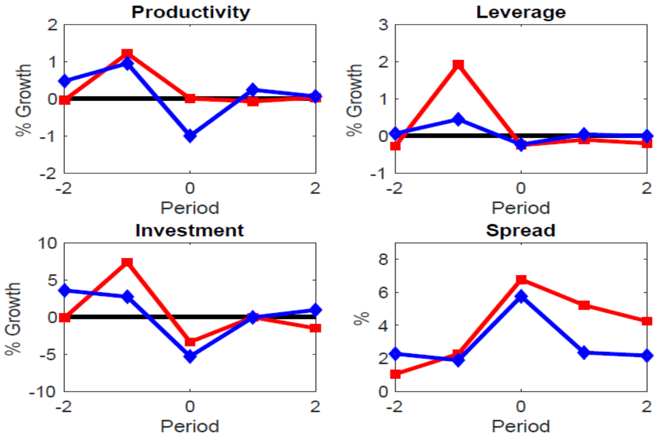


Figure: DE produces 'financial shock'

Moment Matching

Correlation:	Output	Debt	Investment	Spread	(Standard Deviation)
Panel A: Data					
Output	1.000	0.891	0.803	−0.105	(0.017)
Debt		1.000	0.755	−0.169	(0.048)
Investment			1.000	−0.107	(0.053)
Spread				1.000	(0.010)
Panel B: DE Model					
Output	1.000	0.820	0.505	−0.011	(0.012)
Debt		1.000	0.628	0.058	(0.007)
Investment			1.000	0.345	(0.036)
Spread				1.000	(0.019)
Panel C: RE Model					
Output	1.000	0.632	0.559	0.003	(0.016)
Debt		1.000	0.485	0.077	(0.007)
Investment			1.000	0.144	(0.042)
Spread				1.000	(0.009)

Moment Matching: DE vs. RE

- $cov(Output, Spread)$
  - Data: < 0
  - DE: < 0
  - RE: > 0 (why? supply effect)
- $cov(Debt, Spread)$, $cov(Inv., Spread)$
  - Data: < 0
  - DE: > 0 (higher over-reaction ?)
  - RE: > 0