Endogenous Credit Cycles

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Overview

- large literature: financial markets and macroeconomic fluctuations
  - financial system as amplifier of exogenous shocks
  - missing: *lax credit and rapid expansion of output as the seeds of a future downturn*
- this paper: financial market as a source of macroeconomic fluctuations
  - exhibition of fluctuations absent of exogenous shock
  - endogenous boom-bust cycles
- empirical
  - procyclical net worth and endogenous reversion into recession
  - lending standard over the business cycles

Highlights

- adverse selection
  - borrowers with private information: good or bad
  - credit contract under asymmetric information
  - endogenous change of lending standards as source of fluctuations
- net worth and lending standard
  - higher net worth $\Leftrightarrow$ more investment
  - low net worth $\Rightarrow$ costly separation $\Rightarrow$ pooling contract
  - high net worth $\Rightarrow$ easier separation $\Rightarrow$ separating contract
- regime switch and fluctuation
  - low net worth $\Rightarrow$ pooling contract $\Rightarrow$ higher investment $\Rightarrow$ higher net worth $\Rightarrow$ separating contract $\Rightarrow$ lower investment $\Rightarrow$ low net worth

Set-Up

- OLG
- the young:
  - maximize expected old-age consumption of final goods
  - endowed with one unit of labor and supply it inelastically.
  - save their labor income in the production of capital goods.
- the old:
  - own the capital stock and live off their capital income
- technology:
  - the labor from young + capital owned by the old
  - constant-return-to-scale technology
  - capital fully depreciates after utilization

Final Goods

- production technology of final product:

$$y_t = \theta g(k_{t-1}, 1) \tag{1}$$

- wage received by the young:

$$w_t(k_{t-1}) = \theta[g(k_{t-1}) - k_{t-1}g'(k_{t-1})] \tag{2}$$

- capital gain received by the old

$$q_t(k_{t-1}) = \theta g'(k_{t-1}) \tag{3}$$

Capital Goods

- λ^G: good (G) entrepreneurs
- λ^B: bad (B) entrepreneurs
- $1 - \lambda^G - \lambda^B$: households
- heterogeneous investment technology of entrepreneurs:
    - investment can either succeed or fail in subsequent period
    - probability of success: p^j
    - assumption: $p^G > p^B$
    - success: I unit of consumption good $\Rightarrow \alpha^j f(I)$ units of capital
    - assumption: $\alpha^G < \alpha^B$
    - failure: I unit of consumption good $\Rightarrow$ 0 units of capital
    - assumption: $p^G \alpha^G > p^B \alpha^B$

Credit Market

- financial intermediary (banks)
  - competitive and risk neutral
  - take deposit with promised gross interest r_t.
- loan contract: characterized by (I_t, R_t, c_t)
  - I_t: amount of consumption goods lent to borrower
  - R_t: gross interest rate on the loan
  - c_t: percentage of the loan that entrepreneur save as collateral using their own wealth.
- state-contingent repayment and default outcomes
  - success: entrepreneur repays $R_t I_t$ and claims residual value of project
  - failure: bank takes collateral with interest rate

Credit Market

- expected profit of entrepreneur j:

$$\pi^j(I_t, R_t, c_t) = r_t w_t + p^j[q^e_{t+1}\alpha^j f(I_t) - R_t I_t] - (1 - p^j) r_t c_t I_t \quad (4)$$

- expected profit of bank from the contract:

$$\pi^b(I_t, R_t, c_t) = p^j R_t I_t + (1 - p^j) r_t c_t I_t - r_t I_t \quad (5)$$

Full Information

Given (r_t, q^e_{t+1}), first-best contract is $\{I^{j*}_t, R^{j*}_t, c^{j*}_t\}$

- optimal size of funding I^{j*}_t:

$$f'(I^{j*}_t) = \frac{r}{q^e \alpha^j p^j} \quad \text{for j=G,B} \tag{6}$$

  - good entrepreneurs invest more than bad entrepreneurs;
  - investment is independent of entrepreneurs' wealth w_t
- collateral required by banks c^{j*}_t and gross interest rate R^{j*}_t:

$$p^j R^{j*}_t + (1 - p^j) c^{j*}_t r = r \quad \text{for j=G,B} \tag{7}$$

- i.e., gross interest rate R^{j*}_t (not unique) if $w_t = 0$:

$$R^{j*}_t = \frac{r}{p^j} \quad \text{for j=G,B} \tag{8}$$

Asymmetric Information

- *ex ante* banks can't observe types of borrower
- contract in three stages:
  - 1st stage: banks design contract;
  - 2nd stage: entrepreneurs apply for these contract;
  - 3rd stage: banks accept or reject applications.
- assumption:
  - exclusivity: entrepreneurs can apply to no more than one contract
  - no cross-subsidization: banks are not allowed to offer contracts that lose money in expectation.

Separating Equilibrium: 1

Given $\{r, q^e, w_t\}$, contract at separating equilibrium $\{(I_t^G, R_t^G, c_t^G), (I_t^B, R_t^B, c_t^B)\}$:

- feasibility:

$$c_t^j \in [0, \frac{w_t}{I_t^j}] \quad \text{for j=G,B} \tag{9}$$

- incentive compatibility:

$$\pi^j(I_t^j, R_t^j, c_t^j) \geq \pi^j(I_t^i, R_t^i, c_t^i) \quad \text{for } i \neq j \text{ and } i, j \in \{G, B\} \tag{10}$$

- break-even condition for banks:

$$p^j R_t^j + (1 - p^j) c_t^j r = r \quad \text{for j=G,B} \tag{11}$$

- no deviation for banks.

Separating Equilibrium: 2

Proposition 1: $\{(I_t^G, R_t^G, c_t^G), (I_t^B, R_t^B, c_t^B)\}$ satisfies:

- contract chosen by the bad-type is not distorted:

$$(I_t^B, R_t^B, c_t^B) = (I_t^{B*}, R_t^{B*}, 0) \tag{12}$$

- contract chosen by the good-type is distorted:

$$\max_{I^G, R^G, c^G} \pi^G \equiv rw + p^G[q^e \alpha^G f(I^G) - R^G I^G] - (1 - p^G) c^G I^G r$$

s.t.

$$p^G R^G + (1 - p^G) c^G r = r = p^B R^{B*}$$

$$p^B[q^e \alpha^B f(R^{B*}) - R^{B*} I^{B*}] = p^B[q^e \alpha^B f(I^G) - R^G I^G] - (1 - p^B) c^G I^G r$$

$$c^G \in [0, \frac{w}{I^G}]$$

Separating Equilibrium: 3

Proposition 1: $\{(I_t^G, R_t^G, c_t^G), (I_t^B, R_t^B, c_t^B)\}$ satisfies:

- contract chosen by the bad-type is not distorted:

$$(I_t^B, R_t^B, c_t^B) = (I_t^{B*}, R_t^{B*}, 0) \tag{13}$$

- contract chosen by the good-type is distorted:

$$c_t^G = \frac{[q^e p^B \alpha^B f(I_t^G) - \frac{p^B}{p^G} I_t^G r] - [q^e p^B \alpha^B f(I_t^B) - I_t^B r]}{(1 - \frac{p^B}{p^G}) I^B r} \leq 1 \tag{14}$$

$$q^e \alpha^G p^G f'(I_t^G) > r \quad \Rightarrow \quad c_t^G = \frac{w_t}{I_t^G} \tag{15}$$

Separating Equilibrium: 4

$$w_t = \frac{p^B[q^e p^G \alpha^B f(I_t^G) - I_t^G r] - p^G[q^e p^B \alpha^B f(I_t^B) - I_t^B r]}{(p^G - p^B) I^B r} I_t^G \qquad (16)$$

- separation: higher level of collateral or lower level of investment $\Rightarrow$ *lower leverage*
- collateral: a costless way of screening / separating entrepreneurs.
  - good-type entrepreneurs are willing to increase c^G to lower R^G
  - bad-type entrepreneurs are worse off
  - separation in this way becomes very costly when w_t is low [1]
  - increase in w_t enhances the probability of separation
- net worth and investment
  - I_t^G increases in w_t
  - for sufficiently high w_t, first-best can be achieved: $I_t^G = I_t^{G*}$

[1] It can be shown that when $w_t = 0$, $I_t^G < I_t^B$ (inefficiency).

Pooling Equilibrium: 1

Given $\{r, q^e, w_t\}$, contract at pooling equilibrium $\{(\bar{I}_t, \bar{R}_t, \bar{c}_t)\}$:

- feasibility:

$$\bar{c}_t \in [0, \frac{w_t}{\bar{I}_t}] \tag{17}$$

- break-even condition for banks:

$$E_j[p^j \bar{R}_t + (1 - p^j)\bar{c}_t r] = r \tag{18}$$

- no deviation for banks.

Pooling Equilibrium: 2

Proposition 2: Given $\{r, q^e, w_t\}$, a pooling equilibrium $\{(\bar{I}_t, \bar{R}_t, \bar{c}_t)\}$ satisfies

- gross interest rate

$$\bar{R}_t = r\frac{1-(1-\bar{p})\bar{c}_t}{\bar{p}} \tag{19}$$

- good-type entrepreneurs solve the following problem:

$$\max_{\bar{I},\bar{c}} \pi^G \equiv rw + p^G[q^e\alpha^G f(\bar{I}) - \bar{R}\bar{I}] - (1-p^G)r\bar{c}\bar{I}$$

s.t.

$$\bar{p}\bar{R} + (1-\bar{p})\bar{c}r = r$$

$$0 \leq \bar{c}$$

$$\bar{c} \leq \frac{w}{\bar{I}}$$

Pooling Equilibrium: 3

Proposition 2: Given $\{r, q^e, w_t\}$, a pooling equilibrium $\{(\bar{I}_t, \bar{R}_t, \bar{c}_t)\}$ satisfies

- gross interest rate

$$\bar{R}_t = r\frac{1-(1-\bar{p})\bar{c}_t}{\bar{p}} \tag{20}$$

- collateral requirement

$$\bar{c}_t = \frac{w_t}{\bar{I}_t} \tag{21}$$

- investment size

$$p^G \alpha^G f'(\bar{I}_t) = \frac{p^G}{\bar{p}}\frac{r}{q^e} \tag{22}$$

Pooling Equilibrium: 4

- investment size is independent of wealth w_t:

$$p^G \alpha^G f'(\bar{I}_t) = \frac{p^G}{\bar{p}} \frac{r}{q^e}$$

- collateral constraint is binding and is increasing with wealth w_t

$$\bar{c}_t = \frac{w_t}{\bar{I}_t}$$

- degree of cross-subsidization is decreasing with wealth w_t

$$\bar{R}_t = r \frac{1 - (1 - \bar{p}) \frac{w_t}{\bar{I}_t}}{\bar{p}}$$

Equilibrium Contract: 1

$C^{EQ}(r, q^e, w_t)$: separating or pooling contract?

- depend on the level of wealth w_t
- low w_t: separation is costly.
    - for $\bar{p} > \frac{\alpha^B p^B}{\alpha^G}$, the equilibrium is always pooling when $w_t = 0$.
- higher w_t: emergence of separating equilibrium
- cut-off for regime switch: $w^*(r, q^e)$

Equilibrium Contract: 2

what's the impact of regime switch on aggregate investment?

- investment drops as long as $\bar{p} > \frac{\alpha^B p^B}{\alpha^G}$
- when good-type is abundant, pooling equilibrium $\approx$ good-type
  - for $\bar{p} > \frac{\alpha^B p^B}{\alpha^G}$: $\bar{I}_t(r, q^e) > I_t^B(r, q^e)$
- switch to separation contracts investment made by bad-type
- switch to separation contracts investment made by good-type
  - good-type entrepreneurs indifferent at switch point
  - pooling contract: higher R_t due to cross-subsidization
  - pooling contract: higher I_t
  - $\bar{I}_t(r, q^e) > I_t^G(r, q^e, w^*)$.
- discontinuous aggregate investment at the switching point:

$$\bar{I}_t(r, q^e) > I_t^G(r, q^e, w^*) > w^* > I_t^B(r, q^e, w^*)$$

Endogenous Cycle

- timeline
  - investment project undertaken by the old yields capital stock of the economy;
  - production of final goods takes place using capital and labor supplied by the young
  - the old repay their debt; the young save their labor income and invest.
- assumptions
  - unique, stable steady state at full information
  - parameter: $\bar{p} > \frac{\alpha^B p^B}{\alpha^G}$
  - exogenous interest rate: r

Intertemporal Equilibrium

Intertemporal equilibrium of the asymmetric information economy is defined as a trajectory $\{k_t, w_t, q_{t+1}^e, r_t, C^{EQ}(w_t, q_{t+1}^e) : t \geq 0\}$ that satisfies

- contract $C^{EQ}(w_t, q_{t+1}^e)$ as characterized before
- labor and capital market clears: w_t and q_t
- perfect foresight: $q_{t+1}^e = q_{t+1}$

Full Information

- optimal size of funding I_t^{j*} independent of state variables:

$$\alpha^j p^j f'(I_t^{j*}) = \frac{r}{q_{t+1}^e} \quad \text{for j=G,B}$$

- perfect foresight:

$$q_{t+1}^e = q_{t+1} = \theta g'[k_t^*(r_t, q_{t+1}^e)] \tag{23}$$

- capital stock $k_t^*(r_t, q_{t+1}^e)$ independent of state variables:

$$k_t^*(r_t, q_{t+1}^e) = \lambda^G \alpha^G p^G f[I_t^{G*}(r_t, q_{t+1}^e)] + \lambda^B \alpha^B p^B f[I_t^{B*}(r_t, q_{t+1}^e)] \tag{24}$$

No Dynamic: the economy always converges to a unique equilibrium denoted as $\{k^*, w^*, q^*\}$.

Pooling Regime

- optimal size of funding I_t^{j*} independent of state variables:

$$\alpha^j p^j f'(\bar{I}_t) = \frac{r}{q^e_{t+1}} \frac{p^G}{\bar{p}}$$

- perfect foresight:

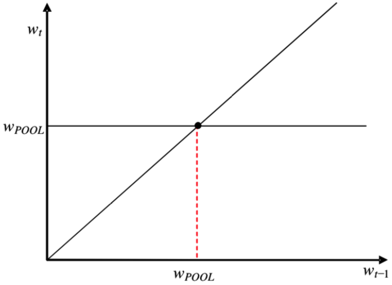
$$q^e_{t+1} = q_{t+1} = \theta g'[k_t^{POOL}(r_t, q^e_{t+1})] \tag{25}$$

- capital stock $k_t^{POOL}(r_t, q^e_{t+1})$ independent of state variables:

$$k_t^{POOL}(r_t, q^e_{t+1}) = [\lambda^G \alpha^G p^G + \lambda^B \alpha^B p^B] f[\bar{I}_t(r_t, q^e_{t+1})] \tag{26}$$

No Dynamic: the economy always converges to a unique equilibrium denoted as $\{k^{POOL}, w^{POOL}, q^{POOL}\}$.

Pooling Regime



Wage Dynamics under Pooling Contracts

Separating Regime

- level of investment $I_t^{B,SEP}(r_t, q_{t+1}^e)$ independent of w_t:

$$\alpha^B p^B f'(I_t^{B,SEP}) = \frac{r}{q_{t+1}^e}$$

- level of investment $I_t^{G,SEP}(r_t, q_{t+1}^e, w_t)$ dependent on w_t

$$\frac{w_t}{I_t^{G,SEP}} = \frac{[q^e p^B \alpha^B f(I_t^{G,SEP}) - \frac{p^B}{p^G} I_t^{G,SEP} r] - [q^e p^B \alpha^B f(I_t^{B,SEP}) - I_t^{B,SEP} r]}{(1 - \frac{p^B}{p^G}) I^{B,SEP} r}$$

- perfect foresight:

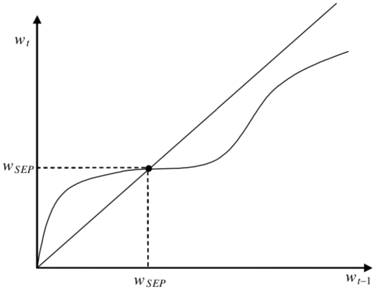
$$q_{t+1}^e = q_{t+1} = \theta g'[k_t^{SEP}(r_t, q_{t+1}^e, w_t)] \tag{27}$$

- capital stock $k_t^{SEP}(r_t, q_{t+1}^e, w_t)$:

$$k_t^{SEP}(r_t, q_{t+1}^e, w_t) = \lambda^G \alpha^G p^G f[I_t^{G,SEP}] + \lambda^B \alpha^B p^B f[I_t^{B,SEP}] \tag{28}$$

We restrict our attention to unique, stable steady state denoted as $\{k^{SEP}, w^{SEP}, q^{SEP}\}$.

Separating Regime



Wage Dynamics under Separating Contracts

Regime Switch

Proposition 3: Assume an economy in which $\bar{p} > \frac{\alpha^B p^B}{\alpha^G}$. For wage $w_t \in [0, \bar{w}]$, there exists a unique pair of switching wages (w_1, w_2) such that:

- if $w_t \leq w_1$: equilibrium loan contracts at time t are pooling;
- if $w_t \geq w_2$: equilibrium loan contracts at time t are separating;
- if $w_1 \leq w_t \leq w_2$: equilibrium loan contracts at time involve randomization between pooling and separating contracts.

Assumption:

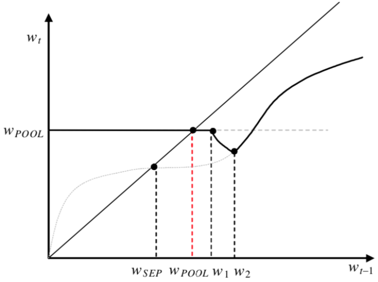
$$w^{SEP} < w^{POOL} \tag{29}$$

Regime Switch: 1

Case 1: $w^{SEP} < w^{POOL} \leq w_1$:

- unique, stable steady state at w^{POOL}
- oscillatory convergence
- monotonic convergence for initial $w_0 < w_1$
- convergence with overshooting for some initial $w_0 > w_1$

Regime Switch: 1



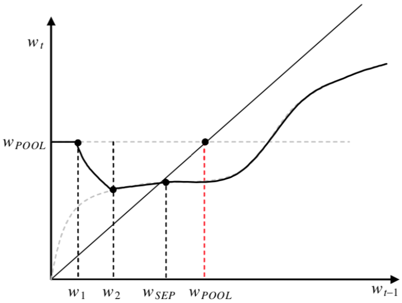
Wage Dynamics under Case 1: $w_{POOL} \leq w_1$

Regime Switch: 2

Case 2: $w_2 \leq w^{SEP} < w^{POOL}$:

- unique, stable steady state at w^{SEP}
- oscillatory convergence
- monotonic convergence for initial $w_0 > w_2$
- convergence with overshooting for some initial $w_0 < w_2$

Regime Switch: 2



Wage Dynamics under Case 2: $w_{SEP} \geq w_2$

Regime Switch: 3

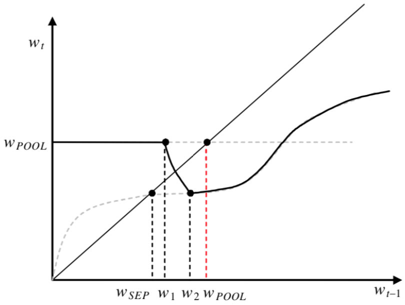
Case 3: $w_1 < w^{POOL}; w^{SEP} < w_2$:

- unique steady state at w^{SEP}
- unstable steady state: permanent fluctuation
- stable steady state: convergence with fluctuation

Intuition:

- low w_t: separation is costly $\Rightarrow$ pooling regime $\Rightarrow$ investment and wages gradually $\uparrow$
- high w_t: switch to partial or complete separating contracts $\Rightarrow$ investment $\downarrow \Rightarrow w_t \downarrow$

Regime Switch: 3



Wage Dynamics under Case 3: $w_{SEP} < w_2$ and $w_{POOL} > w_1$

Conclusion

- implication 1: financial friction
  - investment is increasing with net worth at separating regime
  - investment is independent of net worth at pooling regime
  - investment is more sensitive to net worth at recession bernanke1999financial
- implication 2: bank lending standard
  - changes in lending standards are determined by economy activity (wealth)
  - changes in lending standards are determinant of economy activity (investment)
  - procyclical loan size and countercyclical rates of collateralization
  - "lax" lending standard associated with low variance of interest rate (pooling)
  - "tight" lending standard associated with high variance of interest rate (separating)

Conclusion

- implication 3: positive productivity shock
  - net worth increases ⇒ aggregate investment increases (amplification)
  - aggregate savings increase ⇒ aggregate investment decrease (mitigation)
  - closed economy vs. open economy
  - financial liberalization and macroeconomic stability
- implication 4: sources of fluctuation
  - no aggregate shock
  - adverse selection ⇒ changes in lending standard
  - perfect competition in credit market

Conclusion

- future directions:
  - OLG $\Rightarrow$ infinite horizon: endogenize interest rate r
  - endogenous business cycle (Brunnermeier & Sannikov, 2014)
  - liquidity and macroeconomy (Taddei, 2010)
  - endogenize distribution of different types: extensive margin problem (Hu, 2017) (Fishman et. al, 2019)