Principles of Banking (III): Macroeconomics of Banking (3) Macro-Finance Linkages

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1 Introduction: The Missing Link

2 Leverage Cycle
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   - Market for security and asset price
   - Asset price and leverage cycle

3 Financial Accelerator
(If they care about what I say,) the views expressed in this manuscript are those of the author’s and should not be attributed to Norges Bank.
Dynamic stochastic general equilibrium models were so successful that they dominated central banks’ monetary policy analysis before the crisis. However

- It was assumed that monetary policy could perfectly reach real economy: banking sector is a *black box* that always does the job (which was proved to be wrong);
- Even in those models with financial frictions, banks were passive “financial accelerator” instead of *trouble makers*;
- It has been mostly agreed that, before the crisis, monetary policy with ignorance of *macro-finance linkages* missed the building-up of financial imbalances.
One biggest challenge in central banking research and practice is to address macro-finance linkages, including

- **Business-driven credit cycles**, in which macro shocks are amplified by banking sector. Often addressed by financial accelerator models;
- **Credit-driven business cycles**, in which shocks are generated from inside banking sector and spill over to real economy. Poorly understood;

We focus on two types of financial frictions with strong macro impacts

- **Lender- (Bank-) side frictions**: macro shocks affect banks’ balance sheet, then get amplified by balance sheet adjustments ⇒ **leverage cycle**;
- **Borrower-side frictions**: macro shocks affect borrowers’ collateral value & credit demand ⇒ **financial accelerator**.
Leverage cycle: model setup

- Consider an economy of 2 periods: agents invest in risky projects at $t = 0$, and will get paid at $t = 1$. No private information;

- **Assumption 1**: There are a *fixed* number of identical risky projects. Each
  - Needs 1 unit of initial investment to start at $t = 0$, while the gross payoff $R$
  - Only gets revealed at $t = 1$, perfectly correlated across projects;
  - $R$ is uniformly distributed over $[\bar{R} - z, \bar{R} + z]$, with $\bar{R} > 1$, $z > 0$. Therefore
    \[
    E_0[R] = \bar{R}, \text{~and~} var[R] = \frac{z^2}{3}.
    \]

- Besides risky projects, agents may also hold cash which is risk free.
Leverage cycle: model setup (cont’d)

There are many risk averse consumers, each of them

- Is endowed with wealth $e$ at $t = 0$;
- Can deposit the wealth in the bank and invest directly on risky projects;
- Gets utility from consumption at $t = 1$, or, proceeds from investment. Her expected utility at $t = 0$ is

$$u(c) = E[c] - \frac{1}{2\tau} \text{var}[c].$$

Consumers are risk averse because they do not like volatility. Parameter $\tau$ is parameter for risk tolerance: the higher it is, the more risk consumers can tolerate. Assume $\tau$ is constant across consumers.
Leverage cycle: model setup (cont’d)

- There are many *risk neutral* banks, or *leveraged investors*, each of them
  - Invests only on risky projects, and can borrow from consumers (that’s why banks are “leveraged”);
  - Manages balance sheet using *VaR* (“Value-at-Risk”);

**Definition**

The *VaR* of a portfolio at confidence level $\alpha$ means that the event that the realized loss $L$ exceeds $VaR$ happens at a probability no higher than $1 - \alpha$, i.e., $\text{Prob}(L > VaR) \leq 1 - \alpha$, or equivalently, $\text{Prob}(L < VaR) \geq \alpha$. 
Entrepreneurs fund their projects via issuing securities;  
Security market opens at $t = 0$, each unit sold at price $P$. 

Financial intermediation emerges as a result of heterogeneity in preferences: those who are risk neutral become natural bankers, and those risk averse become depositors. In addition, $Pq_B - e$ is not required to be equal to $e - Pq_C$ here, since banks may raise funds from elsewhere.
Consumers’ decision problem

- At $t = 0$, a consumer ("non-leveraged investor") chooses how much to invest on risky securities to maximize expected utility, i.e.

$$\max_{q_C} u (c) = E [Rq_C + e - Pq_C] - \frac{1}{2\tau} \text{var} [Rq_C + e - Pq_C] = \bar{R}q_C + e - Pq_C - \frac{1}{2\tau} \frac{z^2}{3} q_C^2.$$  

*Remember for random variable $x$, if $\text{var} [x] = \sigma^2$, $\text{var} [Ax] = A^2\sigma^2$ given $A$ is a constant number.*

- First order condition leads to consumers’ demand for security $q_C (P)$

$$\frac{\partial u}{\partial q_C} = \bar{R} - P - \frac{1}{\tau} \frac{z^2}{3} q_C = 0 \implies q_C (P) = \left\{ \begin{array}{ll} \frac{3\tau(\bar{R} - P)}{z^2}, & \bar{R} \geq P; \\ 0, & \text{otherwise.} \end{array} \right.$$
At $t = 0$, a bank ("leveraged investor") chooses how much to invest on risky securities and how much to borrow ("leverage ratio") to maximize expected return, i.e.

$$\max_{q_B} E [Rq_B - (Pq_B - e)] = (\bar{R} - P)q_B + e \quad (1);$$

Assumption 2: Banks are subject to VaR requirement such that they should stay solvent even in the worst case, i.e., be able to repay depositors even when the payoff from risky assets is the lowest.

$$e \geq \text{VaR} \Rightarrow (\bar{R} - z)q_B \geq Pq_B - e \Rightarrow e \geq (P - \bar{R} + z)q_B = \text{VaR} \quad (2).$$

*Banks usually hold least possible equity (why?), or, $e = (P - \bar{R} + z)q_B$, implying banks’ debt from deposits is $pq_B - e = (\bar{R} - z)q_B$.**
Asset price in equilibrium

- Solving bank’s problem defined by (1) and (2), we get bank’s demand for security $q_B(P) = \frac{e}{P-R+z}$;

- Remember consumers’ demand for security $q_C(P)$ is

$$q_C(P) = \begin{cases} \frac{3\tau(R-P)}{z^2}, & R \geq P; \\ 0, & otherwise; \end{cases}$$

- Assumption 1 implies the aggregate supply of security is fixed, denote it by $S$. Depict $q_B(P)$ and $q_C(P)$ with fixed $S$, equilibrium $q_B$, $q_C$ and $P$ are determined simulutaneously.
Asset price in equilibrium (cont’d)

- Equilibrium bank’s demand for security $q_B$, consumers’ demand for security $q_C$ and security price $P$
Asset price and leverage cycle: boom

- To capture the *feedback mechanism* between asset price and leverage in boom-bust cycle, suppose there is a shock to security return at $t = 0.5$, so that both banks and consumers have the chance to adjust their balance sheets;

- At $t = 0.5$, it turns out that the distribution of security return is $[\overline{R^l} - z, \overline{R^l} + z]$, $\overline{R^l} > \overline{R}$, or, the economy is in a *boom*.

  - *Unleveraged investors* (consumers) will immediately respond with higher demand for security $q_c (P)$, leading to higher $q_c (P)$ curve and positive impact on $P$;
Asset price and leverage cycle: boom (cont’d)

- Suppose security price is now $\tilde{P} > P$. The direct impact is higher equity level ("net worth") in leveraged investors’ (banks) balance sheet, given the debt (deposits) level remains the same as before;
- Bank’s VaR constraint is relaxed, too: $\tilde{e} = \tilde{P} q_B - (\bar{R} - z) q_B > e = VaR$, as shown in the figure.

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<th>Assets</th>
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<tr>
<td>Securities $Pq_B$</td>
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<td>Securities $\tilde{P}q_B$</td>
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<td>Deposits $(\bar{R} - z)q_B$</td>
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Asset price and leverage cycle: boom (cont’d)

- The bank thus has incentive to take more debt, buy more security (increase $q_B$), expand balance sheet, and make $VaR$ constraint binding again. This implies

$$\bar{e} = \bar{P}\bar{q}_B - (\bar{R}' - z)\bar{q}_B = \bar{VaR};$$

(new debt level)

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$\bar{e}$ is the new debt level.
Asset price and leverage cycle: boom (cont’d)

- Express $\tilde{q}_B$ with $q_B$ by combining two expressions for $\tilde{e}$:
  $$\tilde{q}_B = \frac{\tilde{P} + z - \tilde{R}}{\tilde{P} + z - \tilde{R}'} q_B;$$
- The consumers’ demand for security is now
  $$\tilde{q}_C = \frac{3\tau}{z^2} (\tilde{R}' - \tilde{P}) = S - \tilde{q}_B.$$  
  Analytical solution of $\tilde{q}_B$ is derived by eliminating $\tilde{P}$

  $$\tilde{q}_B = \left[ 1 + \frac{\tilde{R}' - \tilde{R}}{z + (\tilde{q}_B - S) \frac{z^2}{3\tau}} \right] q_B = f(\tilde{q}_B);$$

- Comparative statics: The impact of shocks to security return on $\tilde{q}_B$ can be easily seen graphically.
Comparative statics (cont’d): Higher $\bar{R}'$ shifts $f(\tilde{q}_B)$ to the right, leading to bank’s higher demand for security.
Asset price and leverage cycle: boom (cont’d)

- Comparative statics (cont’d): $\tilde{q}_B$ is more sensitive to return shock when $z$ is smaller
  - Smaller $z$ implies lower risk in security return, therefore
  - Lower $VaR$, and lower capital ratio is needed. However
  - The bank is more leveraged, so that the impact of return shock is more amplified through leverage, leading to higher volatilities in demand for security and asset price.

- To sum up: in the boom, positive shock to asset return eases $VaR$ constraint, inducing banks to lever up and expand balance sheet, leading to higher asset price and demand, which feeds to further expansion through $VaR$...
Asset price and leverage cycle: boom (cont’d)

We made the entire analysis in steps in order to better understand how economic boom gets amplified through leverage, while actually the equilibrium $\tilde{q}_B$, $\tilde{q}_C$ and $\tilde{P}$ can be simultaneously determined graphically following a positive shock in security return.
The **balance sheet channel** of propagating macro shocks in the boom is summarized in the figure.
Feedback mechanism in leverage cycle

- Characterizing the **balance sheet channel** of propagating macro shocks in the bust is left as your exercise.
- Initial macro shock triggers a *feedback loop* through *balance sheet adjustments*, amplifying initial shock: **“procyclicality”**

![Diagram showing the feedback mechanism in leverage cycle]

1. Initial balance sheet
2. After return shock
3. Final balance sheet

**Asset price boom**
- Stronger balance sheets
- Increasing balance sheets size
- Adjust leverage

**Asset price bust**
- Weaker balance sheets
- Decreasing balance sheets size
- Adjust leverage

**J. C.**

*Macroeconomics of Banking: Macro-Finance*
The economy with perfect financial market

- An economy with a production sector (firms), deploying single input $x$;
- **Assumption 1**: Firms’ technology $f(x)$ is *neoclassical* such that $f'(x) > 0$ and $f''(x) < 0$;
- A representative firm has small initial wealth $W$, and borrows $L$ (at gross interest rate $R$) on top of $W$ from the banking sector for input, i.e., $x = W + L$. It’s decision is
  $$\max_L f(L + W) - RL;$$
- The optimal borrowing comes from the first order condition, $f'(L + W) = R$, marginal product equals marginal cost of borrowing.
Suppose that firms are not guaranteed to behave properly: during production, entrepreneurs may walk away with private benefit, leaving nothing in the firms;

- A firm owns some pledgeable assets $K$, which can serve as collateral and be sold at price $P$;
- Banks should not lend more than $PK$ to the firm;

The firm’s problem is now

$$\max_{L^C} f (L^C + W) - RL^C, \text{ s.t. } RL^C \leq PK;$$

Assumption 2: Suppose $K$ is small so that the borrowing constraint is always binding.
Set up Lagrangian for the optimization problem
\[ \mathcal{L} = f (L^C + W) - RL^C - \lambda (RL^C - PK), \]

And first order condition leads to
\[ f'(x^C) = R + \lambda \] with \( RL^C = PK \) and \( \lambda > 0; \)

Comparing with the case of perfect financial market, \( x^C < x \) since \( f'(x^C) = R + \lambda > f'(x) = R, \) and \( f(x^C) < f(x). \) Lower feasible credit and output.
Credit channel and the business cycle

The impact of such credit constraint becomes more pronounced in a *dynamic, general equilibrium* setup (Bernanke & Gertler, 1989). After an initial macro shock, say, increase in firms’ productivity

- Consumers earn more wage from firms, hence higher demand for firms’ product;
- Firms get higher profit, increasing firms’ value, and more *collateral* available for borrowing;
- Then more borrowing from firms, leading to even higher output for the next period;

Initial boom increases firms’ collateral value, allowing for more borrowing, then even higher output: “*financial accelerator*”.

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Conclusion

- Banking sector can amplify macro shocks, bring small ripples to tsunami
  - *Leverage cycle through banks’ VaR constraint*: boom $\rightarrow$ relax of VaR constraint $\rightarrow$ leverage up with more debts $\rightarrow$ higher asset price $\rightarrow$ further boom...
  - *Financial accelerator through credit constraint of borrowers*: boom $\rightarrow$ higher profit for borrowers $\rightarrow$ higher value of borrowers’ collateral $\rightarrow$ relaxing credit constraint $\rightarrow$ more borrowing for input & further boom...

- Macro-finance linkage has become one of most crucial questions in macro research (see Brunnermaier et al., 2013). A further challenge is to endogenize financial shocks: no good answer yet.
(★: Recommended readings)


