A Model of Financial Crises

– Coordination Failure due to Bad Assets –

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Motivation (1/2)

- How can we understand the current financial crisis?
  - Severe (and possibly persistent) recessions following the collapse of huge asset-price bubbles
    - ★ The Great Depression (1930s)
    - ★ 1991–2002 in Japan
    - ★ The current global crisis
  - Facts:
    - ★ Enormous volumes of bad assets
      Nonperforming loans (1990s in Japan),
      Toxic securities (Current crisis)
    - ★ Freezing of asset transactions
    - ★ Sharp contraction in aggregate output

Motivation (2/2)

- Findings in neoclassical studies on the *great depressions in the 20th century*
  - Productivity (TFP) decline has been a key driving force in:
    - ★ The Great Depression (Cole and Ohanian 1999; Chari, Kehoe and McGrattan 2007; Kehoe and Prescott 2002)
    - ★ The 1990s in Japan (Hayashi and Prescott 2002; Kobayashi and Inaba 2007)
  - Labor-wedge deterioration has been a key driving force in:
    - ★ The Great Depression (Chari, Kehoe and McGrattan 2007; Mulligan 2002)
    - ★ The 1990s in Japan (Kobayashi and Inaba 2007)
    - ★ The usual business cycles (Shimer 2009)
- We need a model of financial crisis that can explain
  - Labor-wedge deteriorations

Labor Wedge (1/2)

- Labor wedge is a market distortion expressed as an (imaginary) labor income tax.
- The neoclassical growth model
  - Consumer

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t),$$

$$\text{subject to} \quad c_t + k_{t+1} - (1-\delta)k_t \leq r_t^k k_t + (1-\tau_t) w_t l_t,$$

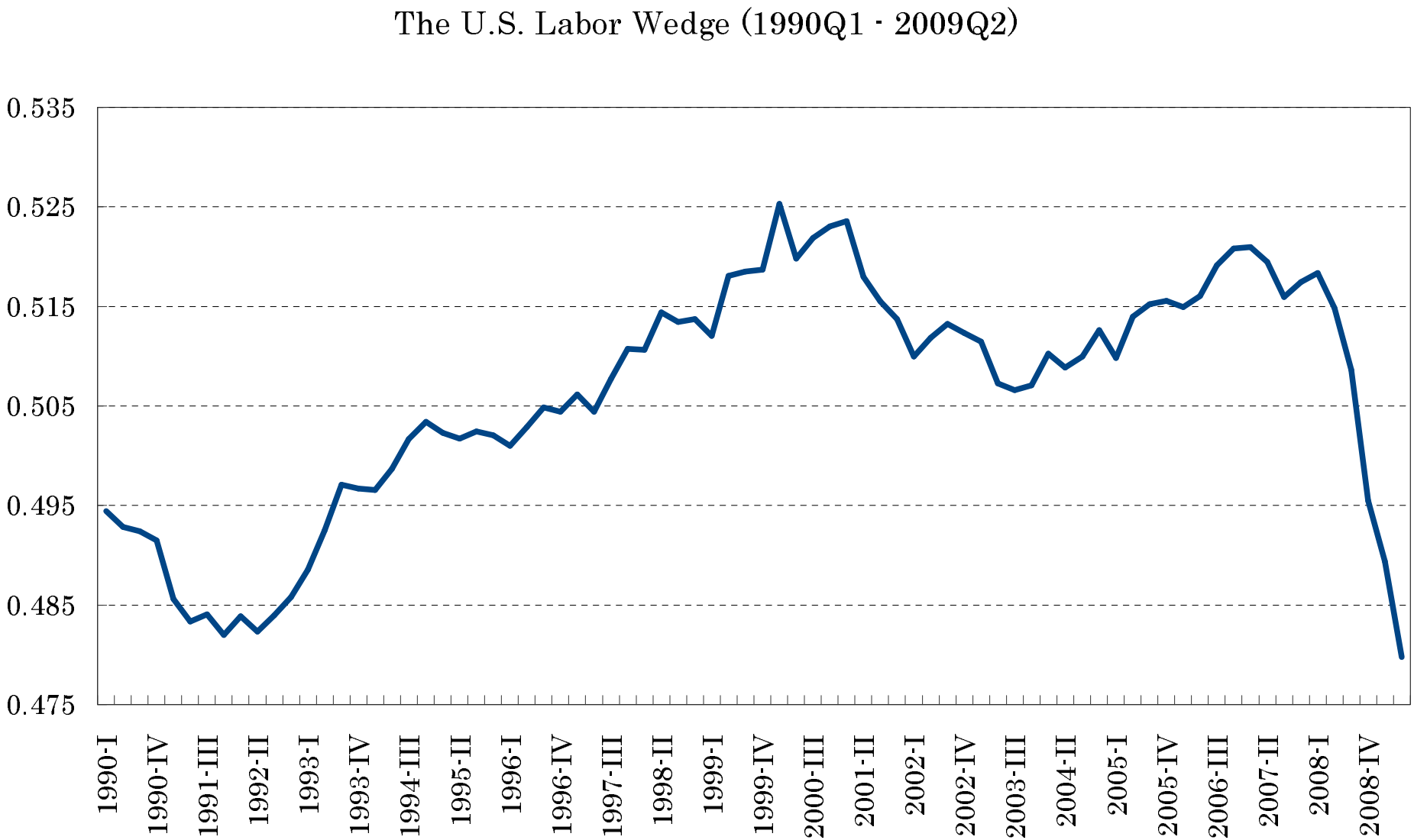
  - Firm

$$\max \pi_t = A_t k_t^{\alpha} l_t^{1-\alpha} - r_t^k k_t - w_t l_t.$$

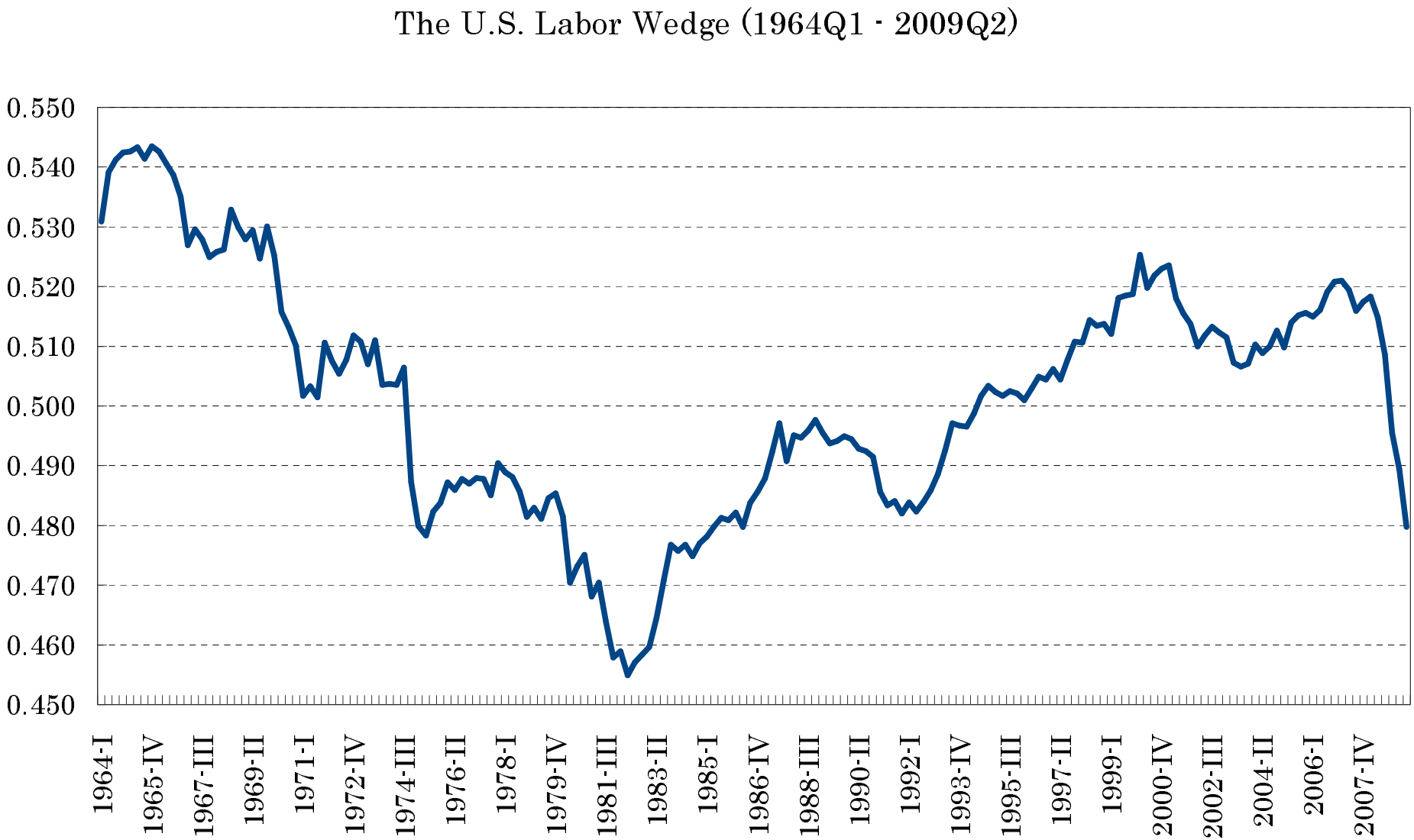
- The labor wedge $1 - \tau_t$ is measured by

$$1 - \tau_t = \frac{-U_l / U_c}{(1-\alpha) A_t (k_t / l_t)^{\alpha}} = \frac{MRS}{MPL}.$$

U.S. Labor Wedge (1990-2009)



U.S. Labor Wedge (1964-2009)



Labor Wedge (2/2)

- Usual explanations for countercyclical movements in the labor wedge
  - Labor and consumption taxes
  - Time-varying disutility of work
  - Bargaining power of the labor union
  - Search frictions in the labor market
- Our hypothesis: Financial constraints may affect the labor wedge.

This Paper

- Hypothesis:
  - Corporate bonds (or loan assets) are traded in the interbank market.
  - The emergence of bad assets and asymmetric information causes freezing in asset trading among banks. (The Market for Lemons)
  - Market freezing constrains the availability of bank loans as working capital for productive firms, causing a deterioration of the labor wedge.
- Features of the model:
  - Enormous volume of bad assets
  - Freezing of asset transactions

    (Beaudry and Lahiri 2009; Diamond and Rajan 2009)
  - Output declines (Beaudry and Lahiri 2009)
  - Labor wedge deterioration

Baseline – A Neoclassical Growth Model

- Consumer

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t),$$

$$\text{subject to} \quad c_t + i_t \leq r_t^k k_t + w_t l_t + \pi_t,$$

$$k_{t+1} = (1 - \delta) k_t + i_t.$$

- Firm

$$\max \pi_t = A_t K_t^{\alpha} L_t^{1-\alpha} - r_t^k K_t - w_t L_t.$$

- Equilibrium conditions

$$K_t = k_t,$$

$$L_t = l_t,$$

$$c_t + k_{t+1} - (1 - \delta) k_t = A_t k_t^{\alpha} l_t^{1-\alpha}.$$

Our Model

- Our model builds on the neoclassical growth model.
  - Real model. Outside money is introduced as the bank reserves.
- The key market friction is asymmetric information between banks:
  - Banks hold corporate bonds.
  - The banks need money for additional short-term lending;
    To raise money, banks need to sell the corporate bonds to other banks.
  - Firms need money (or media of exchange) to pay wages because of anonymity in the (labor) market.
  - If bad assets are present in the market, banks cannot distinguish between good bonds and bad assets on other banks' balance sheets. (Information asymmetry)
  - No banks buy bonds from other banks if they believe bad assets are in the market.

Market Structure (1/3)

- A one-sector economy with consumers, firms and banks.
- At the beginning of the period t:
  - Consumers hold bank deposits (d_t).
  - Firms hold capital (k_t).
  - Banks hold corporate bonds (b_t) and cash reserves (m_t) injected by the government.

$$d_t = b_t + m_t,$$
$$b_t = k_t.$$

- No asymmetric information between the firm and the lending bank. (Asymmetric information exists between banks.)

Market Structure (2/3)

- At the end of the period t, b_t and d_t earn interest at the market rate:

$$
\begin{aligned}
b_t &\Longrightarrow (1 + r_t) b_t, \\
d_t &\Longrightarrow (1 + r_t) d_t, \\
m_t &\Longrightarrow (1 + r_t^m) m_t.
\end{aligned}
$$

  where $r_t^m m_t$ is the government injection.

- Monetary Policy (financed by a lump-sum tax, g_t)
  - The government sets the money supply $\overline{m}_t$.
  - The government sets the rate of injection r_t^m such that banks' demand for reserve (m_t) equals the money supply: $m_t = \overline{m}_t$.

Market Structure (3/3)

- During the period t, the Labor market and the Goods market open sequentially.
  - Labor Market (Anonymous market, cash payment is required)
    - ★ Firms want to borrow $w_t l_t$ from banks at interest rate x_t. (x_t may be 0.)
    - ★ Banks need $w_t l_t$ units of (real) money.
    - ★ Banks sell b_t (at the price of $1 + r_t$) to other banks to raise money.
    - ★ Banks are subject to $w_t l_t \leq m_t + (1 + r_t) b_t$.
    - ★ Firms pay $w_t l_t$ in cash. Consumers then deposit $w_t l_t$ in banks immediately.
  - Goods Market (Walrasian market, cash is not necessary)
    - ★ Firms produce the consumption goods, $y_t = A_t k_t^{\alpha} l_t^{1-\alpha}$.
    - ★ Firms sell c_t to consumers and install k_{t+1}, by issuing bonds, $b_{t+1} = k_{t+1}$.

Normal Equilibrium (1/2)

- No bad assets on the bank balance sheets.
- Banks can sell b_t in exchange for $(1 + r_t)b_t$ units of money in the interbank market. (Because there is no risk of default.)
- Banks are subject to the asset-in-advance (AIA) constraint:

$$s_t \leq m_t + (1 + r_t)b_t.$$

- The AIA constraint is slack, because $b_t = k_t$
- In equilibrium

$$x_t = 0,$$
$$s_t = w_t l_t,$$
$$r_t^m = r_t.$$

- The equilibrium is identical to the baseline neoclassical growth model.

Normal Equilibrium (2/2)

- Consumer $\max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t)$,
  subject to $c_t + d_{t+1} \leq (1 + r_t)d_t + w_t l_t - g_t$.
- Firm $\max V(k_t) = \pi_t + \frac{1}{1+r_t} V(k_{t+1})$,
  subject to $b_{t+1} = k_{t+1}$.

  where $\pi_t = A_t k_t^{\alpha} l_t^{1-\alpha} + (1 - \delta)k_t - k_{t+1} - (1 + x_t)w_t l_t - (1 + r_t)b_t + b_{t+1}$,
- Bank (Note $\{r_t m_t\}_{t=0}^{\infty}$ is injected by the government.)

$$\max V^b(m_t) = \pi_t^b + \frac{1}{1 + r_t} V(m_{t+1}),$$

where $\pi_t^b = (1 + r_t)(b_t + m_t - d_t) - b_{t+1} - m_{t+1} + d_{t+1} + x_t s_t$,

subject to $b_{t+1} + m_{t+1} \leq d_{t+1}$,

$s_t \leq m_t + (1 + r_t)b_t$. (Asset-in-Advance)

- Equilibrium $s_t = w_t l_t$, $m_t = \overline{m}_t$, and $g_t = r_t \overline{m}_t$.

Financial Crisis

- Thus far we have showed:
  - If b_t is exchanged for money in the interbank market, the model reduces to the baseline neoclassical growth model.
- We model a financial crisis as a time when b_t is not accepted in the interbank market. The following assumptions are necessary:
- **Assumptions**
  - Emergence of bad assets, n.
  - Asymmetric Information. Banks cannot tell the good assets, b_t, from the bad assets, n.

Bad Assets (1/2)

- What is the bad asset, n?
  - One unit of bad asset is paper (looks like a corporate bond) that is promised in exchange for one unit of goods at the end of the current period.
  - The issuer of the bad asset is nonexistent.
  - The real value of the bad asset is 0.
  - n units of the bad asset is endowed to all banks randomly at the beginning of period 0, when the financial crisis breaks out.
    - Bank i is endowed with n_i.
    - n_i may be different from n_j for $i \neq j$.
    - $\int_0^1 n_i di = n$.

Bad Assets (2/2)

- Information asymmetry on bad asset, n.
  - Banks know that n on their own balance sheets are the bad assets.
  - Banks cannot distinguish other banks' holdings of bad assets (n) from the good assets (b_t).
  - Only after a bank buys paper in the interbank market does the bank know whether the paper is n or b_t.

Conditions for Bad Asset Revelation

- The cost, $\gamma\, n$, is required to reveal the bad assets. ($\gamma\, n$ is the dead weight loss.)
- Once $\gamma\, n$ is paid (by consumers or banks), all agents become able to distinguish n from b_t costlessly.
- Banks can dispose of n only after revelation.
  - Banks are endowed with n_i at $t = 0$.
  - If they don't pay $\gamma\, n_i$, they must hold n_i at $t = 1, 2, 3, \cdots$.

Coordination Failure

- Market for Lemons
  - In the interbank market, banks who want money are sure to offer the bad asset, n, for sale.
  - Anticipating this, (other) banks that can buy assets never accept b_t, because b_t and n are indistinguishable for the buying banks.
  - The value of b_t becomes 0 in the interbank market.
  - b_t cannot be traded in the interbank market. (The market freezes.)
- Banks have no incentive to pay $\gamma\ n$ (network externality):
  - Suppose Bank i reveals n_i by paying $\gamma\ n_i$; but other banks do not.
  - Banks know that bad assets still exist in the interbank market. They don't know who has them and who doesn't (asymmetric information).
  - Banks still refuse to buy b_t.
  - Bank i cannot sell b_t in the interbank market.

Crisis Equilibrium (1/3)

- Consumer $\max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t)$,
  subject to $c_t + d_{t+1} \leq (1 + r_t)d_t + w_t l_t - g_t$.
- Firm $\max V(k_t) = \pi_t + \frac{1}{1+r_t} V(k_{t+1})$,
  subject to $b_{t+1} = k_{t+1}$.

  where $\pi_t = A_t k_t^{\alpha} l_t^{1-\alpha} + (1 - \delta)k_t - k_{t+1} - (1 + x_t)w_t l_t - (1 + r_t)b_t + b_{t+1}$,
- Bank (Note $\{r_t^m m_t\}_{t=0}^{\infty}$ is injected exogenously.)

$$\max V^b(m_t) = \pi_t^b + \frac{1}{1 + r_t} V(m_{t+1}),$$

where $\pi_t^b = (1 + r_t)(b_t - d_t) + (1 + r_t^m)m_t - b_{t+1} - m_{t+1} + d_{t+1} + x_t s_t$,

subject to $b_{t+1} + m_{t+1} \leq d_{t+1}$,

$s_t \leq m_t + 0 \times b_t$. (Asset-in-Advance)

- Equilibrium $s_t = w_t l_t$, $r_t = r_t^m + x_t$, and $m_t = \overline{m}_t$.

Crisis Equilibrium (2/3)

- Reduced form
  - Consumer

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t),$$

$$\text{subject to} \quad c_t + k_{t+1} - (1-\delta)k_t \leq r_t^k k_t + w_t l_t - g_t.$$

  - Firm $\max A_t k_t^{\alpha} l_t^{1-\alpha} - r_t^k k_t - (1 + x_t) w_t l_t.$
  - Equilibrium condition (Bank)

$$w_t l_t = m_t.$$

★ m_t is injected exogenously by the government.
★ x_t is the interest rate of intra-period loans.
($x_t = 0$ if the AIA constraint is slack.)

Crisis Equilibrium (3/3)

- Dynamics

$$c_t + k_{t+1} - (1-\delta)k_t = A_t k_t^{\alpha} l_t^{1-\alpha}, \tag{1}$$

$$w_t l_t = m_t, \qquad \text{where} \quad w_t = -U_{l\,t}/U_{c\,t}, \tag{2}$$

$$\frac{U_{l\,t}}{U_{c\,t}} = -\frac{(1-\alpha)A_t(k_t/l_t)^{\alpha}}{1+x_t}, \tag{3}$$

$$U_{c\,t} = \beta U_{c\,t+1}\left\{\alpha A_{t+1}(l_{t+1}/k_{t+1})^{1-\alpha} + 1 - \delta\right\}. \tag{4}$$

- Labor wedge $1-\tau_t$:

$$1-\tau_t = \frac{-U_l/U_c}{(1-\alpha)A_t(k_t/l_t)^{\alpha}} = \frac{1}{1+x_t}.$$

Steady States

We assume $U(c_t, 1 - l_t) = \ln c_t + \phi \ln(1 - l_t)$ and $m_t = \overline{m}$.

- Baseline Case without Bad Assets

$$l^* = l(k^*) = [\alpha^{-1} A^{-1} (\beta^{-1} - 1 + \delta)] k^*, \tag{5}$$

$$c^* = c(k^*) = [\alpha^{-1} (\beta^{-1} - 1 + \delta) - \delta] k^*, \tag{6}$$

$$\frac{c(k^*)}{\phi\{1 - l(k^*)\}} = (1 - \alpha) A \left(\frac{\alpha A}{\beta^{-1} - 1 + \delta} \right)^{\frac{\alpha}{1-\alpha}}. \tag{7}$$

- Crisis Case with Bad Assets

$$l^c = l(k^c) = [\alpha^{-1} A^{-1} (\beta^{-1} - 1 + \delta)] k^c, \tag{8}$$

$$c^c = c(k^c) = [\alpha^{-1} (\beta^{-1} - 1 + \delta) - \delta] k^c, \tag{9}$$

$$\frac{c(k^c) l(k^c)}{\phi\{1 - l(k^c)\}} = \overline{m}, \tag{10}$$

$$\frac{c(k^c)}{\phi\{1 - l(k^c)\}} = \frac{1}{1 + x^c} (1 - \alpha) A \left(\frac{\alpha A}{\beta^{-1} - 1 + \delta} \right)^{\frac{\alpha}{1-\alpha}}. \tag{11}$$

Comparison of Steady States

- Quantities

$$c^c < c^*,$$
$$l^c < l^*,$$
$$k^c < k^*.$$

- Labor wedge

$$1 - \tau^c = \frac{1}{1 + x^c} < 1 \quad (= 1 - \tau^*).$$

The Mechanism at Work

- The emergence of bad assets causes asymmetric information. (Can't distinguish bad assets from good assets)
- Asymmetric information freeze interbank asset trading.
- As a result, the amount of money available for working capital loans is constrained. (Coordination failure)
- Coordination failure causes a structural change (from a nonbinding to a binding AIA constraint). Output and the labor wedge persistently deteriorate.
- No proper incentive exists for private agents to reveal private information about the bad assets (or to remove the bad assets).

Caveat

- If firms hold sufficient money (m_t^f) in advance, the model reduces to the usual Cash-in-Advance model.
- Under the following assumptions, it is shown that $\forall t$, $m_t^f = 0$ even if firms are allowed to hold cash.
- Assumptions
  - The initial value of m^f is zero: $m_0^f = 0$.
  - Firms cannot hoard bank borrowings as internal reserves (m_t^f).
    - ★ No portion of b_{t+1} can be held as m_{t+1}^f.
    - ★ $b_{t+1} = k_{t+1}$ for all t.

Policy Implications (1/2)

- The revelation of bad assets, n, restores the market for b_t. (Welfare improves if $\gamma\ n$ is not excessive.)
  - Banks should once again become confident that there are no more bad assets in the market.
  - Assumption: Banks know the total amount of n in the market.
  - Revelation of *all* n in the market is necessary and sufficient.
- Banks have no incentive to reveal n.
- Intervention by the government may be justified:
  - Stringent asset evaluations (“stress test”), which should be done repeatedly
  - Government purchases of the bad assets
  - Reintroduction of stringent accounting rules for banks
  - Policy scheme for recapitalization (or temporary nationalization) of banks

Policy Implications (2/2)

- Macroeconomic policy and bad asset removal: Their goals may be the same, i.e., relaxing the financial constraints (AIA constraint) in the market.
- Fiscal Policy
  - In the morning, give banks (or firms) a subsidy in the form of cash, m_t^g.
  - Impose a tax on consumers, τ_t, at night, where $\tau_t = m_t^g$.
  - The Ricardian equivalence holds; fiscal policy is still welfare improving because it relaxes the AIA constraint:

$$w_t l_t \leq m_t + m_t^g.$$

- Monetary Policy
  - Lend m_t^g to banks in the morning and collect it at night.
  - This policy also relaxes the AIA constraint.

Business Cycles

- Productivity changes can be driven by the freezing of the asset market (due to bad-asset externality).
  - Financial constraints on intermediate goods can appear as TFP changes (Chari, Kehoe, McGrattan 2007).
  - The constraints may change as asset trading freezes or unfreezes.

- Trading of a certain asset class freezes (due to bad-asset externality)
  $\Longrightarrow$ Productivity and the labor wedge deteriorate. (Recession)
- Trading of a certain asset class unfreezes
  $\Longrightarrow$ Productivity and the labor wedge improve. (Boom)

Future research

- Introduction of a fiat currency and nominal variables.
- Introduction of production technology of payment services (or inside money).
- Business cycle accounting for the US economy in 2000–2010.

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