A Model of Financial Crises
– Coordination Failure due to Bad Assets –

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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
    \[
    \max \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t),
    \]
    subject to \[c_t + k_{t+1} - (1 - \delta)k_t \leq r^k_t k_t + (1 - \tau_t)w_t l_t,\]
  - Firm
    \[
    \max \pi_t = A_t k_t^{\alpha} l_t^{1-\alpha} - r^k_t k_t - w_t l_t.
    \]
- The labor wedge \(1 - \tau_t\) is measured by
  \[
  1 - \tau_t = \frac{-U_l/U_c}{(1-\alpha)A_t(k_t/l_t)^{\alpha}} = \frac{MRS}{MPL}.
  \]
The U.S. Labor Wedge (1990Q1 - 2009Q2)

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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**

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

subject to \( c_t + i_t \leq r_t^k k_t + w_t l_t + \pi_t, \)

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

- **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:

\[
\begin{align*}
  b_t &\implies (1 + r_t)b_t, \\
  d_t &\implies (1 + r_t)d_t, \\
  m_t &\implies (1 + r_t^m)m_t.
\end{align*}
\]

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 $\bar{m}_t$.
  - The government sets the rate of injection $r_t^m$ such that banks’ demand for reserve ($m_t$) equals the money supply: $m_t = \bar{m}_t$. 

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
  \[
  x_t = 0, \\
  s_t = w_t l_t, \\
  r^m_t = r_t. 
  \]
- 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 \( b_{t+1} + m_{t+1} \leq d_{t+1} \),
  \( s_t \leq m_t + (1 + r_t)b_t \). \hspace{1cm} \text{(Asset-in-Advance)}

- **Equilibrium**
  \( s_t = w_t l_t, m_t = \overline{m}_t, \) and \( g_t = r_t \overline{m}_t \).
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, $n$. 
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 $i \neq j$.
  - $\int_0^1 n_idi = n$. 

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Crises and Banks
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 $b_t$. 

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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.)
  \[
  \max V^b(m_t) = \pi^b_t + \frac{1}{1 + r_t} V(m_{t+1}),
  \]
  where \( \pi^b_t = (1 + r_t)(b_t - d_t) + (1 + r_t^m)m_t - b_{t+1} - m_{t+1} + d_{t+1} + x_t s_t \),
  subject to
  \[
  b_{t+1} + m_{t+1} \leq d_{t+1},
  \]
  \[
  s_t \leq m_t + 0 \times b_t. \quad \text{(Asset-in-Advance)}
  \]

- **Equilibrium**
  \[
  s_t = w_t l_t, \quad r_t = r_t^m + x_t, \text{ and } m_t = \overline{m}_t.
  \]
Crisis Equilibrium (2/3)

- Reduced form
  - Consumer
    \[
    \max_{t=0}^{\infty} \beta^t U(c_t, 1 - l_t),
    \]
    subject to
    \[
    c_t + k_{t+1} - (1 - \delta)k_t \leq r^k_t k_t + w_t l_t - g_t.
    \]
  - Firm
    \[
    \max A_t k_t^\alpha l_t^{1-\alpha} - r^k_t k_t - (1 + x_t)w_t l_t.
    \]
  - 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.)
Dynamics

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

\[ w_t l_t = m_t, \quad \text{where} \quad w_t = -\frac{U_{l,t}}{U_{c,t}}, \tag{2} \]

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

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

Labor wedge \( 1 - \tau_t \):

\[ 1 - \tau_t = \frac{-U_{l,t}/U_{c,t}}{(1 - \alpha)A_t(k_t/l_t)^\alpha} = \frac{1}{1 + x_t}. \]
Steady States

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

- **Baseline Case without Bad Assets**

  \[
  l^* = l(k^*) = [\alpha^{-1} A^{-1} (\beta^{-1} - 1 + \delta)] k^*, \quad (5)
  \]
  \[
  c^* = c(k^*) = [\alpha^{-1} (\beta^{-1} - 1 + \delta) - \delta] k^*, \quad (6)
  \]
  \[
  \frac{c(k^*)}{\phi \{1 - l(k^*)\}} = (1 - \alpha) A \left( \frac{\alpha A}{\beta^{-1} - 1 + \delta} \right)^{\frac{\alpha}{1 - \alpha}}. \quad (7)
  \]

- **Crisis Case with Bad Assets**

  \[
  l^c = l(k^c) = [\alpha^{-1} A^{-1} (\beta^{-1} - 1 + \delta)] k^c, \quad (8)
  \]
  \[
  c^c = c(k^c) = [\alpha^{-1} (\beta^{-1} - 1 + \delta) - \delta] k^c, \quad (9)
  \]
  \[
  \frac{c(k^c) l(k^c)}{\phi \{1 - l(k^c)\}} = \bar{m}, \quad (10)
  \]
  \[
  \frac{c(k^c)}{\phi \{1 - l(k^c)\}} = \frac{1}{1 + x^c} (1 - \alpha) A \left( \frac{\alpha A}{\beta^{-1} - 1 + \delta} \right)^{\frac{\alpha}{1 - \alpha}}. \quad (11)
  \]
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 \( (m^f_t) \) in advance, the model reduces to the usual Cash-in-Advance model.
- Under the following assumptions, it is shown that \( \forall t, m^f_t = 0 \) even if firms are allowed to hold cash.

Assumptions

- The initial value of \( m^f \) is zero: \( m^f_0 = 0 \).
- Firms cannot hoard bank borrowings as internal reserves \( (m^f_t) \).
  - No portion of \( b_{t+1} \) can be held as \( m^f_{t+1} \).
  - \( b_{t+1} = k_{t+1} \) 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, $m^g_t$.
  - Impose a tax on consumers, $\tau_t$, at night, where $\tau_t = m^g_t$.
  - The Ricardian equivalence holds; fiscal policy is still welfare improving because it relaxes the AIA constraint:

    $$w_t l_t \leq m_t + m^g_t.$$

- **Monetary Policy**
  - Lend $m^g_t$ 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)

⇒ Productivity and the labor wedge deteriorate. (Recession)

Trading of a certain asset class unfreezes

⇒ 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).
References


