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Chapter 1

Models of Banking Crises: Explaining Associations with Output Decline and Financial Liberalization

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Abstract

Banking crises which occurred frequently in developing countries for the past quarter century are sometimes associated with output decline and interest rates liberalization. This paper introduces representative models which explain how banking crises are associated with output decline and interest rates liberalization. First, we introduce two bank runs models, based on uncertainty in liquidity demand, and on a low return of investment. Second, we introduce two models of financial collapse, where asymmetric information between bank and borrowers and between bank and depositors is a source of banking crisis. Third, we introduce a model that explains relationship between financial liberalization and a possibility of bank insolvency as a result of risky investment by bank.

Keywords: Banking Crisis, Asymmetric Information, Financial Liberalization

1. Introduction

For the past quarter century, many developing countries suffered banking crises. Banking crises in developing countries are sometimes associated with output decline and preceded interest rate liberalization. Following appendix A of Noy (2004), table 1 lists periods of systemic banking crises from 1980 to 2003 and interest rates liberalization in selected developing countries together. Table 1 also shows the lowest GDP growth rates within the five-year period of the start of the crisis period. The periods of systemic banking crises and the lowest GDP growth rates are from Caprio, Klingebiel, Laeven, and Noguera (2005). Periods of liberalization of interest rates are from Hutchison and Glick (2001). From table 1, we observe that developing countries sometimes experience output decline during systemic banking crises and that interest rates liberalization preceded banking crises. We need to know how banking crises are associated with output decline or interest rate liberalization. Among the previous literature of introducing models of banking crises, Calomiris and Gorton(1991) classifies banking panics models into random withdrawal theory and asymmetric information theory. Mishkin(1991) discusses financial crises from the viewpoint of asymmetric information. Comprehensive introductions are Freixas and Rochet (Chapter7:1997), Allen and Gale (2002), and Rochet(2004). This paper focuses on introducing representative banking crises models that are useful in explaining associations between banking crises and output decline or associations between banking crises and financial liberalization, which have been peculiar characteristics in developing countries for the past quarter century. Among the banking crises models, I introduce two models of bank runs (Diamnond Dybvig (1983) model and Allen Gale (1998) model), two models of financial collapse where the bank are not willing to lend because of existence of low probability of repayment by borrowers (Mankiw(1986) model), or where an equilibrium where both types of early and late withdrawers attain maximum utility (Smith(1984) model) is unstable. Finally, a model that explains relationship between financial liberalization and a possibility of bank insolvency because of the prevalence of risky investment by bank (Hellmann, Murdoch, and Stiglitz (2000) model).

2. Diamond Dybvig model

The model has three periods ($T = 0,1,2.$). The output requires one unit of input. The input put in period 0 yields $R > 1$ output in period 2, provided that the input is not liquidated in period 1. If liquidated in period 1, the input yields 0 in period 2. Consumers are divided into two types: type 1 and type 2. Type 1 consumers are interested in consuming only in period 1. Type 2 consumers are interested in consuming only in period 2. Type 2 can liquidate input in period 1 and store it for consumption in period 2. Consumers do not know which type they are in period 0, but in period 1 they know to which type they belong, privately. Let c_T denote goods received in period T. For type 2, c_1 means the input which they store in period 1 and will be consumed in period 2. Consumers maximize expected utility. The relative risk aversion coefficient of the utility function is larger than one. The discount rate ρ is less than or equal to one, and larger than $1/R$. Constant t of consumers are type 1. Consumers receive one unit of input at period 0.

Given these situations, consumers will invest input in period 0 and in period, 1 type 1 consume one, and type 2 will not liquidate input. Type 2 will consume R in period 2. This is an autarky situation; there will be no trade in current and future consumption.

If types of consumers were publicly observable in period 1, an optimal insurance policy can be implemented. Let denote c_k^i consumption of type $i(=1,2)$, and of period $k(=1,2)$. Under the optimal insurance policy, optimal consumption c_k^{i*} satisfies

$$c_1^{2*} = c_2^{1*} = 0\,. \tag{1}$$

$$u'(c_1^{1*}) = \rho R u'(c_2^{2*})\,. \tag{2}$$

Resource constraint becomes

$$tc_1^{1*} + ((1-t)c_2^{2*}/R) = 1\,. \tag{3}$$

From the assumptions that discount rate ρ is larger than $1/R$, and that the relative risk aversion coefficient is larger than one, equation (2) implies $c_2^{2*} < R$ and $c_1^{1*} > 1$. This means that consumption becomes smoother than autarky and that welfare improvement is achieved by this optimal insurance policy.

The result of the optimal policy can be achieved by demand deposit contract. Let r_1 denote the fixed claim per deposit in period 1 withdrawal. Under the contract, r_1 is equal to c_1^{1*}. Assuming every agent behaves rationally taking into account of other agents rational actions, equilibrium will be achieved as the outcome of the optimal insurance. If every agent expects that only type 1 withdraw and that type 2 do not withdraw in period 1, and behaves as the expectation, the deposit contract is realized without interruption of production, and consumers' welfare improves from that of autarky.

However, another equilibrium involves bank runs. Agents recognize that if every agent withdraws deposits in period 1, the bank's assets fall short of the amount of requested withdrawal. When expectation that bank runs might arise, rational consumers would do what they think other people would do; they would rush to the bank to withdraw. The bank must serve depositors' requests of withdrawal indefinitely until bank's reserve becomes 0 in the order of depositors' arrival to bank. When bank's reserve runs out, the bank serves withdrawal requests by liquidating loans. Because production is interrupted, bank runs in this model involve output loss. The bank's function of provision of liquidity by transforming illiquid assets into liquid assets is a double-edged knife; it also prepares a precondition for bank runs. The mere expectation of occurrence of bank runs is sufficient to initiate bank runs in the model, and the expectation need not necessarily be based on economic fundamentals.

3. Allen Gale model

There are three periods $T = 0,1,2$. Consumers have endowments E of consumption good. Consumers are either early consumers who consume only in period 1, or late consumers who consume only in period 2. The probability of becoming an early consumer and a late consumer is equal. Consumers do not know which consumers are in period 0, but know in period 1. Because the type of consumers are not observable, late consumers can imitate early consumers. Consumers store their endowments at a bank. The bank holds a risky asset X and a safe asset L. The safe asset has zero return, which can be understood as a storage technology. The risky asset has a stochastic return whose probability density function is $f(R)$. The return of the risky asset R is known in period 1 and realizes in period 2. Late consumers can withdraw their deposits in period 1, and store by period 2. Consumers maximize expected utility $E[u(c_1(R)) + u(c_2(R))]$ subject to the following constraints.

$L + X \le E$ (Holding of safe and risky assets does not exceed the endowments.)

$c_1(R) \le L$ （Consumption of early consumers does not exceed the amount of safe asset.）

$c_1(R) + c_2(R) \le L + RX$ (Total amounts of consumption of early and late consumers do not exceed the total amounts of the safe asset and the risky asset with return.)

$c_1(R) \le c_2(R)$ (Because late consumers can imitate early consumers, late consumers' consumption is at least as much as early consumers.)

The solution to the above problem is

$c_1(R) = c_2(R) = (RX + L)/2$ if $L \ge RX$ (When return R is found to be zero in the first period, and the return is L, consumers divide the safe asset between them. As R rises, they can consume more.)

$c_1(R) = L,\ c_2(R) = RX$ if $L \le RX$ (When R is greater than or equal to L/X, early consumers can consume L, while late consumers can consume RX.)

$L + X = E$ (Holding of safe and risky assets is equal to initial endowments.)

$E[u'(c_1(R))] = E[u'(c_2(R))R]$ (equality of expected marginal utilities.)

The above intertemporal resource allocation is depicted in Figure 1.

Allen and Gale show that the above problem can be realized by demand deposit contract. Unlike Diamond and Dybvig model, under Allen Gale model, both types of consumers are guaranteed equal level of consumption if the bank runs occur and early consumers and early withdrawing-late consumers can not obtain the promised amount ($\bar{c}$) to the early consumer. If bank runs occur, late consumers' consumption is allocated in such a way that it is paid from RX, and the consumption level is equal to the early consumers' consumption level which is equal to that of early withdrawal late consumers. Let the rate of early withdrawal-late consumers denote $\alpha(R)$. Then, from $c_1(R) + \alpha(R)c_2(R) = L$, $\alpha(R) = L/c_1(R) - 1$. When bank runs do not occur, $c_1(R) = \bar{c}$, $c_2(R) = RX$. When $\bar{c} = L$, the previous intertemporal optimization problem is the same as demand deposit contract. Bank runs occur when return is sufficiently low ($L > RX$), and the bank can not honor the promised amount of $\bar{c}$ to early consumers. While the way of withdrawal is based on first come, first served principle as is the case with Diamond Dybvig model, arrangement of payment in the event of bank runs in Allen Gale model is that every consumer is honored equally. Liquidation of risky assets in the first period is not possible in Allen Gale model, while it is possible in Diamond Dybvig model. While in the Diamond Dybvig model bank runs occur by expectations of bank runs which are not necessarily related to fundamentals, in Allen Gale model, bank runs occur because of low return of assets, which was constant in the Diamond Dybvig model. While Allen Gale model can explain an association between bank runs and output decline, causality runs from economic fundamentals to bank runs.

4. Mankiw model

Borrowers know their own investment return R and probability of repayment P. The bank can not observe each return and probability of repayment. However, the joint distribution $f(R,P)$ is public knowledge. Let r, ρ, Π denote interest rate of loan, return of bank in investing in the safe asset, and average probability of repayment. Borrowers apply for loans under $\Pr < R$.

Upward sloping line in Figure 2 shows a condition whether borrowers apply loans or not. Borrowers apply for loans in the areas A and B. Borrowers do not apply for loans in the areas C and D. Investment is socially productive in the areas B and D, and not socially productive in the areas A and C. A rise in interest rate of loans from r_0 to r_1 reduces the area of A, which implies reduction of socially unproductive investment undertaken. However, B, socially productive investment undertaken, is also reduced. As r rises, borrowers with relatively high probability of repayment do not to apply for loans.

Let denote average probability of repayment Π. Bank's expected value of repayment becomes Πr and in equilibrium

$$\Pi r = \rho . \tag{4}$$

Average probability of repayment Π is conditional expectation of probability given return is greater than expected loan rate[1].

$$\Pi(r) = E(P \mid R > \Pr) \tag{5}$$

The Π is not necessarily a monotonically decreasing function of r. However, because borrowers with higher repayment probability do not tend to apply for loans as r rises, Π tends to be lowered as r rises. The simultaneous equation system composed of equations (4) and (5) may not have any solutions. If ρ, the return of a safe asset for the bank, is too high, financial collapse results.

Example. The case R is constant irrespective of changes in P. Assume uniform distribution of P over the interval from 0 to 1.

Case where $r < R$

$$E(P \mid R > \Pr) = E(P) = \frac{1}{2}$$

Case where $r > R$

$$E(P \mid R > \Pr) = \int_0^{\frac{R}{r}} p \frac{r}{R} dp = \frac{R}{2r}$$

Thus,

$$\Pi(r) = E(P \mid R > \Pr) = \begin{cases} \dfrac{1}{2} & r < R \\ \dfrac{R}{2r} & r > R \end{cases}$$

Equation (4) (LL curve) and (5) (BB curve) are shown in Figure 3 and Figure 4. Figure 3 depicts the case in which a solution exists and financial intermediation occurs under $R > 2\rho$. In Figure 4, due to a rise in ρ by monetary tightening, the LL curve shifts upward under $R < 2\rho$. The system of equations (4) and (5) does not have any solutions. Even if a socially productive

[1] The bank is rational in that it minimizes mean squared error.

investment opportunity （$R > \rho$） exists, in so far as $R < 2\rho$, the investment opportunity is not realized with no financial intermediation.

5. Smith model

The model has three periods. Depositors deposit 1 unit at bank in period 0. Depositors withdraw either in period 1 or in period 2. There are two types of depositors. Type 1 has a lower probability p_1 of withdrawal in the period 1 than p_2 of type 2. Asymmetric information exists between the bank and depositors; the bank does not know the types of depositors. If deposit is withdrawn in period 2, the return is R. If deposit is withdrawn in period 1, the return is $R - P$, where P is a penalty. The returns that bank have by investing 1 unit of deposit in period 1 or in period 2 is Q_1 and Q_2, respectively. From the assumption of perfect competition in the banking industry, bank's profit is zero. Let consumers type denote $j = 1,2$, then consumers budget constraint become $p_j(R_j - P_j) + (1 - p_j)R_j = p_j Q_1 + (1 - p_j)Q_2$.

Depositors maximize expected utility $p_j U(R_j - P_j) + (1 - p_j)U(R_j)$ subject to the above constraint. From the first order condition, $U'(R_j - P_j) = U'(R_j)$. Thus, $R_j - P_j = R_j$, which implies in equilibrium $P_j = 0$.

Figure 5 shows separating equilibrium. Three strait lines are depicted in the figure. $\pi_1 = 0$, $\pi_2 = 0$ lines show zero profit condition of bank for type 1 and type 2, respectively. The dashed line shows average zero profit condition of bank for both types. At point B, type 2's indifference curve (EU_2) is tangent on the zero profit line for type 2. The point where type 1 can attain the highest utility under asymmetric information is point A which is on the indifference curve of type 1 (EU_1). At point A, the zero profit line for type 1 intersects with the indifference curve of type 2. The right region on the zero profit condition of type 1 from point A is feasible for type 1, but this region attracts type 2. Because the bank can not distinguish between type 2 and type 1, this region can not be realized. By offering a different package to type 1 (point A) type 2(point B), this economy can attain two equilibria. However, we can have another situation as depicted in Figure 6 which shows pooling equilibrium. In this economy, type 1's indifference curve crosses zero profit line from average depositors. By moving to a contract shown at point C which is located on the zero profit line from average depositors, and which is above the type 1's indifference curve, both types can increase their utility. However, point C can not be a stable equilibrium. At point C in Figure 7, type 1's indifference curve is tangent on the zero profit line from average depositors. Point C is on the Type 2's indifference curve. The slope of the type 2's indifference curve is steeper than that of type 1 because of higher withdrawal probability in period 1. Under an environment where deposit interest rate is liberalized, the bank has an incentive to offer a contract shown at point D. The bank can attract only type 1 and earn a positive profit. This unstable equilibrium can be regarded as a source of instability of the banking system under an environment of liberalized interest rates.

6. Hellmann, Murdock, and Stiglitz model

Consider a bank which can invest either in a prudent asset or a risky asset. Suppose a bank invests in a prudent asset of the amount of $1+k$, where k is capital. The rate of return is α .Opportunity cost of capital is ρ which is assumed to be larger than α. The deposit interest rate is r_i. The profit rate of the bank is $\alpha(1+k)-\rho k-r_i$. On the other hand, competitor bank offers r_{-i} of the deposit rate. The total amount of deposits that the bank can collect is $D(r_i, r_{-i})$, which is positively associate with r_i and negatively associated with r_{-i}. The total profit of investing in a prudent asset thus becomes $\pi_P = m_P(r_i, k)D(r_i, r_{-i})$ where $m_P(r_i, k) = \alpha(1+k) - \rho k - r_i$. The risky investment yields γ with probability of θ and β with probability $1-\theta$. If the bank has a β rate of return, the investment is a failure; the bank is assumed to become insolvent. The expected rate of return of the risky asset is assumed to be smaller than that of investment in a safe asset. However, γ is assumed to be larger than α.

The total profit of investing in a risky asset thus becomes $\pi_R = m_R(r_i, k)D(r_i, r_{-i})$ where $m_R(r_i, k) = \theta(\gamma(1+k) - r_i) - \rho k$. Let denote discount rate δ. The bank is assumed to maximize the infinite streams of expected profits: $V_P = \pi_P/(1-\delta)$ in investing in a prudent asset, and $V_R = \pi_R/(1-\delta\theta)$ in investing in a risky asset. V_P is called the franchise value.

Let r denote the interest cost of deposit at the asset allocation stage. Assume that the bank will invest in a prudent asset if $\pi_R(r, r_{-i}, k) - \pi_P(r, r_{-i}, k) \leq (1-\theta)\delta V_P(r, r_{-i}, k)$ holds. Otherwise, the bank will invest in a risky asset. From the inequality, a critical deposit interest rate $\hat{r}(k)$ below which the bank invests in prudent asset is derived as follows.

$$\hat{r}(k) = (1-\delta)\left(\frac{\alpha-\theta\gamma}{1-\theta}\right)(1+k) + \delta[\alpha(1+k) - \rho k]$$

Maximization of infinite streams of expected profits under the condition that the bank and the competitors offer the same interest rates yields
$m_P(r_P, k) = D(r_P, r_P)/(\partial D(r_P, r_P)/\partial r_i)$.

From the equation, deposit rate in investing in a prudent asset becomes $r_P(k) = [\alpha(1+k) - \rho k]\varepsilon/(\varepsilon+1)$. ε is an interest rate elasticity of deposits. Because the V_P is a decreasing function of k, the bank will hold no capital in equilibrium, namely, $r_P(0) = \alpha\varepsilon/(\varepsilon+1)$.

Financial liberalization policy involves increased competition, decontrol of deposit interest rates, and wider choice of asset allocation such as investment in real estates. Increased competition is expected to bring about larger interest rate elasticity with deposits. This raises $r_P(0)$, and bank's profit and franchise value lowers. Combined with the liberalized environment that the bank are free to set deposit interest rate, and that the bank have a wider choice in asset allocation, banks have a higher probability of embarking on risky investment. The bank will invest in a risky asset, hold no capital voluntarily and pay $r_R(0) = \gamma\varepsilon/(\varepsilon+1)$ under the financially liberalized environment with a sufficiently high interest rate elasticity of deposits.

Figure 8 depicts $\hat{r}(k)$ and $r_P(k)$ lines on the $r-k$ plane. The $\hat{r}(k)$ line is upward sloping if discount rate is sufficiently small. The $r_P(k)$ line is downward sloping. In the area above $\hat{r}(k)$, a bank embarks on investing in a risky asset. If a regulator imposes capital requirement $\bar{k}$ which is larger than $\underline{k}$, the bank will invest in a prudent asset and pay $r_P(\bar{k})$. However, by controlling deposit interest rate together with capital requirement, the bank can be better off by lowering the level of capital from $\bar{k}$ to k_0 without lowering depositors' welfare. This shows that deposit interest rate controls together with capital requirement is Pareto improving.

7. Summary and concluding remarks

We investigated models of banking crises that help explain their associations with output decline and financial liberalization. In the Diamond Dybvig model, bank runs occur if depositors think bank runs occur, with no particular reasons in fundamentals. In contrast, bank runs in Allen Gale model occur as a result of low return of investment by bank. Both models explain output fall associated with banking crises. Whereas bank runs can occur from mere expectation of bank runs as in Diamond Dybvig model, we should not fail to recognize that bank runs can occur from weak economic fundamentals. Investigation of Mankiw model and Smith model show that asymmetric information between bank and borrowers and asymmetric information between depositors and bank can make financial markets malfunction. These models suggest that asymmetric information can be one source of banking crises. Although financial liberalization policy has been conducted for the past quarter century in developing countries for the purpose of increasing efficiency in financial intermediation, it can have a perverse effect on the stability of the banking system, by increasing interest rates to attract depositors with low probability of withdrawal in early period (Smith model), or by undermining prudent behaviors of banks through increased competition (Hellmann, Murdoch, and Stiglitz model).

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Table 1. Systemic Banking Crises, Lowest GDP Growth Rates, and Financial Liberalization in Selected Developing Countries (1980-2003)

	Systemic Banking Crisis	Lowest GDP growth	Year*(a)	Financial Liberalization*(b)
Argentina	1980-1982	-5.7	1981	1977-1997
	1989-1990	-7.5	1989	1977-1997
	1995	-4.2	1995	1977-1997
	2001-	-10.9	2002	1977-1997
Bangladesh	Late1980s-96	2.2	1988	n.a.
Bolivia	1986-1988	-2.6	1986	1985-1997
Brazil	1990	-4.3	1990	1975-1997
	1994-1999	0.1	1998	1975-1997
Burundi	1994-	-8.4	1996	n.a.
Cameroon	1987-1993	-7.8	1988	n.a.
	1995-1998	-2.5	1994	n.a.
Chile	1981-1983	-10.3	1982	1975-1997
China	1990s-	3.8	1990	n.a.
Columbia	1982-1987	0.9	1982	1980-1997
Costa Rica	1994-1996	0.9	1996	n.a.
Dominican Republic	2003-	n.a.	n.a.	n.a.
Ecuador	Early 1980s	-2.8	1983	1986-1987 , 1992-1997
	1996-1997	1.7	1995	1986-1987 , 1992-1997
	1998-2001	-6.3	1999	1986-1987 , 1992-1997
Egypt	Early 1980s	3.8	1991	1991-1997
El Salvador	1989	1.0	1989	1991-1997
Equatorial Guinea	1983-85	n.a.	n.a.	n.a.
Ghana	1982-1989	-6.9	1982	n.a.
Guinea-Bissau	1995-1996	3.2	1994	n.a.
Hungary	1991-1995	-11.9	1991	n.a.
Indonesia	1997-2002	-13.1	1998	1983-1997
Jamaica	1996-2000	-1.1	1996	1991-1997
Kenya	1985-1989	1.8	1984	1991-1997
	1992	-0.8	1992	1991-1997
	1993-1995	-0.8	1992	1991-1997
	1996-	4.1	1996	1991-1997

(continued)

	Systemic Banking Crisis	Lowest GDP growth	Year*(a)	Financial Liberalization*(b)
Korea, Rep. of	1997-2002	-6.7	1998	1984-1997
Madagascar	1988	1.2	1987	n.a.
Malaysia	1997-2001	-7.4	1998	1978-1997
Mali	1987-1989	-0.5	1987	no liberalization
Mexico	1981-1991	-4.2	1983	1989-1997
	1994-2000	-6.2	1995	1989-1997
Morocco	Early 1980s	-2.8	1981	n.a.
Mozambique	1987-?	-11.4	1988	n.a.
Nepal	1988	1.7	1987	n.a.
Nicaragua	Late1980s-	-12.4	1988	n.a.
Nigeria	1991-1995	2.7	1997	1990-1993
Panama	1988-1989	-13.4	1988	n.a.
Paraguay	1995-2000	3.1	1994	1990-1997
Peru	1983-1990	-11.8	1983	1980-1984 , 1990-1997
Philippines	1983-1987	-7.3	1984	1981-1997
	1998-	-0.6	1998	1981-1997
Romania	1990-1996	-12.9	1991	n.a.
Sierra Leone	1990-1996	-19.0	1992	n.a.
Sri Lanka	1989-1993	2.3	1989	1980-1997
Swaziland	1995-?	3.8	1995	n.a.
Thailand	1983-1987	5.6	1983	1989-1997
	1997-2002	-10.5	1998	1989-1997
Turkey	1982-1985	3.6	1982	1980-1982 , 1984-1997
	2000-	-4.7	1999	1980-1982 , 1984-1997
Uganda	1994-1996	8.3	1993	1991-1997
Uruguay	1981-1984	-10.3	1983	1976-1997
	2002-	-10.8	2002	1976-1997
Venezuela	1994-1995	-2.3	1994	1981-1983 , 1989-1997
Zambia	1995-?	-8.7	1994	n.a.
Zimbabwe	1995-1996	0.2	1995	n.a.

Sources: The construction of this table depends on the idea in appendix A (Banking crises and domestic financial liberalization) of Noy (2004). The periods of systemic banking crises, the lowest GDP growth rates, and the year*(a) when the lowest growth rates were recorded, are all from Caprio and others (2005). Financial liberalization periods *(b) are from Hutchison and Glick (2001).

Notes: Systemic banking crisis means systemic bank insolvency. Financial liberalization means interest rates liberalization. Systemic banking crises data are presented in accordance with the data availability of financial liberalization. The lowest GDP growth rate means the lowest real GDP growth rate within the five-year period of the start of the crisis period.

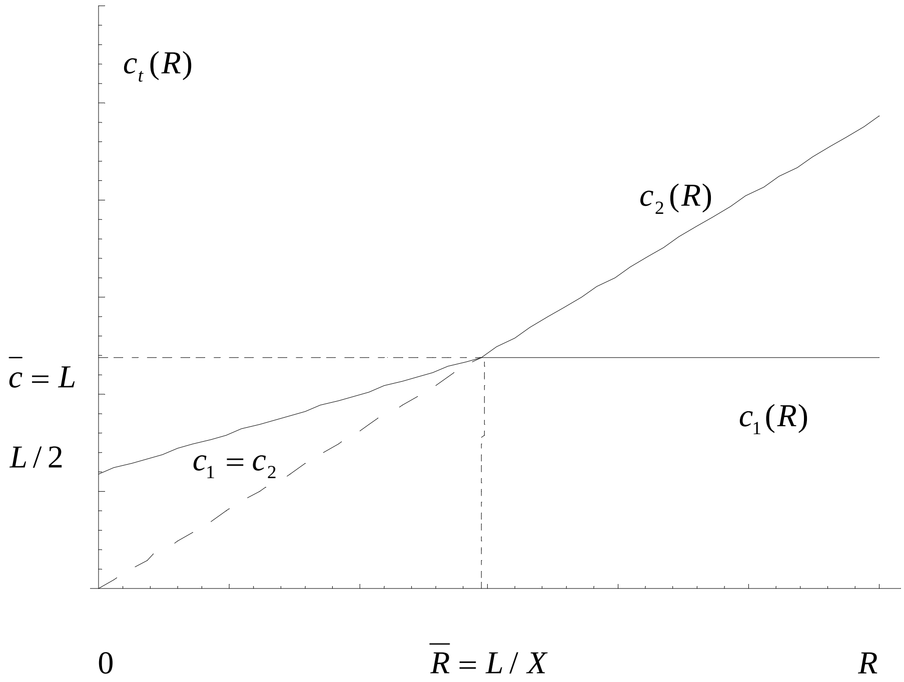

Figure 1. Consumption and Return of Risky Asset

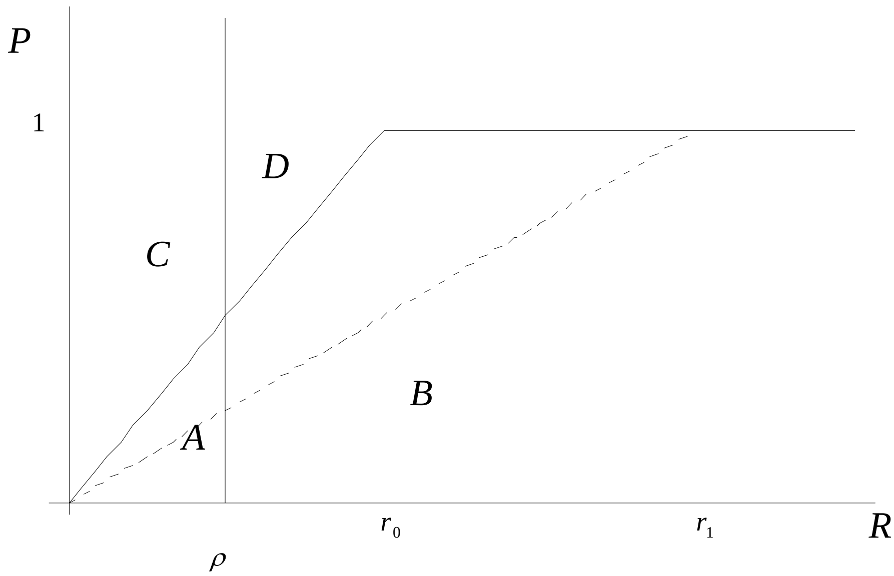

Figure 2. Probability of Repayment and Investment Return

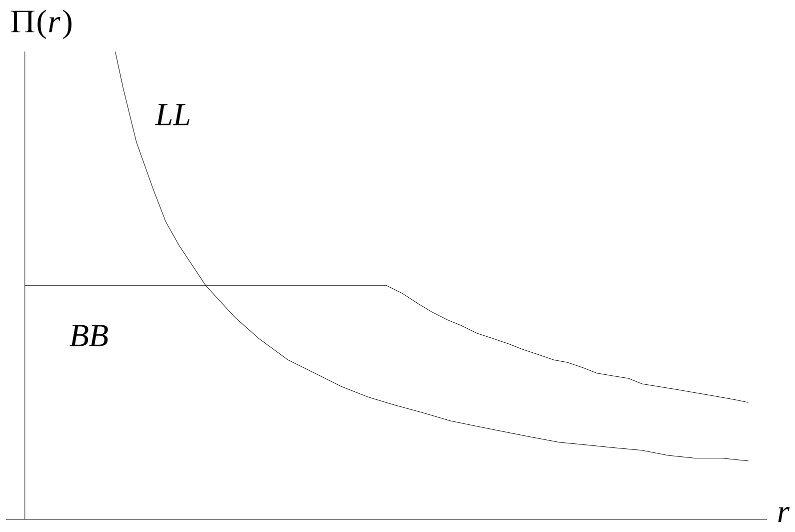

Figure 3. Average Repayment Rate and Loan Interest Rate ($R > 2\rho$)

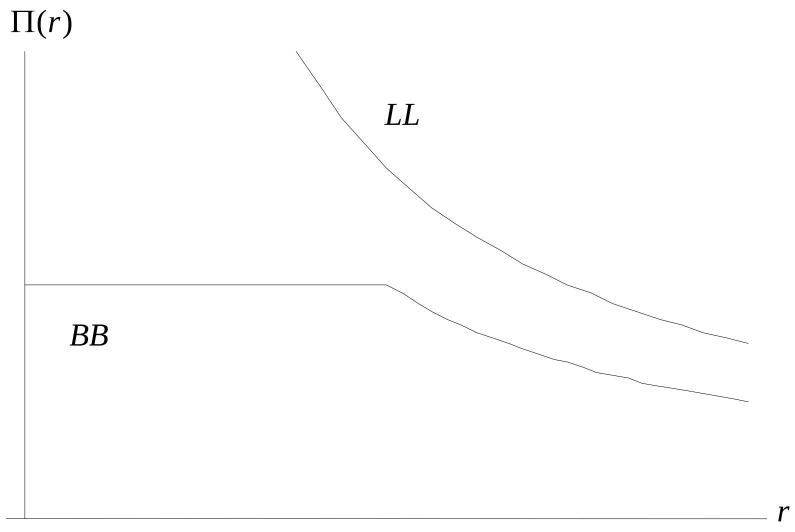

Figure 4. Average Repayment Rate and Loan Interest Rate ($R < 2\rho$)

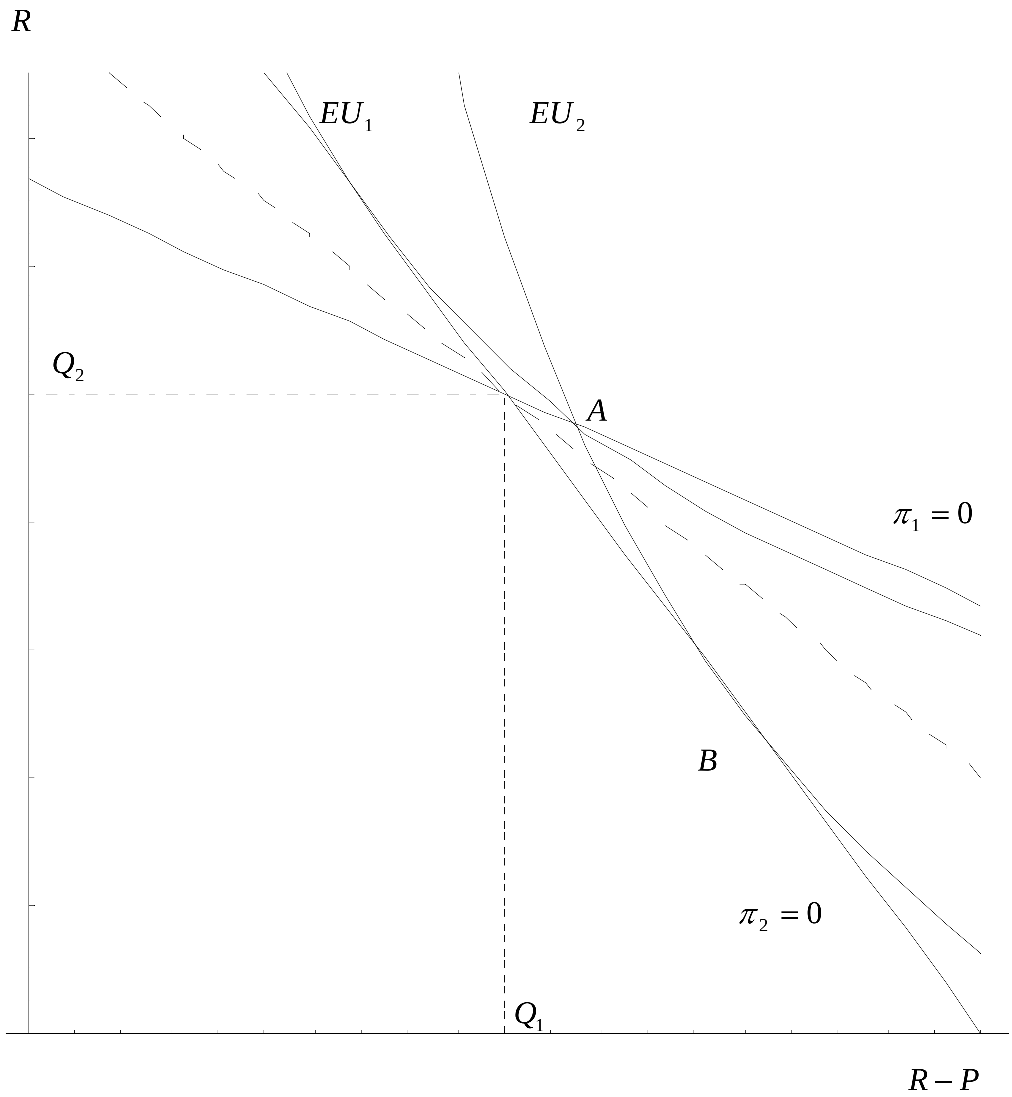

Figure 5. Separating Equilibrium

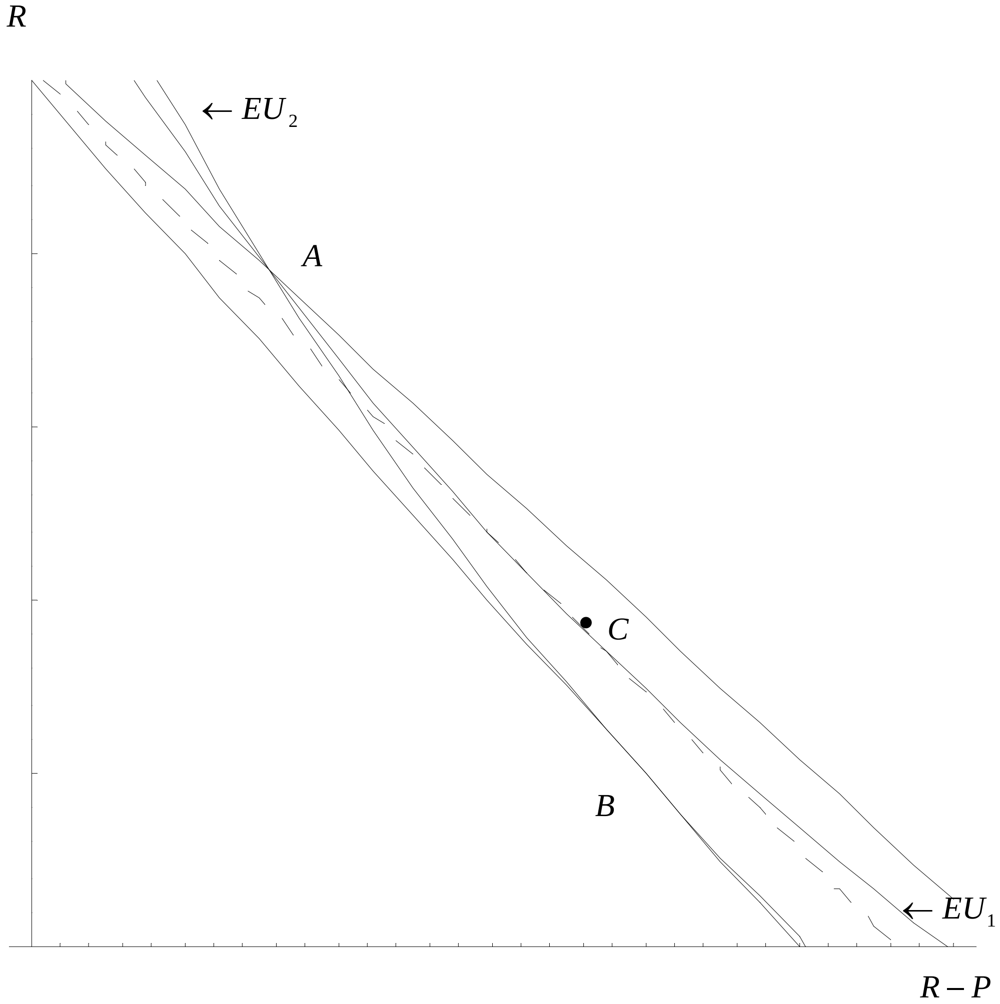

Figure 6. Pooling Equilibrium

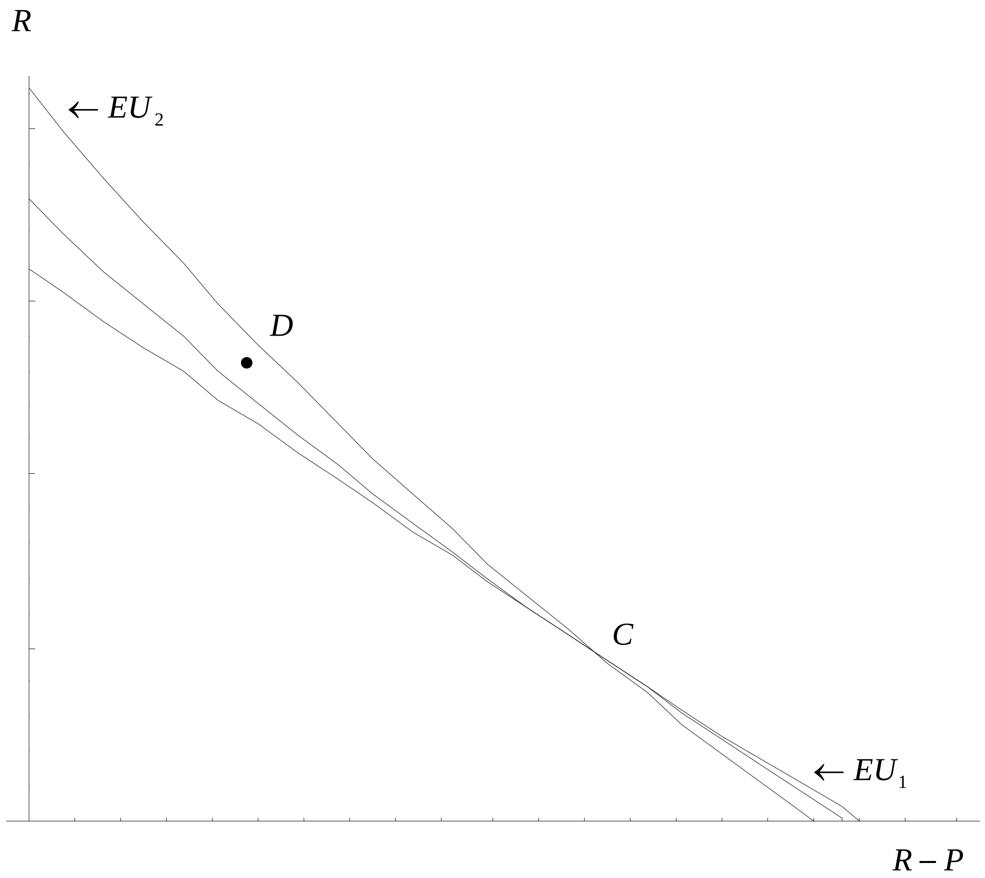

Figure 7. Failure of Pooling Equilibrium

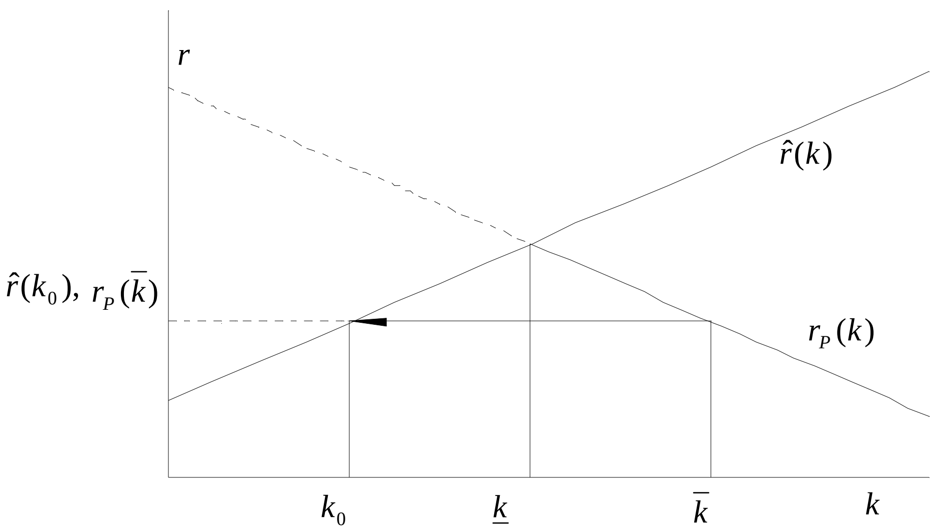

Figure 8. Pareto Improvements with Deposit-Rate Control