The Effect of *Heterogeneous* Participants on the Payment and Settlement System: Systemic Risk and Investment Return

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Abstract

Among the default risks, systemic risk is of the biggest concern over the safety and efficiency of the payment and settlement system. When homogeneous financial institutions are linked with each other through the credit chain, a *gridlock* takes place as equilibrium in the payment and settlement system. A heterogeneous participant in the system could, however, have incentive to fulfill the obligation when otherwise homogenous participants strategically default. That is, fulfillment of obligation turns out to be a Nash equilibrium strategy for the heterogeneous participant whose level of investment return differs from those of remaining participants. The larger the benefit is, the stronger incentive a financial institution has to keep the system working properly. The current paper sheds new light on the effect of heterogeneous financial institutions on the robustness of payment and settlement system under the general equilibrium setup.

Keywords: Payment and Settlement System, Gridlock, Credit Chain, Systemic Risk, and Nash Equilibrium

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"genetic diversity possessed by a species is essential to its long term survival"

– Brendan Duffy

1. Introduction

The importance of safe and efficient payment and settlement system lies not only in the development of financial markets through the use of various payment instruments (e.g. cash, bank deposits, bonds, equities and derivatives etc.) but also in the enhancement of economy as a whole through the frictionless transfer of funds. Considering the volume and the total value of transactions, we should correctly understand the features of settlement risks associated with the payment of debt because the settlement risk is one of the key components that determine how the system should be managed and who should be the participants in the system. To that regard, the current paper encompasses the issues on default risks associated with the payment network system in terms of seamless operation of the payment and settlement system as well as on the features of participating financial institutions in the payment network with respect to the overall level of safety and efficiency of the system. Narrow focus of the current paper deals with the process of transmission of settlement risk to the systemic risk and with the effect of heterogeneous participants on the safety and efficiency of the payment and settlement system.

As for the payment system innovations, Greenspan (1996) claims that the reduction of the cost associated with the *reserve requirements* and the interest accrued on the free loans such as float are of main concern. These innovations inevitably raise the questions of how to control the shifting of credit or liquidity risks that arise due to the timing gap of payment and settlement to the related institutions through the system. As the consequent systemic risk via the credit risk

(moral hazard) such as the intraday debit positions, the real-time gross settlement system has been proposed and adopted by many EU countries as well as Asian ones[1] for their large value payment system (LVPS) with the help of the technological advances. Angelini (1998), however, has shown that the increased reserve requirements induced by the adoption of real-time gross settlement approach could incur the liquidity risk resulting from the intentional delay of outgoing payments among the banks. Thus the banks are subject to the higher than optimal level of end-of-day reserve holdings.

In *Angell* report (BIS 1989) issued by the Bank for International Settlements (BIS), the credit and liquidity risk under the netting schemes could be aggravated into systemic risk depending upon the financial condition of any central counterparty. Thus, the *Angell* report points out the potential of financial contagion of credit or liquidity risk among the banks especially when the financial condition of the central counterparty is weak. However, the concern raised in the *Angell* report could be resolved when the central bank assumes the position of central counterparty. Thus the recent development of the payment and settlement system is prone to emphasizing the relative advantage of the net settlement system over the gross settlement system particularly to the extent of pervasion of systemic risk.

Along with the technological progress, the recent debates on the design of the large value payment systems reflect the spirit of new paradigm developed under the more elaborate theoretical research on the features of settlement risks. In 1997, the committee on payment and

[1] According to the Bank of Korea (2004), the BOK-wire takes the real-time gross settlement (RTGS) approach to eliminate the systemic risk induced by the increase of credit risk and liquidity risk under the *net settlement system*. However, the ground for the RTGS has been undermined as the credit risk could be contained even under the net settlement system and the liquidity risk might be aggravated due to the increased reserve requirement under the *gross settlement system*.

settlement systems (CPSS) of the BIS supports the real-time gross settlement (RTGS) approach since the guaranteed continuous intraday finality could reduce the duration of exposure and serve to reduce the settlement risk.

According to the *Padoa-Schioppa* report (BIS 2005a), however, the CPSS admits that RTGS is not the only mechanism to achieve the continuous intraday finality. A combination of technological progress, proper oversight initiatives reducing systemic risk, increasing significance of time-critical payment, and competitive pressure to control the costs and risks of participating in LVPS serves to develop a new innovative system which could achieve the same level of risk (or service) as under the RTGS system, but at the reduced overall cost. In particular, the liquidity risk could be exacerbated by the RTGS systems that required higher than optimal level of reserve. In the meantime, recent debates on the permission for the non-bank financial intermediaries to participate in the retail payment system in Korea[2] rely on the seemingly obsolete premises that credit risk could be easily transmitted to systemic risk as suggested in the *Angell* report (1989). For example, Lee and Gu (2006) claims that non-bank financial securities companies are susceptible to the credit risk since they put large portion of their assets on the volatile stock market[3]. These critiques, however, seem far-fetched since they exaggerate the occurrence of systemic risk resulting from the credit risk even though the credit risk could be contained *ex ante* under the proper monitoring by the central bank as a central counterparty and

[2] Since the Ministry of Finance and Economy of Korea announced the proposal of legislation of '*Financial Investment Services and Capital Market Act*' (provisional title) on the 17th February 2006, large volume of debates have been aroused rampantly on the participation of non-bank financial sectors in the payment and settlement system.
[3] Korea Institute of Finance (KIF) has produced substantially large volume of critiques against the permission of the non-bank financial institutions to participate in the retail payment system. Among others, Ji, Dong-Hyun, Bon-sung Gu, and Jabonn Kim(2006) claims that the non-bank financial institutions should obtain the bank-license in order to participate the payment network.

ex post under the loss sharing rule among the participants in the payment network.

As a response to the increasing implementation of the netting approach within the group of ten countries[4], the importance of central bank oversight of payments and settlement systems has been put forward such that more formal and systematic oversight becomes a core responsibility of the central bank. Another *Padoa-Schioppa* report (BIS, 2005b) analyzes the need for oversight and the source of central bank's responsibilities for oversight and describes the scope and the involved activities of oversight. These newly adopted perspectives are promoted partly not only by recognizing the presence of liquidity cost associated with the reserve requirement but also by understanding the process under which the individual default takes place and propagates across the payment and settlement system.

Despite the well arranged oversight by the central bank, it is crucial for the safe and efficient payment and settlement system to provide the participants with the incentives not to commit defaults. Heavy scrutiny over the features of credit risk, liquidity risk and systemic risk and over the ways how they are interrelated with each other could open a new path for the payment and settlement system (Rochet and Tirole 1996a, Rochet and Tirole 1996b, Freeman 1996, Angelini 1998, Kahn and Roberds 1998, Kahn and Roberds 2001, Freixas, Parigi, and Rochet 2000, Kahn, Mcandrews, and Roberds, 2003). These researches elucidate the features of settlement risks and particularly the channels through which the systemic risk takes place.

The objective of the current paper does not lie in comparison of the relative advantages over

[4] Several large value payment systems are operated as the *real-time net settlement system* such as LVTS(Large Value Transfer System) in Canada, CHIPS (Clearing House Inter-bank Payment System) in U.S., and PNS (Paris Net Settlement) in France (BIS, 2003, 2005b, and 2006).

the two types of settlement approach, *net* versus *gross*. We explore the ways on how to improve the safety and efficiency of the payment and settlement system by containing the systemic risk which, otherwise, could take place as a gridlock within the system. Utilizing the model developed in Kahn, Mcandrews, and Roberds (2003), we demonstrate that the systemic risk could be effectively prevented from occurring by providing one with the incentive not to default even if others face an incentive to default strategically. Thus, heterogeneity among the participants in the system could play a key role in generating *non-homogeneous* incentives. The current paper is constructed as follows. In section 2, the literature review on the settlement risks follows and the model is proposed in the section 3. The conclusion follows with the conjectures and implication of the propositions suggested in the section 3.

2. Literature Review

Settlement risks associated with any form of payment take place when a payor involved with payment obligation fails to deliver the funds from the payor to the payee. Of the most concern are the credit risk, the liquidity risk, and the systemic risk. Credit risk is the risk that the payor, its bank, or other intermediary decides not to fulfill the transfer of funds due to either the shortage of funds or the strategic default. Liquidity risk is said of that the funds cannot be transferred in the due time because of the illiquidity of the assets or temporary market breakdown. Systemic risk is the risk that the credit risk or liquidity risk is evolved into financial contagion among the financial intermediaries.[5] Even though many researchers generally agree

[5] For more general definition of systemic risk, see Rochet and Tirole (1996b).

with the respective features of settlement risks, they differ from each other on the channels through which the settlement risks take place.

Berger, Hancock, and Marquardt (1996) adopts a broad view on the systemic risk that it is the result of extension of either credit risk or liquidity risk or both. Thus it is natural for them to suggest a framework for the payment and settlement system, based on the trade-off relationship between the settlement risk as a whole and the overall cost. This perspective on the systemic risk rooted in the *Angell* report (BIS 1989) underlies the analysis of netting schemes and the principles for central bank oversight in the *Lamfalussy* report (BIS 1990)[6]. This line of concern leads to the arrangement of risk control mechanism for the net settlement approach such as "defaulters pay" methods, "survivors pay" methods, and "third parties pay" methods, even though many systems adopt a combination of the methods in practice (BIS 1997: *Real-Time Gross Settlement Systems*). The first methods are effective in reducing the moral hazard of the agents in the system but impose higher liquidity costs for the agents because of the required collateral. The second methods are linked to the loss-sharing rule, where the loss incurred by an agent's default is shared among the remaining agents. The third methods are realized when the central bank takes the role as a central counterparty for the payment and settlement system.

Defaulters pay methods are tied with the increase of collateral requirements resulting in the opportunity cost, which could outweigh the costs of more lenient credit policy. Thus the relative weights of the respective types of costs determine the optimal policy of credit extended by a

[6] The report focuses on the principles for central bank oversight in light of credit and liquidity management practice by the banks even though it recognizes the incentive issues among the participants. However, the incentive issues are limited to the moral hazard of the participants with respect the asset management.

central bank (Furfine and Stehm 1998). As for the second and third arrangements, Rochet and Tirole (1996a) points out that the payment network is susceptible to the agents' moral hazard in asset management due to the lack of peer monitoring. Thus the liquidity provision, which is connected with the insolvency problem, should be monitored by the central bank. Freixas, Parigi, and Rochet (2000) claims that the loss of information regarding the solvency of financial intermediaries leads to the welfare loss because the liquidation of insolvent banks could be delayed.

Contrary to the notions presented in the last two papers, Kahn and Roberds (1998) claims that the well arranged oversight by the central bank over the bank's asset quality could reduce the payment network participants' incentive to distort the investment decision. Thus the contagion of settlement failures due to the credit risk or moral hazard could be contained by the timely intervention of the alert regulator. Therefore, the default risk is an endogenous variable under the control of the payment network participants. This line of thought is related to the papers by Freeman (1996) and Green (1997) among others. Freeman (1996) shows that, when the central bank provides intraday loan, the *un*enforceable private debt could be substituted for the enforceable claim held by the central counter party. Then the welfare could be enhanced by reducing, otherwise, higher shadow costs of debt such as collateral requirements necessary to prevent the contagion from occurring. Green (1997) also demonstrates that the welfare could be improved under the net settlement system as long as the original debt obligation could be replaced with the net claims. The larger distortions arise, the more is the debt that the debtors have to clear via third parties at the discounted value.

Several sources of systemic risk other than credit risk are explored. Imperfect or incomplete information is a prominent candidate for the source of financial contagion. Freixas and Parigi (1998) shows that the extent of information asymmetry regarding the bank's investment return could lead to the trade-off between the safety and efficiency of the payment systems. The high probability of low investment return could lead to financial contagion triggered by the depositors' anticipation as in Diamond and Dybvig (1983). According to Rochet and Tirole (1996a), poor inter-bank monitoring over the quality of assets could lead to the systemic risk via the liquidity provision by the central bank. Thus it calls for more intense oversight by the central counterparty over the participants in the payment network system. In Freixas, Parigi, and Rochet (2000), facing the uncertain liquidity shock, banks connected with the inter-bank credit line reduce the cost of holding liquid assets. However, a sudden early liquidation of investment due to the depositors' asymmetric preference over the consumption could trigger the unnecessary speculative gridlock. Thus a shock in one region serves as a signal and creates a self-fulfilling crisis in another region. In contrast, Allen and Gale (2000) claims that, even under the complete information as to the solvency of bank, the spillover effect could dominate and lead to the contagion when the claims on the troubled region suffering from the temporary liquidity shock fall in value. However, the bank rather than the depositors should be more aware of the quality of investment. Thus higher return of the investment could endow the financial institutions with an increased incentive to honor the obligation, which in turn could reduce the occurrence of systemic risk.

As for the relationship between the *strategic* default and the quality of assets, Kahn and

Roberds (1998) compare the relative merits of the two payment networks with respect to the moral hazard regarding the quality of assets and the costs associated with holding reserves. Net settlement dominates real-time gross settlement as long as the quality of assets is fixed despite the increased probability of individual default. However, if the quality of assets is a choice variable, distorted incentive to transfer the risk to other participant through the network could result in the increase of the costs of net settlement.

Employing the general equilibrium models, Kahn and Roberds (2001) demonstrate that the intraday credit could ease the burden of costs due to the credit constraints. However, the liquidity costs cannot be properly eliminated if the intraday credit is available on the requirements of collateral. In particular, the heterogeneity of payment system participants should abate effectiveness of collateral requirements further. Thus the intraday credit provided by the central bank should be adjusted depending upon the costs associated with the payment and settlement systems. Extending this line of thought, Kahn, Mcandrews, and Roberds (2003) show that the net settlement is free of a certain type of gridlock situation resulted from the strategic delay of payment. In their model, the credit chain is established under the incomplete contract enforcement such that of the most fundamental concern is the extent of fulfillment of payment obligations among the members of the credit chain. The level of investment return of the financial institutions' allocation of assets could be a source of systemic risk triggered by the strategic default.

Utilizing the basic construct of the model developed in Kahn et al. (2003), the current paper explores the path which leads to deeper understanding of the links between the financial

institutions' investment (or *retail* activities) and their participation in the payment and settlement systems. In the literature of *Payment* Economics according to Lacker and Weinberg (2003), the current research sheds light on the role of central bank over the inter-bank settlement arrangement and the effect of heterogeneity of participants on the payment and settlement system. Thus the current paper produces policy implications in three aspects: oversight by the central bank on the financial institutions, arrangements of the certainty of settlement, and constituents of the payment and settlement system.

3. Model

Incomplete contract enforcement underlies the current model such that the legal rules for default and bankruptcy remain constant as exogenous. Thus the model allows us to focus on the effect of strategic default and heterogeneous participant on the payment and settlement system. Strategic default is basically incentive problem. Initially, homogenous financial institutions, i.e. banks, comprise the participants in the payment system in the economy.

3.1. Environment of the Model

In the payment system, there are N banks engaged in the *payment and settlement game* where they are linked with each other through the credit chain. There will be three time periods, $t = 0, 1, 2$ spanning a single trading day. There are two types of financial goods: intermediate goods and final goods. Intermediate goods are not used for consumption but for producing final goods such that the intermediate goods are subject to deterioration unless they are delivered to

other banks. Hence the banks have incentive to engage in the trading of intermediate goods leading to the formulation of credit chain. At $t = 0$, each bank is endowed with one unit of intermediate good which can be used to produce final good at $t = 2$. The intrinsic value of intermediate good is standardized as 1 at $t = 0$. Then the two involved banks agree on the delivery and payment contract over the intermediate good at the market price P without bargaining over the price[7] at $t = 1$. The final good is realized with the value at F and the settlement of P is expected to take place at $t = 2$.

The trade of intermediate goods in the current model could be interpreted as the trade of financial claims that give rise to inter-bank obligations in the context of the inter-bank payment network. When the bank i agreed with the bank $i+1$ on the delivery of intermediate good at time 1, the bank $i+1$ is obliged with the payment of P at time 2. Therefore the necessary condition[8] for the banks to engage in trading of intermediate goods is $F > P > 1$. Then replication of this process could produce the credit chain among the N banks within the system. Therefore, a representative bank i could be a creditor to the bank $i+1$ and a debtor to the bank $i-1$ simultaneously.

A bank's position as a creditor within the system differs from as a debtor in terms of the payoff from the system as well as the extent of effect on the system. As the payment obligation to the bank i denoted as P_i is not fulfilled, the bank $i+1$ is in default as a debtor whose attachable asset denoted as A_{i+1} is subject to partial claim by the bank i. Although the bank i holds a claim

[7] This assumption precludes the bargaining complexity without loss of generality that the payment obligation ends up with lower than market price since the opportunity cost of the intermediate good is zero at $t = 2$.
[8] The price for the intermediate good is mostly larger than 1 since the positive interest rate is imposed on the loan. However, the price P could be lower than 1 depending upon the characteristics of loan or the circumstances of economy.

on the bank i+1, the payoff to the creditor (bank i) relies on the default decision by the bank i+1, whereas the payoff to the debtor (bank i+1) is self-determined. Thus, the bank i+1 as a debtor could take some fraction α of its own asset through diversion of wealth if it decides not to fulfill the obligation where $\alpha < 1$[9]. Consequently, if the bank i+1 defaults the settlement P_i to the bank i at time 2, the bank i is eligible for a fraction[10] β of the attachable asset of the bank i+1 where $\beta < 1$. Therefore, each fraction α and β denotes the share of the attachable asset for the debtor and creditor respectively when a debtor fails to fulfill the settlement. In case of default, the sum of fraction cannot exceed one such that $\alpha + \beta < 1$, since each bank's attachable asset is susceptible to the decay of value due to the loss of capital reputation. We could tidy up the contingent payoff to the creditor and debtor respectively as follows.

First, payoff to the bank i when it decides to *default* as a debtor

i) Payoff = $\alpha A_i + P_i$ if the bank i+1 settles

ii) Payoff = $\alpha A_i + \beta A_{i+1}$ if the bank i+1 does not settle

Second, payoff to the bank i when it decides to *not default* as a debtor

iii) Payoff = $A_i - P_{i-1} + P_i$ if the bank i+1 settles

iv) Payoff = $A_i - P_{i-1} + \beta A_{i+1}$ if the bank i+1 does not settle

Third, payoff to the bank i as a creditor

v) Payoff = P_i if the bank i+1 settles

vi) Payoff = βA_{i+1} if the bank i+1 does not settle

[9] Due to the imperfect information, the supervising authority cannot enforce the perfect monitoring over the bank's asset. So the portion α exceeds zero but less than 1.
[10] The portion βA denotes the residual claim on the attachable asset.

As shown above, the payoff to the bank i as a creditor is determined by the debtor's default decision, whereas the payoff to a debtor is self-determined regardless of whether the bank i+1 settles or not. Thus, the debtor could influence the payment and settlement system more significantly than the creditor. Once the credit is issued, the debtor takes the driver's seat. The above result is easily reduced to the following contingent payoff.

Payoff to the debtor: $\max [\alpha A_i , A_i - P_{i-1}]$

Payoff to the creditor: $\min [P_i , \beta A_{i+1}]$

One might wonder if the immediate exit of the bank out of the system rendered by the default would be too strong assumption. Since the participants in the payment system should be better off with the retention of participation in the payment network, the incentive to default should be diminished. As the current one-shot game could be easily extended to the repeated game, the *folk theorem* could be the case even under the loss sharing rule which accommodates the survivors pay method. If *tit- for-tat* strategy dominates, however, the system provides too much resiliency to the inefficient banks, which could loosen the market discipline. Similar implication is proposed in Freixas, Parigi, and Rochet (2000) where the central bank should be vested with the right to close down the bank whose investment return is low. Thus, the basic thrust of the forced exit under the current one-shot game could remain valid under the repeated game.

3.2. Payoffs, Actions, and Strategies

In this payment and settlement game, we look for the symmetric sub-game perfect Nash

equilibria in pure strategies. The attachable asset available to the bank is the realized final good since the settlement failure will take place at t=2. There are four different types of action available to the bank i contingent upon the actions of the bank i+1. The elements of action set denoted as *Action Set* of the bank i in the game are defined as follows.

Action Set = $\{a_1, a_2, a_3, a_4\}$

a_1 = (i defaults $\mid i$+1 defaults)

a_2 = (i fulfills $\mid i$+1 defaults)

a_3 = (i defaults $\mid i$+1 fulfills)

a_4 = (i fulfills $\mid i$+1 fulfills)

Then, the corresponding payoffs of the bank i denoted as $\pi(a_1)$, $\pi(a_2)$, $\pi(a_3)$, and $\pi(a_4)$ respectively are as follows. The attachable assets are final good and the fulfilled payment.

$$\pi(a_1) = \alpha F_i + \beta F_{i+1}$$

$$\pi(a_2) = F_i - P_{i-1} + \beta F_{i+1}$$

$$\pi(a_3) = \alpha(F_i + P_i)$$

$$\pi(a_4) = F_i + P_i - P_{i-1}$$

As symmetric condition is assumed for the participants in the payment network under the homogeneity of participants and with the presence of competition among them, we could drop the subscripts such that $F_i = F_{i+1}$ and $P_i = P_{i-1}$ without loss of generality. The above payoffs are converted as follows.

$$\pi(a_1) = \alpha F + \beta F$$

$$\pi(a_2) = F - P + \beta F$$

$$\pi(a_3) = \alpha(F + P)$$

$$\pi(a_4) = F + P - P$$

Hence there are four different strategies available to the bank i depending upon the corresponding payoffs.

$S^i_1 = [i \text{ defaults} \mid i+1 \text{ defaults}]$ iff $\pi(a_1) = \alpha F + \beta F > \pi(a_2) = F - P + \beta F$ (1)[11]

$S^i_2 = [i \text{ fulfills} \mid i+1 \text{ defaults}]$ iff $\pi(a_1) = \alpha F + \beta F \leq \pi(a_2) = F - P + \beta Fi$ (2)

$S^i_3 = [i \text{ defaults} \mid i+1 \text{ fulfills}]$ iff $\pi(a_3) = \alpha(F + P) > \pi(a_4) = F + P - P$ (3)

$S^i_4 = [i \text{ fulfills} \mid i+1 \text{ fulfills}]$ iff $\pi(a_3) = \alpha(F + P) \leq \pi(a_4) = F + P - P$ (4)

So far, we have investigated the debtors' incentive to participate in the payment system. But we need to check out the creditor's incentive compatible constraint. The creditor might prefer debtor's default to fulfillment under the incomplete contract. The creditor chooses rather not to receive the payment if the claim on the attachable asset is larger than the payment such that $P_{i-1} < \beta (F_i + P_i)$. This would be the case even under the repeated game as long as the future benefit from the continuum of payment system is discounted. Thus we need the creditor's incentive compatible constraint for the payment system to exist and work properly as follows.

$$P \geq \beta(F + P) \quad (5)$$

Thus the creditor's incentive compatible constraint is a necessary condition for the system to continue its service and operation within the economy.

[11] In Kahn et al. (2003), the "*mutually assured default*" is derived from the condition $\alpha F > F - P + \beta F$ when $a=0$ in the equation (7) for tractability. However, it seems far fetched because they ignore the bank i is still eligible for the partial seizure βF of the attachable asset of the bank $i+1$. From our point of view, mutually assured default could take place if $\alpha F + \beta F > F - P + \beta F$ when the bank $i+1$ defaults and $\alpha F + P > F - P + P$ when the bank $i+1$ fulfills. This leads to significant divergence in the analysis as well as in the consequential results between the current paper and Kahn et al. (2003).

In order to derive meaningful implications for the interaction between the payment system and the real sector, we derived a new variable, *F/P*, which is proved later on to play a key role in determining the equilibrium strategies. This ratio of the values of final good and the intermediate good should be properly interpreted as the investment return of the bank and assumed to be larger than one, $F/P > 1$. Then the equilibrium strategies of the bank *i* are given as follows.

S^i_1= [*i* defaults | *i*+1 defaults] iff $\frac{F}{P} < \frac{1}{1-\alpha}$ (6)

S^i_2= [*i* fulfills | *i*+1 defaults] iff $\frac{F}{P} \geq \frac{1}{1-\alpha}$ (7)

S^i_3= [*i* defaults | *i*+1 fulfills] iff $\frac{F}{P} < \frac{\alpha}{1-\alpha}$ (8)

S^i_4= [*i* fulfills | *i*+1 fulfills] iff $\frac{F}{P} \geq \frac{\alpha}{1-\alpha}$ (9)

The creditor's incentive compatible constraint is also converted as follows.

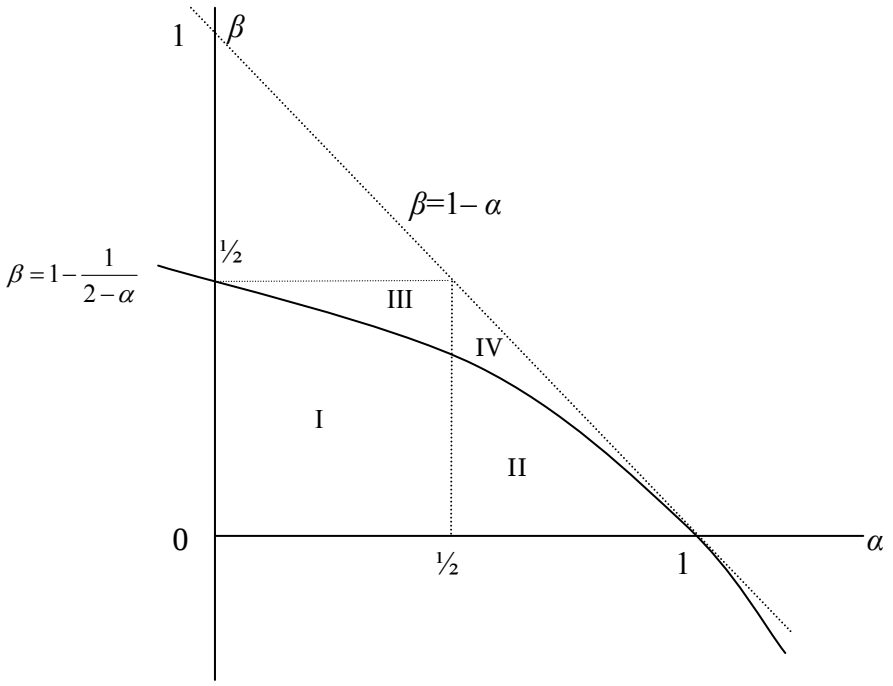
$$1 < \frac{F}{P} \leq \frac{1-\beta}{\beta} \quad (10)$$

From the equations presented above, the necessary and sufficient conditions on the parameters α, β are defined as follows. As the fractions of attachable asset cannot exceeds one such that $\alpha+\beta < 1$, the threshold value of equation (8) is always lower than that of equation (10), i.e. $\frac{\alpha}{1-\alpha} < \frac{1-\beta}{\beta}$. As the system should be devoid of the creditor's incentive to induce default, the creditor's claim on the attachable asset must be limited as $\beta < \frac{1}{2}$ according to the equation (10). However, the threshold value in equation (6) could be larger than or smaller than that of

equation (10) depending upon the parameter values, $\frac{1}{1-\alpha} \lesseqgtr \frac{1-\beta}{\beta}$ [12] equivalent to $\beta \lesseqgtr 1-\frac{1}{2-\alpha}$. Thus we could tidy up the conditions on the parameters α, β for the system to work in the economy as follows.

$$\alpha+\beta < 1,\ \alpha >0,\ \ \beta < \frac{1}{2},\ \text{and}\ \ \beta \lesseqgtr 1-\frac{1}{2-\alpha} \tag{11}$$

Then, the relationship between the parameters α and β is well represented in the coordinate plane (α, β) in the Figure 1.

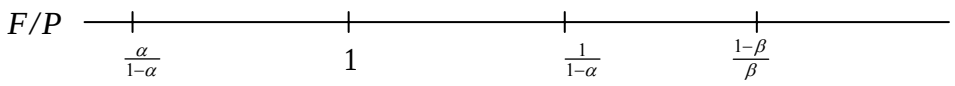


<Figure 1> Location of Parameters in the Coordinate Plane of (α, β). The areas denoted as I, II, III, and IV are demarcated by the combination of the threshold values. Area I is demarcated by $0<\alpha<½$, $0\le\beta<½$, and $\beta < 1-\frac{1}{2-\alpha}$. Area II is demarcated by $½ \le\alpha<1$, $0\le\beta<½$, and $\beta < 1-\frac{1}{2-\alpha}$. Area III is demarcated by $0<\alpha<½$, $0\le\beta<½$, and $\beta \ge 1-\frac{1}{2-\alpha}$. Finally area IV is demarcated by $½ \le\alpha<1$, $\beta<1-\alpha$, and $\beta \ge 1-\frac{1}{2-\alpha}$.

[12] This inequality is equivalent to $\frac{\beta}{1-\beta} \lesseqgtr 1-\alpha$. The right hand side of this inequality $1-\alpha$ implies the share of asset subject to creditor's claim as well as the extent of monitoring over the bank's asset in default. The left hand side indicates the ratio of creditor's claim on the residual asset to the non-pledgeable asset and the degree of punishment on the banks in default.

3.3. Homogenous Participants

Homogeneity among the participants indicates that the each bank enjoys similar level of investment return. This assumption should not be far fetched since the banks loan rate tends to converge to a certain level without severe externality. First, if $\frac{1}{1-\alpha} \leq \frac{1-\beta}{\beta}$ and $0<\alpha<½$ are the case, then the consequential relationship among the threshold values are $\frac{\alpha}{1-\alpha}<1<\frac{1}{1-\alpha}<\frac{1-\beta}{\beta}$. The value line of *F/P* is given as follows with the critical threshold values. Then the structure of value line of *F/P* in Figure 2 corresponds with the area I in the Figure 1.



<Figure 2> Value line of *F/P* when $\frac{1}{1-\alpha}<\frac{1-\beta}{\beta}$ and $0<\alpha<½$

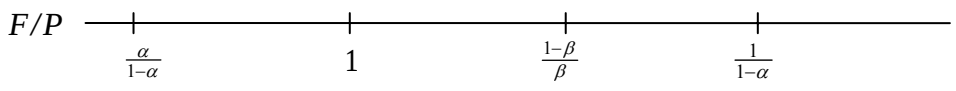
The bank *i* as a debtor will choose its own strategy depending upon where its own investment return is located along the value line of *F/P*.

Proposition 1] When $\frac{\beta}{1-\beta}<1-\alpha$ and $0<\alpha<½$, gridlock could take place if the investment return *F/P* of the bank *i* falls between 1 and $\frac{1}{1-\alpha}$, that is, a debtor's default could trigger the gridlock among the participants. However, if the investment return *F/P* falls between $\frac{1}{1-\alpha}$ and $\frac{1-\beta}{\beta}$, the gridlock will not occur.

Proof) From the equation (6), S^i_1= [*i* defaults | *i*+1 defaults] is the equilibrium strategy for the

bank i since $F/P<\frac{1}{1-\alpha}$. Also, S^i_4= [i fulfills $\mid i$+1 fulfills] is another equilibrium strategy according to the equation (9) since $\frac{\alpha}{1-\alpha}<1<F/P$ when $0<\alpha<½$. Therefore the contingent strategy is the Nash equilibrium strategy such that the bank i chooses default when others default and fulfills when others fulfill. On the other hand, if $\frac{1}{1-\alpha} \le \frac{F}{P} \le \frac{1-\beta}{\beta}$, then the equilibrium strategy for the bank i is S^i_2= [i fulfills $\mid i$+1 defaults] due to the equation (7) and S^i_4= [i fulfills $\mid i$+1 fulfills] due to the equation (9) since $\frac{\alpha}{1-\alpha}<\frac{1}{1-\alpha}<\frac{F}{P}$ Therefore the fulfillment is the dominant strategy for the bank i even when its predecessor defaults. Q.E.D.

The proposition 1 implies that the payment system is vulnerable to the systemic risk such as the occurrence of gridlock despite the intensive monitoring over the bank's asset by the central bank ($0<\alpha<½$), when the participants' investment return is low $1<F/P<\frac{1}{1-\alpha}$. Under the intensive monitoring where the extent of diversion is low such that $0<\alpha<½$, however, the relatively high investment return such as $\frac{1}{1-\alpha}\le\frac{F}{P}\le\frac{1-\beta}{\beta}$ could provide the banks with incentive to fulfill the obligation despite the occurrence of default. The level of investment return is important in providing incentives not to engage in chain reaction of defaults among the banks.



<Figure 3> Value line of F/P when $\frac{1-\beta}{\beta} \le \frac{1}{1-\alpha}$ and $0<\alpha<½$

This value line in the Figure 3 corresponds with the area III in the Figure 1. Since F/P is always located between 1 and $\frac{1-\beta}{\beta}$, the following proposition results in.

Proposition 2] When $\frac{1-\beta}{\beta} \leq \frac{1}{1-\alpha}$ and $0<\alpha<½$ is assumed, an occurrence of default triggers the gridlock in the chain reaction of defaults as $1<F/P<\frac{1-\beta}{\beta}$.

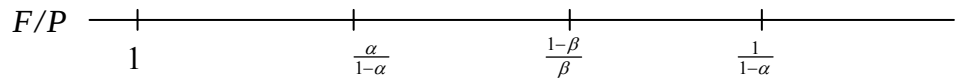
Proof) Since the investment return is always located between $\frac{\alpha}{1-\alpha}$ and $\frac{1}{1-\alpha}$, the equilibrium strategy will be S^i_1= [i defaults | i+1 defaults] and S^i_4= [i fulfills | i+1 fulfills] according to the equations (6) and (9). Q.E.D.

Despite the intensive monitoring by the central bank, the payment system is vulnerable to the systemic risk through gridlock as long as $\beta \geq 1-\frac{1}{2-\alpha}$. If the creditor's claim on the attachable asset is large, the payment system becomes susceptible to the gridlock. Therefore, the proposition 2 produces an important policy implication regarding the size of pledgeable fraction β of the attachable asset. Severe punishment (denoted as large fraction β) could lead to the vulnerable payment system to the systemic risk. When the diversion of asset is large such that $½\leq\alpha<1$ due to the weak monitoring and $\frac{1}{1-\alpha}<\frac{1-\beta}{\beta}$, the value line corresponds with the area II in the figure 1.

<Figure 4> Value line of F/P when $½\leq\alpha<1$ and $\frac{1}{1-\alpha}<\frac{1-\beta}{\beta}$.

When the diversion of asset is large such that $½\leq\alpha<1$ and $\frac{1}{1-\alpha}\geq\frac{1-\beta}{\beta}$, the value line

corresponds with the area IV in the figure 1.



<Figure 5> Value line of *F/P* when ½≤*α*<1 and $\frac{1}{1-\alpha} \geq \frac{1-\beta}{\beta}$.

Within the figures 4 and 5, it is noteworthy that $\frac{1}{1-\alpha}$ is larger than two since ½≤*α*<1. Thus when diversion of wealth is relatively large due to the lack of proper monitoring over the asset, the investment return should be unrealistically high such that $2 \leq \frac{1}{1-\alpha} < \frac{F}{P} < \frac{1-\beta}{\beta}$ in order for the banks to fulfill the obligation despite the predecessor's default. Otherwise, the payment system is always vulnerable to the systemic risk such as gridlock. As for the monitoring intensity, the central bank should take appropriate steps against the diversion of wealth by the banks, otherwise the payment system fails if $\frac{F}{P} < \frac{\alpha}{1-\alpha}$.

Proposition 3] If diversion of assets is easy due to the lack of proper monitoring, ½≤*α*<1, the payment system collapses even with the investment return larger than one.

Proof) From the figure 4 and 5, if investment return is located at $1 < \frac{F}{P} < \frac{\alpha}{1-\alpha}$, then the bank's strategy is S^i_3 = [*i* defaults $\mid$ *i*+1 fulfills] because of the equation (8) and S^i_1 = [*i* defaults $\mid$ *i*+1 defaults] due to the equation (6). Q.E.D.

This proposition 3 indicates that the proper monitoring over the assets by the central bank is

indispensable in order to retain the robustness of the payment system. This result complies with the standard proposed in the *Padoa-Schioppa* report on *Central bank oversight of payment and settlement systems* (BIS 2005b).

3.4. Heterogeneous Participants

A new participant *j* is introduced to the payment and settlement system, whose investment return is denoted as $\frac{F_j}{P}$. Then, with the intensive monitoring over the assets $0<\alpha<½$, this new participant linked with other participants through the credit chain has incentive to fulfill the obligation despite its debtor's default even if other participants' investment return is low $\frac{\alpha}{1-\alpha} \le \frac{F_{i\neq j}}{P} < \frac{1}{1-\alpha}$ as long as $\frac{1}{1-\alpha} \le \frac{F_j}{P} < \frac{1-\beta}{\beta}$. Therefore a default could be prevented from developing into the gridlock due to the presence of heterogeneous participant.

Proposition 4] Under intensive monitoring by the central bank with $0<\alpha<½$, a heterogeneous participant will choose fulfillment of obligation as long as its investment return is as high as $\frac{1}{1-\alpha} \le \frac{F_j}{P} < \frac{1-\beta}{\beta}$, even if other participants' investment return is low such that $\frac{\alpha}{1-\alpha} \le \frac{F_{i\neq j}}{P} < \frac{1}{1-\alpha}$. Then the payment network could be immune to the systemic risk such as gridlock.

Proof) If the participant *j*'s investment return is high such that $\frac{1}{1-\alpha} \le \frac{F_j}{P} \le \frac{1-\beta}{\beta}$, then the equilibrium strategy for the participant *j* is S^j_2 = [*j* fulfills $\mid j+1$ defaults] due to the equation (7) and S^j_4 = [*j* fulfills $\mid j+1$ fulfills] due to the equation (9) since $\frac{\alpha}{1-\alpha} < \frac{1}{1-\alpha} < \frac{F_j}{P}$. Thus fulfillment is the dominant strategy for the participant *j* even when its predecessor defaults. Q.E.D.

The implication of the proposition 4 is not limited to the case of non-bank financial institution for the payment network. Recent expansion of banking operation from the conventional deposit and loan business to the non-bank financial business should enhance the safety and efficiency of the payment and settlement systems. The intuition which lies beneath the current analysis is that higher investment return through the network could provide the increased incentive for the participants to retain the payment network and to fulfill the obligation through the network under the proper monitoring by the central bank over the assets of financial institutions. Thus the result of current paper should not be necessarily limited to the case of securities companies but extended to the whole financial intermediary.

3.5. Defaulters Pay Method (Collateral)

From the figure 2 through 5, it is noteworthy to mention that the size of creditor's portion β of the pledgeable assets is irrelevant to the debtor's decision on whether to default or not. If β is larger than ½, the payment system cannot exist because of the violation of incentive compatible constraint for the creditors such that the creditor prefers default to fulfillment of obligation. Especially for the area I in figure 1, the intensity of monitoring by the central bank should be increased to reduce the diversion of wealth α as β is increased. According to the figure 2, the distance between $\frac{1}{1-\alpha}$ and $\frac{1-\beta}{\beta}$ is shortened as β is increased. Then, α should be decreased for the payment network to prevent a default from developing into the systemic risk as the investment return is located as $\frac{1}{1-\alpha} < \frac{F}{P} < \frac{1-\beta}{\beta}$. Thus, the reduced α implies the increased cost of monitoring by the central bank. Therefore the *defaulters pay method* is limited in improving the

safety and efficiency of the payment network in light of monitoring cost.

4. Conclusion

Recent trend of the banking sectors to expand their operation to the non-banking businesses should have welfare implication unless it is achieved at the expense of non-banking sectors. In light of current analysis, the expansion of banking operation into the non-banking sectors should indicate that the financial investment return for the banks is increased. Thus the financial institutions could have stronger incentive to sustain the robustness of payment and settlement system to the benefit of whole financial system. However, the same result could be achieved when a heterogeneous participant is admitted to the payment and settlement system.

A heterogeneous participant has incentive to fulfill the settlement obligation even if other participant commits a default. Fulfillment of the obligation despite the default turns out to be a dominant strategy for the heterogeneous participant when its investment return is higher than others. Thus allowing the non-banking financial institutions to participate in the payment network even in the large value payment system would be desirable in light of welfare increase as long as the intensive monitoring by the central counter party is guaranteed.

The current paper highlights several important aspects of interaction of investment returns in the real sector with the safety and efficiency of the payment and settlement system. Utilizing the model of Kahn et al. (2003), we have demonstrated that the debtor's incentive to default could be ameliorated by the increased investment return and the reduced diversion of wealth due to the intense monitoring. Overall increase of the investment return would definitely improve

the safety and efficiency of the payment and settlement system. Particularly, the current analysis highlights the effect of the heterogeneous participant on safety and efficiency of the payment and settlement system under the general equilibrium setup. The larger the benefit is, the stronger incentive a financial institution has to keep the system working properly.

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