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DESIGNING INCENTIVE COMPATIBLE REGULATION IN BANKING

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ABSTRACT

In the model of the Precommitment Approach, first put forth by Kupiec and O'Brien (1995), the appropriate amount of capital is specified according to the first-order condition which minimises total cost. Although the regulator, without having any information on the banks' riskiness (i.e. the regulator only offers a unique penalty rate), may not be able to identify whether banks announcing higher levels of capital are riskier, the choice of capital level is regarded incentive compatible as long as it coincides with the regulator's objective. We develop a model from the perspective of mechanism design in which the regulator's strategy is to choose both the level of capital requirement and the penalty rate. The model concludes that the regulator can construct incentive compatible contracts from which it can reveal the banks' riskiness truthfully. Nevertheless, it has also become clear that both the original framework and our approach have a certain limit in order to achieve the normative capital requirement whereby the riskier banks hold higher level of capital. This result suggests that the regulator be aware of private information on the banks' riskiness *ex ante*; the monitoring role of the regulator and the effectiveness of the incentive compatible regulation are complementary.

Keyword: mechanism design, Precommitment Approach
JEL Classification: D82, E58, G38

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1. Introduction

The purpose of this paper is to examine an alternative framework of incentive compatible regulation and see if the regulator could achieve the norm whereby riskier banks be required higher capital holding.

According to the Precommitment Approach, banks pre-announce the appropriate level of capital which covers the maximum value of expected loss that might arise in the trading account, and if the actual loss after a certain interval exceeds its pre-announced value, they will be penalised. This framework will create the right incentive for banks – they choose the level of capital that minimises the total cost which consists of the expected cost of penalty and the cost of raising capital.

Nevertheless, it may not be apparent whether the regulator will always implement the mechanism through which banks reveal their riskiness truthfully. To be more precise, the approach relies solely on the first-order condition of cost minimisation, where the regulator only needs to offer a unique penalty rate and lets each bank select the right amount of capital which satisfies the first-order condition. This implies that the regulator may need no information *ex ante* with regards to the riskiness of each bank, i.e. the regulator can extract private information *ex post* by observing how much capital each bank will choose to hold after setting the unique penalty rate. It, however, may not be certain whether riskier banks will always self-select a higher level of capital requirement – the choice of capital holding depends on the bank's private information such as the shape of the density function of its investment return, and there is a possibility that riskier banks choose to select smaller amounts of capital. This implies that there may be a case where the normative capital requirement where riskier banks hold higher capital cannot be satisfied under the Precommitment Approach. Owing to this concern, we examine a general framework of the original approach, where the regulator is viewed as offering incentive compatible contracts that consist of both the level of capital and the penalty rate, and see if the normative capital holding is fulfilled.

The paper is organised as follows. In the next section, we briefly review the Precommitment Approach and see that in some cases it may not be possible to reveal each bank's riskiness by observing how much capital it will decide to hold. In Section 3, we develop a model from the perspective of mechanism design whereby the regulator designs a menu of contracts. We then examine under different scenarios whether the regulator could achieve the norm where riskier banks decide to hold higher level of capital. Finally, Section 4 concludes the paper.

2. Outline of the Precommitment Approach

In this section, we briefly review the model set forth by Kupiec and O'Brien (1995, hereafter K&O), who first proposed the Precommitment Approach. We will examine the case where monetary fines are used as means of penalty, and see how the fines work by letting banks hold optimal levels of capital, according to the innate qualities of the assets in their trading accounts[1].

[1] At this point, it is necessary to explain what K&O intend to say by "incentive compatible" in their approach. K&O stress since the regulator's objective is to let banks precommit levels of capital that satisfy the desired VaR capital coverage, it is incentive compatible as long as banks achieve the regulator's goal – incentive compatibility is allegedly satisfied if they hold the amount of capital that is equivalent with the desired VaR capital requirement. As we will see shortly, this can be seen by rearranging Equation 2-2 as follows: $F(-k) = \eta / \rho$. The left-hand side of this equation is the probability that losses exceed the level of capital, which represents the basis for a VaR capital requirement. In this interpretation of incentive compatibility, it does not matter whether or not banks with higher risk level hold higher capital – as long as they hold the right amount of capital that is consistent with the desired VaR capital requirement, they are regarded incentive compatible with the regulator's objective. We feel this interpretation rather

First, the net return of assets in their trading accounts is denoted by Δr, which follows the density function, $dF(\Delta r)$, and banks hold capital equivalent to *k*. In the model, there are two cost factors: one is the cost associated with raising capital, and the other is the expected cost of penalty. The penalty is imposed if the actual net loss exceeds the precommitted amount, i.e. if the net return is lower than –*k*, then the penalty is imposed. Assuming that the penalty is imposed proportional to the excess loss, the total cost function is written as follows.

$$C(k, \rho) = \eta k - \rho \int_{-\infty}^{-k} (\Delta r + k) dF(\Delta r) \tag{2-1}$$

where η is the marginal cost of capital, and ρ is the penalty rate. The first term represents the cost of raising capital and the second term shows the total expected cost of penalty. Taking the first derivative with respect to *k*, we have

$$\frac{\partial C(k, \rho)}{\partial k} = \eta - \rho F(-k) = 0. \tag{2-2}$$

Given the rate of penalty, banks choose their optimal levels of capital which satisfy Equation 2-2.

Although K&O do not go beyond this point, let us extend the model in such a way that it incorporates the riskiness of banks[2]. Suppose now that there exist two types of banks:

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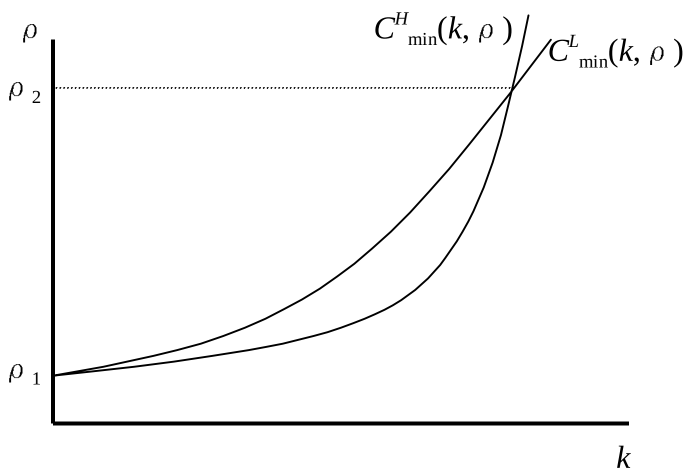
unique. Generally speaking, incentive compatibility may not be an instrument which assures consistency with the principal's objective. There may be a case where capital requirement is consistent with the principal's objective, which nevertheless does not satisfy incentive compatibility constraints.

[2] To be more precise, we take the riskiness of banks as exogenous. This may contradict with what K&O maintain. The underlying idea of the Precommitment Approach claims that banks, after being offered a penalty rate, would either commit capital, adjust risk, or do both in order to satisfy the first-order condition.

banks with more risky assets (hereafter, we call them "H-type banks") whose density function is denoted by $dF^H(\Delta r)$, and those with less risky assets (hereafter, "L-type banks") whose density function is denoted by $dF^L(\Delta r)$. We assume the variance of $dF^H(\Delta r)$ is larger than that of $dF^L(\Delta r)$. Then, we can imagine one example of the minimum cost curves, for H-type and L-type banks, on which the first-order condition is always satisfied, as in Figure 2-1.

(Figure 2-1) One Example of Minimum Cost Curve for High-risk and Low-risk Banks



$C^H_{\min}(k,\rho)$ is the minimum cost curve for H-type banks, and $C^L_{\min}(k,\rho)$ is the minimum cost curve for L-type banks. The curves show the following relationship: the higher penalty rate the regulator offers, the higher the capital requirement is for banks to satisfy the first-order condition. The figure also generalises the case where H-type banks have a less steep curve when k is low, while they face a steeper curve when k is high. This is due to the following reason. When k is low (i.e. close to the mean of the density function), an

Here, the riskiness is taken as an endogenous strategy for the banks. Nonetheless, if we take both the risk adjustment and capital holding as endogenous variables, banks do not have any preference ordering among the pairs of these variables as long as they satisfy the first-order condition. Then there may not be an incentive for banks to "separate" – they can be pooled by choosing the same pair. Consequently, the regulator may not need to identify the risk characteristics of banks.

additional increase in the penalty rate requires H-type banks to add more capital than L-type banks to retain the first-order condition, because the magnitude of changes in the density function per 1-unit increase in capital level is less for H-type banks, whose variance is larger, than the magnitude of changes for L-type banks. On the contrary, when *k* is high (i.e. close to the tail of the density function), we can imagine the case where an additional increase in the penalty rate requires L-type banks to add more capital than H-type banks to re-establish the first-order condition. This is because the magnitude of changes in its density function per 1-unit increase in capital level is less for L-type banks. We now have two different situations as follows.

(i) If the regulator charges a penalty rate higher than ρ_2, then L-type banks choose to hold higher levels of capital.

(ii) If the regulator charges $\rho \in [\rho_1, \rho_2]$, then H-type banks choose to hold higher levels of capital.

What we have seen is summarised as follows. K&O[3] assume that the regulator, without knowing the banks' riskiness, can let banks reveal their riskiness by charging the unique penalty rate, because each bank, given the penalty rate, voluntarily chooses the level of capital which minimises the total cost. They further claim that the choice of capital level is incentive compatible for every bank. For the regulator, without knowing where the minimum cost curves lie, it is not possible to assess the riskiness of banks, just by observing the levels of capital, i.e. there are cases where high risk banks hold more capital, while in other cases, they choose to hold less capital.

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3 To be fair, their recent paper (Kupiec and O'Brien (1997)) mentions the importance of information for the regulator to assess the risk characteristics of banks.

In this situation, we are not sure whether the regulator can overcome the private information, i.e. the riskiness of each bank, just by penalising at the uniform rate. We will next suggest a general model in which the regulator offers contracts which consist of the level of capital and the penalty rate, and lets banks self-select a contract among them, enabling the regulator to assess the riskiness of each bank correctly. We will see how we could satisfy the normative requirement where high-risk banks choose to hold higher levels of capital whereas low-risk banks choose to hold lower levels of capital.

3. The Model

The following model is designed to see if the regulator could reveal the banks' riskiness by offering them a menu of contracts and letting each of them self-select one from the menu. There are two observations we are interested in. First, we would like to see how incentive compatibility can be satisfied in both the Precommitment Approach and the model presented below. Second, we would like to examine in two models if the normative standard of capital requirement, whereby banks with riskier assets choose to hold higher levels of capital than those with less risky assets, is fulfilled.

3.1 Setup of the Model

There are two different players in the game: the regulator and the banks. The banks are categorised according to the innate qualities of the assets in their trading accounts. For simplicity, we assume there are two types of banks, namely "H-type" for a bank with high-risk assets and "L-type" for a bank with low-risk assets. What we mean by high-risk is that the bank's portfolio consists of more risky (larger variance) assets. These types are private information, i.e. the banks know their own types while the regulator does not know *ex ante* which bank belongs to which type. One may argue, however, that the regulator can obtain each bank's type through monitoring or from the records of on-site supervision. Nevertheless, we assume that most of the assets in the trading accounts are held short term, and banks can form the portfolios with different levels of riskiness, so that the information concerning the riskiness of a portfolio at the time of on-site supervision may not be valid for a long time; hence there is a rationale to assume that the regulator is not informed about the types. Note again what we are concerned with here is the quality of the banks' assets in their *trading accounts*. It may not be appropriate to extend the same interpretation to the assets in their banking accounts. As these assets are held for much longer periods, the validity of the information obtained through monitoring lasts longer, so that the scope for private information is much more limited.

Next, let us explain the sequence of events in the model. There are three periods in the game, and in each period the following events take place.

Period 0

1. Banks collect 1-unit of deposit whose rate of interest is normalised to 0. The deposit has to be paid back to depositors at the end of the game (i.e. at Period 2).
2. They then invest the money in financial assets.

Period 1

1. The regulator offers a menu of contracts which consist of different levels of capital requirement and penalty rates corresponding to each level of capital requirement.
2. Banks choose a contract from the menu. For them, accepting a contract means that they hold $k_i \in (0,1)$ (i = H, L) as capital.

Period 2

1. The return on investment, $\tilde{r}$, is realised.
2. If the return fails to achieve the precommitted level, the regulator penalises the bank.

Let the return on investment be a stochastic variable in the range of $[r^-, r^+]$, and it follows a density function, $dF(\tilde{r})$. We denote the return on investment by $dF_H(\tilde{r})$ for an H-type bank and $dF_L(\tilde{r})$ for an L-type bank. We assume the variance of $dF_H(\tilde{r})$ is larger than that of $dF_L(\tilde{r})$, but otherwise we will not assume any specific shape of distribution functions[4].

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[4] We believe this grasps one aspect of K&O who are critical to such simplifying assumptions as first-order / second-order stochastic dominance.

The regulator penalises the bank if the net loss from the investment, $-(\tilde{r}-1)$, exceeds the precommitted value k_i; hence the penalty is imposed if $1-k_i \geq \tilde{r}$. Let the penalty rate be denoted by p_i (i = H, L), so that the amount of penalty is $p_i \times [(1-k_i)-\tilde{r}]$.

We analyse three different cases according to the relative size of the cumulative density[5].

Case 1: $F_H(1-k_i) \geq F_L(1-k_i)$ for $k_i \in (0,1)$

The cumulative density for H-type is always larger than the one for L-type[6].

Case 2: $F_H(1-k_i) \geq F_L(1-k_i)$ for k_i close to 0

$F_H(1-k_i) < F_L(1-k_i)$ for k_i close to 1

The cumulative density for H-type is larger when the level of capital is close to 0, whereas it is smaller when the level of capital is close to 1.

Case 3: $F_H(1-k_i) \leq F_L(1-k_i)$ for k_i close to 0

$F_H(1-k_i) > F_L(1-k_i)$ for k_i close to 1

The cumulative density for H-type is smaller when the level of capital is close to 0, whereas it is larger when the level of capital is close to 1.[7]

(Bank's Cost Function)

We now write the bank's cost function as follows.

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[5] Following three cases may not cover all the possibilities – as the bank portfolio becomes more complex, the shape of distribution becomes more complex as well, and the cumulative densities for H-type and L-type may intersect repeatedly. Still, the fundamental idea developed below can be applied to any complex cases.

[6] Note that the opposite case where the cumulative density for H-type is always smaller than the one for L-type does not exist.

[7] Note also that we have implicitly assumed that all these events from Case 1 to 3 take place in the feasible range for the level of capital holding.

$$C_H^H \equiv \int_{r^-}^{1-k_H} p_H[(1-k_H)-\tilde{r}]dF_H(\tilde{r}) + \eta\, k_H$$

where $C^{\,i}_{\,j}$ represents the cost function of the bank which has an innate riskiness of j and announces the riskiness i. The first term in this cost function is the expected cost of a penalty and the second term is the cost associated with raising capital equivalent to k_H where η is the marginal cost of capital. Likewise, we can define the cost function of an L-type bank as follows.

$$C_L^L \equiv \int_{r^-}^{1-k_L} p_L[(1-k_L)-\tilde{r}]dF_L(\tilde{r}) + \eta\, k_L$$

3.2 Regulator's Programme

Let us now analyse how the regulator designs the mechanism in which the H-type and L-type banks reveal their types truthfully. The following programme is a starting point[8].

$$\min_{\begin{Bmatrix} k_L, k_H \\ p_L, p_H \end{Bmatrix}} \quad L = \delta \times \left[[k_L - (1 - F_L^{-1}(\frac{\eta}{p_L}))]^2 + [k_H - (1 - F_H^{-1}(\frac{\eta}{p_H}))]^2 \right] + (1-\delta) \times \max(0, k_L - k_H) \qquad where \quad k_L \neq k_H$$

$$\begin{aligned} C_H^H \quad &= \quad \int_{r^-}^{1-k_H} p_H[(1-k_H)-\tilde{r}]dF_H(\tilde{r}) + \eta\, k_H \\ &\leq \quad \int_{r^-}^{1-k_L} p_L[(1-k_L)-\tilde{r}]dF_H(\tilde{r}) + \eta\, k_L \quad \equiv \quad C_H^L \end{aligned} \qquad (\mathrm{IC_H})$$

$$\begin{aligned} C_L^L \quad &= \quad \int_{r^-}^{1-k_L} p_L[(1-k_L)-\tilde{r}]dF_L(\tilde{r}) + \eta\, k_L \\ &\leq \quad \int_{r^-}^{1-k_H} p_H[(1-k_H)-\tilde{r}]dF_L(\tilde{r}) + \eta\, k_H \quad \equiv \quad C_L^H \end{aligned} \qquad (\mathrm{IC_L})$$

8 Here we have neglected individual rationality constraints for H-type and L-type by simply assuming that the regulator will not offer contracts which exceed the reservation level of cost for both types.

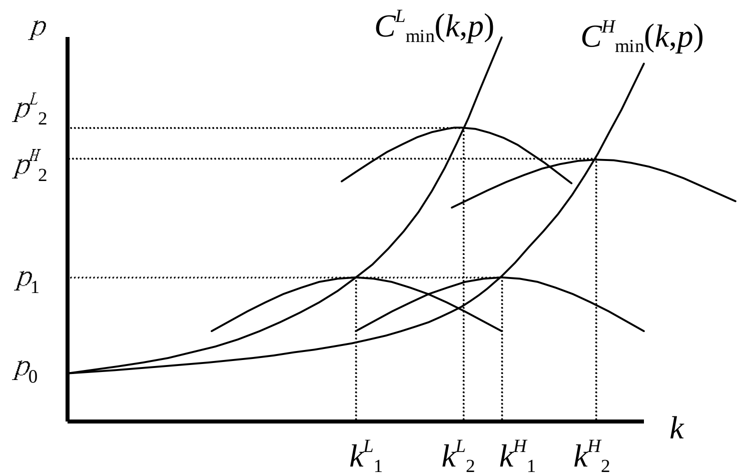
The loss function of the regulator consists of both the deviation of capital holding from the level specified by the first-order condition, and the difference of capital holding between banks with different risk levels. The term in the parenthesis following δ represents any capital holding that is not equivalent with the optimal level is regarded costly for the regulator. This applies to both L-type and H-type. The term following $(1-\delta)$ shows that the regulator is willing to let high-risk banks hold more capital. As long as high-risk banks hold more capital, the regulator does not incur any loss. This is consistent with the norm where the level of capital holding increases with riskiness.

Two inequalities following the regulator's objective function are called "incentive compatibility constraints" for H-type and L-type. We denote them by (IC_H) and (IC_L) respectively. These constraints guarantee that each type will select the contract that is designed by the regulator to be chosen by the banks of the same type. By choosing the wrong contract, the bank will suffer from higher cost. We take any pair of contracts which satisfy the incentive compatible constraints as one of a number of possible solutions.

Case 1: $F_H(1-k_i) \geq F_L(1-k_i)$ For $k_i \in (0,1)$

In this case, the minimum cost curve, where the first-order condition is satisfied, for H-type is always below the curve for L-type (see Figure 3-1).

(Figure 3-1) Minimum Cost Curve: Case 1



In this figure, we have also depicted the "iso-cost curve," where the total cost remains constant, as reverse U-shaped function. The curvature of the iso-cost curve is easily checked. The slope of the curve is always 0, when it crosses the minimum cost curve. This is due to the fact that, in case of H-type,

$$\left.\frac{dp}{dk}\right|_{C=const.} = \frac{F_H(1-k_H)-\eta}{\int_{r^-}^{1-k_H}[(1-k_H)-\tilde{r}]\,dF_H(\tilde{r})}$$

is 0 whenever the first-order condition is satisfied. Next, we check the marginal cost. Additional holding of capital has two different channels through which it will influence the total cost. First, it will reduce the range of $\tilde{r}$, in which the penalty is imposed (*penalty cost saving effect*), so the more capital the bank holds, the less expected cost it will incur. Second, more capital holding means the total cost of raising capital increases (*capital cost effect*). On the right-hand side of the minimum cost curve, the iso-cost curve is downward sloping because the marginal cost is positive. In other words, the capital cost effect exceeds the penalty cost saving effect, so that the more capital the bank holds, the more costly it is;

hence, in order to retain the same level of cost, the penalty rate needs to be reduced. On the left-hand side of the minimum cost curve, the iso-cost curve is upward sloping because the marginal cost is negative. In other words, the penalty cost saving effect exceeds the capital cost effect, so that the more capital the bank holds, the less costly it is; hence, in order to retain the same level of cost, the penalty rate needs to be raised.

Here, the menu of contracts can be incentive compatible. One example of the menu is depicted in Figure 3-1. If the regulator provides (k_2^L, p_2^L) and (k_2^H, p_2^H), L-type will choose the former and H-type will choose the latter. They minimise the loss function of the regulator, i.e. the menu identifies the level of capital holding which satisfies the first-order condition and H-type is offered a higher level of capital. They also satisfy incentive compatibility, namely that

$$\int_{r^-}^{1-k_2^H} p_2^H[(1-k_2^H)-\tilde{r}]dF_H(\tilde{r})+\eta\, k_2^H \quad < \quad \int_{r^-}^{1-k_2^L} p_2^L[(1-k_2^L)-\tilde{r}]dF_H(\tilde{r})+\eta\, k_2^L$$

for an H-type bank and

$$\int_{r^-}^{1-k_2^L} p_2^L[(1-k_2^L)-\tilde{r}]dF_L(\tilde{r})+\eta\, k_2^L \quad < \quad \int_{r^-}^{1-k_2^H} p_2^H[(1-k_2^H)-\tilde{r}]dF_L(\tilde{r})+\eta\, k_2^H$$

for an L-type bank.

At the same time, the regulator offering the unique penalty rate also guarantees incentive compatibility as well as it minimises the loss function. To see this point, suppose the regulator offers p_1 in Figure 3-1. The pairs of (k_1^L, p_1) and (k_1^H, p_1) are incentive compatible, namely that

$$\int_{r^-}^{1-k_1^H} p_1[(1-k_1^H)-\tilde{r}]dF_H(\tilde{r})+\eta\, k_1^H \quad < \quad \int_{r^-}^{1-k_1^L} p_1[(1-k_1^L)-\tilde{r}]dF_H(\tilde{r})+\eta\, k_1^L$$

for an H-type bank and

$$\int_{r^-}^{1-k_1^L} p_1[(1-k_1^L)-\tilde{r}]dF_L(\tilde{r})+\eta\, k_1^L \quad < \quad \int_{r^-}^{1-k_1^H} p_1[(1-k_1^H)-\tilde{r}]dF_L(\tilde{r})+\eta\, k_1^H$$

for an L-type bank.

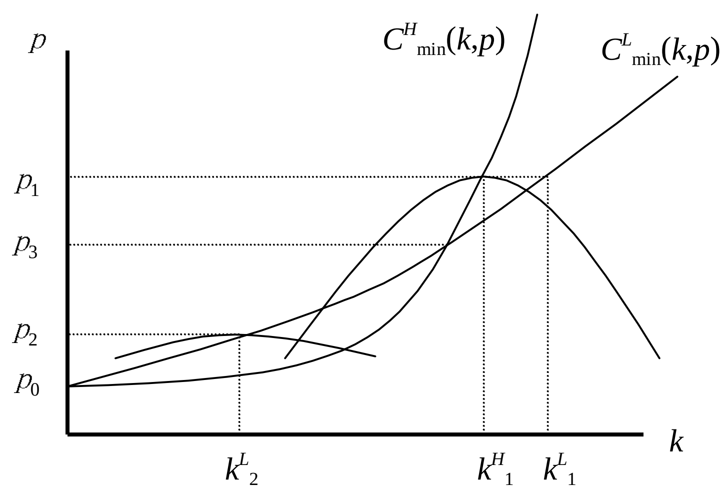
Because our model and the original approach satisfy both incentive compatibility and the fact that the riskier banks hold more capital, it looks the menu of contracts with different penalty rates may not be necessary – as long as the single penalty rate is offered by the regulator, the regulator's objective is fulfilled[9].

Case 2: $F_H(1-k_i) \geq F_L(1-k_i)$ for k_i close to 0

$F_H(1-k_i) < F_L(1-k_i)$ for k_i close to 1

Next case we are interested in is that the minimum cost curves intersect at $k > 0$ (see Figure 3-2).

(Figure 3-2) Minimum Cost Curve: Case 2



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[9] This observation implies that the Precommitment Approach is a special case of our model where $p^L = p^H$, i.e. the penalty rates offered to L-type and H-type are identical.

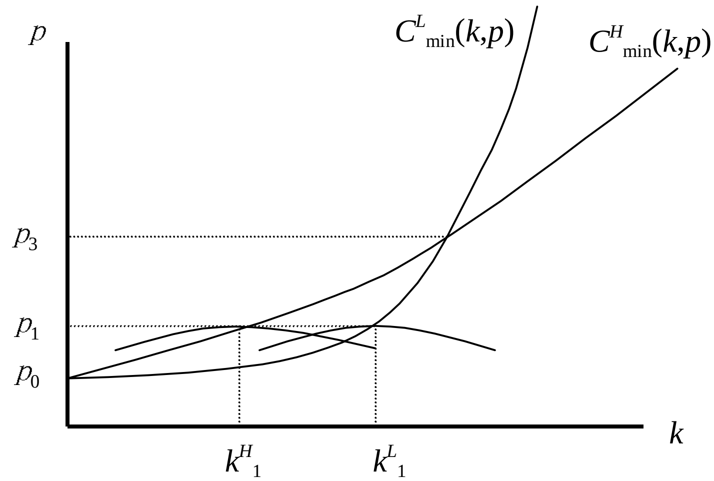
In the Precommitment Approach, any penalty rate which lies between p_0 and p_3 will derive the same result as in Case 1, but the problem arises once the penalty rate above p_3 is imposed. Here, the regulator cannot achieve its objective any more – although the capital levels chosen by the banks are incentive compatible, the regulator incurs an additional loss by letting L-type hold more capital than H-type. Our approach, on the other hand, may be able to overcome this problem. Suppose in Figure 3-2 the regulator offers two contracts, (k_2^L, p_2) and (k_1^H, p_1). It is indeed the case that L-type chooses the former and H-type chooses the latter (incentive compatibility is satisfied). Moreover, the regulator achieves its objective by minimising the loss, because an additional loss is not incurred as long as H-type chooses to hold more capital than L-type. We therefore conclude that there are two alternatives to modify the Precommitment Approach in this case. First, the regulator collects necessary information concerning the bank's risk characteristics to make sure that it will not impose the penalty rate above p_3. Any penalty rate between p_0 and p_3 will achieve its objective and the regulator will be able to assess each bank's riskiness by observing the level of capital on the basis that the more capital the bank chooses to hold, the riskier it is. Second, the regulator again collects necessary information on the bank's riskiness and provide banks with two contracts with different penalty rate. The point to stress is that either of the two alternatives cannot be achieved unless the regulator is involved in extensive activities associated with information gathering of the bank's risk characteristics.

Case 3: $F_H(1-k_i) \le F_L(1-k_i)$ for k_i close to 0

$F_H(1-k_i) > F_L(1-k_i)$ for k_i close to 1

Finally, we have the case opposite to Case 2 (see Figure 3-3).

(Figure 3-3) Minimum Cost Curve: Case 3



Again, in the Precommitment Approach, any penalty rate above p_3 will derive the same result as in Case 1, but $p \in (p_0, p_3)$ must be avoided. Unfortunately, our approach may not be able to overcome this caveat either. Any pairs of contracts, one of which deals with the penalty rate below p_3, cannot achieve the regulator's objective, because they let H-type hold less capital. Thus, in order to achieve the normative capital requirement, two contracts have to be offered with the penalty rates above p_3, but then, the regulator's objective can also be achieved by offering the single penalty rate as in the Precommitment Approach, under the condition that the regulator knows p_3, the penalty rate where the two minimum cost curves intersect. Perhaps, it would be simpler to rely on the single penalty rate above p_3, in which case incentive compatibility is automatically satisfied, rather than designing the menu of contracts where the regulator needs to make sure that incentive compatibility is satisfied.

4. Conclusion

In this paper, we developed a model from the perspective of mechanism design, and saw that in some cases, the penalty also plays an important role in fulfilling the norm whereby riskier banks hold more capital than less risky ones. Let us summarise our argument.

In the original framework of the Precommitment Approach, the regulator can allegedly reveal each bank's riskiness by offering a unique penalty rate. Nonetheless, the appropriate level of capital for each bank depends on the bank's private information such as the shape of the density function of its investment return. Thus, it is not sure whether riskier banks always choose to hold more capital than less risky ones.

We then developed a model of mechanism design in which the regulator offers a menu of contracts that consists of levels of capital and corresponding penalty rates. We found that the regulator can implement incentive compatible contracts in which banks will voluntarily separate themselves from those with other levels of riskiness. We examined three cases. First, if the cumulative density for H-type is always greater than the one for L-type, then both the original framework and our approach achieve the regulator's objective: the level of capital holding is equivalent with the amount specified by the first-order condition and also it increases as the bank's riskiness goes up. In this case, it would probably be easier for the regulator to implement the original approach rather than setting out contracts with different penalty rates. Second, we examined the case where the cumulative density for H-type is greater than the one for L-type for small amounts of capital, whereas it is smaller for large amounts of capital. In this case, our model may be able to achieve the regulator's objective. On the contrary, there is a range within which the penalty rate should fall into in the original approach; otherwise, the regulator's objective is not thoroughly fulfilled in the sense that incentive compatibility is satisfied whereas the normative capital requirement cannot be achieved. Third, we examined the case where the cumulative density for H-type is smaller than the one for L-type for small amounts of capital, whereas it is greater for large amounts of capital. In this case, neither approach achieves the regulator's objective as long as either one or two penalty rates take the value where the cumulative density for H-type is smaller. In order to avoid this, the penalty rate must be set in the range where the cumulative density for H-type is larger; then both the original model and ours achieve the regulator's objective. In this case, it would probably be easier, as in the first case, to implement the original approach.

We saw both the original setting in the Precommitment Approach and our approach based on the mechanism design have a certain limit to establish the best result as specified in the regulator's objective function. Here, the key element is how much information the regulator need access to in order to assess the risk characteristics of the banks. In their recent paper, Kupiec and O'Brien (1997) also mention the information needs for the regulator to develop the incentive compatible regulation. It is left for future task to examine how much information is necessary for the regulator and to what extent there may be a limit to the banks to disclose their riskiness truthfully.

Lastly, let us briefly make a few remarks. First, as we have just described, incentive compatible contracts cannot be provided unless the regulator obtains various pieces of information. In this sense, the incentive compatible regulation will not replace the traditional role of the regulator as an *ex ante* monitor of banks – the provision of incentive compatible contracts and the monitoring by the regulator can be complementary. Second, it has been suggested that public disclosure (i.e. whenever the actual loss exceeds the precommitted value, the regulator informs the market of the fact) will replace the regulator's penalty. This might be feasible if market participants are well aware of the information from which they can assess others' riskiness, and if they can impose a penalty in such a way that the premium imposed in the market satisfies incentive compatibility.

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