THE KOREAN ECONOMIC REVIEW
Volume 14, Number 2, Winter 1998

ON AN ASSISTED BUYBACK SCHEME OF NORTH KOREAN DEBT : A STRATEGIC ANALYSIS

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The objective of this paper is to consider an assisted buyback scheme of North Korean debt and to generate the conditions that may lead to a mutually beneficial policy prescription. This paper argues that a mutually beneficial assisted buyback may arise if (1) the unification cost is substantial (2) the relative benefit from the reforms to status quo is greater than or equal to one and (3) the intrinsic probability of collapse of the current North Korean debt is reasonably high. Given that the conditions (1) and (2) are satisfied, the instability of the current North Korean regime invites the assisted buyback. With the assisted buyback, the hesitant North can start reforms. Hence, a crisis in the North facilitates the introduction of reforms via the assisted buyback by the South. Notice that the current secondary debt market price does not play any significant role in determining the assisted buyback decision by the South. Even if the current debt market price were high, the assisted buyback scheme could be a welfare-improving policy for the South as long as the above conditions are satisfied.

JEL Classification: F34, P52
Keywords: Assisted Buyback, Secondary Debt Market Price,
Unification Cost, Probability of Collapse

I. PRELIMINARY REMARKS

As North Korea (or the North will be used interchangeably) suffered from a

Received for publication: Mar. 3 1998. *Revision accepted:* Apr. 2, 1998.

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food shortage in 1995, the economic crisis in the North undoubtedly deepened. Moreover, as of 1994, the total amount of North Korean (defaulted) external debt was about 10 billion US dollars and reached approximately 50% of its 1994 GNP. Yet, it is uncertain when the North will undertake reforms to cure the ills of its conomy. Given the limited options are available for South Korea (or the South), this paper introduces a descriptive model of a specific aid scheme that can induce the North to start reforms.

1.1. Situation Analysis

(This subsection draws heavily from Hong and Lee(1997) and Lee(1997A).)

Since the mid 80's, North Korea has been unable to service its external debt and thus been excluded from the international capital market. As the historical evidence of sovereign debt defaults and lending resumptions demonstrates, defaulted nations are unable to re-borrow from international capital market unless they make settlements with the existing creditors.[1] However, as the North has suffered from the economic crisis and a shortage of foreign reserves, it is unlikely and unable to make settlements with its existing creditors in the near future (without foreign assistance or debt forgiveness).

The North Korean debt has recently been traded at a discounted(average) price of between 0.2 to 0.4 dollars per a dollar of the its debt as of the period between 1994 and 1996. The North Korean debt is classified as "exotic," (as in case of Vietnam) meaning that it is information-elastic and insensitive to economic fundamentals.[2] Any "political" news concerning or affecting the status (or the outlook) of the current North Korean regime may influence its price substantially. For example, the U.S. decision to lift sanctions against the North or the introduction of a reform package by the current North Korean regime would affect its discounted price significantly rather than changes of macroeconomic indicators.

South Korea, on the other hand, has to prepare for uncertainty regarding North Korea. This uncertainty mainly concerns with the unification cost and a possibility of reforms. In the event of collapse of the current North Korean regime, the South may have to finance substantial unification cost. This paper provides an abstract definition of unification cost: the cost of adjustment and restructuring to transform the centrally planned North into a market-oriented economy. Regarding the North Korean defaulted debt, the South may have to assume full responsibility in the event of unification.[3] Then this should be counted as a component of the

from the helpful comments of two anonymous referees. Of course, the usual disclaimer applies.

[1] Cole, Dow, and English(1991) reported some stylized features from historical evidence of sovereign debt defaults and lending resumptions. They observed that even after very long periods of defaults, in one case exceeding 50 years, countries have had to settle old debts before obtaining new loans.

[2] See Emerging Market Debt Research on North Korea(1995).

unification cost. This component may be trivial compared to the unification cost as a whole. However, at this point, the issue of North Korean debt may be a starting point to reduce the unification cost.

1.2. Main Results

This paper introduces an assisted buyback (aid) scheme and to specify the conditions that may lead to a mutually beneficial policy prescription. An assisted buyback scheme refers to a practice that a donor (the South) provides funds required for the repurchase of a debtor's (the North) external debt at its current discounted price. On the other hand, a self-financed buyback scheme refers to a devise where a defaulted debtor uses its own resources to repurchase its own debt. This paper assumes that the North does not have enough funds to engage in a self-financed buyback scheme.

This paper argues that an assisted buyback scheme can be mutually beneficial if (1) the (fixed) unification cost is substantial (2) the ratio of benefits from reforms to status quo is greater than or equal to one and (3) the intrinsic probability of collapse of the current North Korean regime is sufficiently high. It is reasonable to assume that the conditions (1) and (2) are satisfied. Then the intrinsic instability of the current North Korean regime can invite the assisted buyback and induces the North to undertake reforms. This implies that a crisis may facilitate the introduction of structural reforms. A crisis in the North may be costly to the South which bears substantial unification cost in case of collapse. Then a crisis in the North can induce the South to provide the assisted buyback. Now that this scheme wipes out the external debt, the North can undertake reforms as the probability of reform success is increased. The assisted buyback that wipes out the North Korean debt can be regarded as a settlement which must be a prerequisite for the foreign capital inflow. The assisted buyback scheme makes the hesitant North to start reforms.

This paper draws some interesting intuitions. First, the timing of assisted buyback must be contingent on the instability status of the current North Korean regime given that the unification cost is substantial and the ratio of benefits from reforms to status quo is greater than or equal to 1. Since a mutually assisted buyback may arise when the North is unstable, this indicates that the beneficial intervention has to occur at that point. Second, the our result does not depend on the current secondary debt market price of North Korean debt. A low current debt market price of North Korea does not automatically lead to the intervention by the South. Even if the secondary debt market price were high, the assisted buyback scheme could be a welfare-improving policy for the South if the above-mentioned conditions are satisfied.

[3] We provide justification for this assumption later in Section 2.

1.3. Organization

The organization of this paper is as follows. Section \ref{model} develops a simple model to derive a mutually beneficial condition of an assisted buyback. This section also provides some justifications for underlying assumptions and offers a policy prescription for the South. The final section contains the discussion of future research directions.

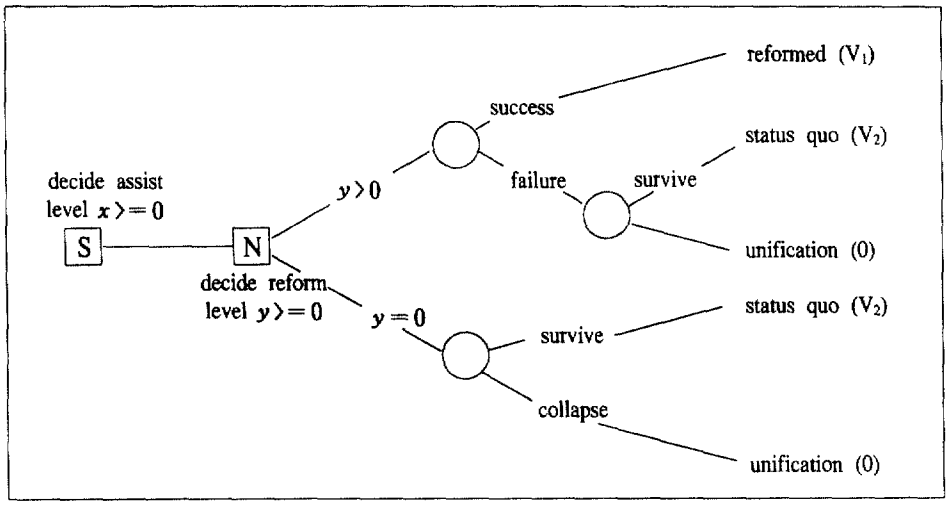
Ⅱ. A SIMPLE MODEL

This section presents a simple one-period two-stages game-theoretic model to provide a policy prescription for the South. Its focus is on the (possible) interaction between two risk-neutral parties (the North and South) under an uncertain environment.[4] The sequence of events is described as follows:[5]

Sequence of Events

1. Prior to the realization of the status of the current North Korean regime, South Korea decides whether it engages in the assisted buyback scheme or not.
2. After the action taken by the South, North Korea chooses an adjustment effort level for reforms before the realization of its status.

[Figure 1] Sequence of Events



[4] Even though other surrounding nations may affect strategic decisions of the North, we concentrate strategic interactions between the two Koreas for the sake of simplicity. See the final section for this point.

[5] See Lee (1997A) for a different sequence of events.

Let State 1 and State 2 be the events of reform success (with probability, q) and reforms failure (with probability, $(1-q)$), respectively. In the event of reform success, the North fully repays its debt while does not repay any in the other event. State 2 is subdivided into the events of survival (status quo) and the collapse of the current North Korean regime.

North Korean reforms deserve some comments. Hence, we start with our definition of North Korean reforms.

Definition 2.1 (Reform) Reforms in this paper refer to the programs that North Korea adopts in order to transform itself from a centrally planned to a market-oriented economy.[6]

We introduce the probability of reform success such that it depends on adjustment effort of the current North Korean regime and the level of assisted buyback. Dornbusch(1990) claimed that the arrival of aid may be the occasion for reform since it creates a sufficient probability of reform success. Similarly, an assisted buyback may substitute for costly reform effort that the North can take. The settlement of the defaulted debt with the existing creditors is the precondition for foreign capital inflow.[7]

Notice that sufficient foreign reserve is essential for the reform success. An assisted buyback scheme may act as the settlement, and, in return, it may induce foreign capital inflow (even though we do not explicitly model this process) and help the North to start reforms. In order to derive an explicit solution, we adopt the following functional form for the probability of reform success:

$$q(x,\ y)=\frac{y}{(1-x)+y} \tag{2.1}$$

y represents the North's adjustment effort for reform and x indicates the level of assisted buyback by the South. Notice that two choice variables $(x,\ y)$ are normalized in terms of maximum values. Note that by this particular function, the maximum reform success probability without any assistance is $\frac{1}{2}$. It can be set to any value between 0 and 1 by multiplying the function by a proper constant. The point is that it is essential to acquire external assistance in order to secure the reform success.

Let $\bar{p}$ be the collapse probability of the current North Korean regime prior to an adjustment effort for reforms. We assume that $\bar{p}$ is exogenously given. This probability indicates the intrinsic characteristics of the current North Korean

[6] In this paper, reform programs may include privatization, introduction of bankruptcy laws, removal of price rationing, liberalization of trade and capital market, etc.

[7] See Cole, Dow, and English for this point(1991).

regime (or here we call the intrinsic probability of collapse of the current North Korean regime). Once it fails to reform itself, the probability of collapse is given by

$$p(y) = \bar{p} + (1 - \bar{p})y. \tag{2.2}$$

The premise for (2.2) is the adjustment efforts spent in unsuccessful reforms would accelerate the collapse of the current North Korean regime. Considering the current state of the North Korean regime, it is important to realize that North Korean reforms are irreversible. Once "nvestments" in reforms are made in such programs, it is difficult to reverse the course.[8] According to our definition, reforms refer to the introduction of liberalization policies into a society where the two generations of extreme control and dynastic ideology prevail. Once the current regime made commitment in reform policies, that commitment made by such a regime cannot be easily reversed. It is possible to observe some frictions on the course but unlikely to reverse its course. For example, Russia does not reverse its course despite of its strong opposition. Another reason for the irreversible nature of such reform program is the external influences. Once the current regime undertakes reforms, the foreign assistance and coordination with foreign nations may play an important role in determining the success of reforms. As it departs from its course of liberalization, it may risk its own survival.

Another important assumption is that the current North Korean regime collapse directly results in the unification.[9] Due to the intrinsic characteristic of the current North Korean regime, this paper will interchangeably refers to the event of unification as the event of collapse of the current regime. The current regime with the continuation of dynastic tradition based on the ideology of *Juche'* has ruled the North since 1945. In case of collapse, it is possible for other faction to replace the current regime but the new regime may not last long since no faction can replace its dynastic tradition and ideology that sustains the North so far.

Following from the precedence of international law and the recent experience of German unification, we state Assumption 1.

Assumption 1: In the event of peaceful unification (due to the collapse of the current North Korean regime), South Korea assumes full responsibility of the North's external debt.[10]

Notice that this assumption stems from "peaceful" unification. Even though the South (presumably) can negotiate the amount that it must pay following the

[8] Reform attempts may lead to a rise to a collapse of the current regime. See (2.2).

[9] Of course, we are aware of other possibilities. However, this is a strong candidate for the reasons specified below.

[10] However, after the unification following the American Civil War in 1865, the North (Lincoln Administration) did not obey the debts issued by the South. This exception was possible since the unification was achieved thru the costly conflict between two regions (war).

collapse, it is most likely to honor international precedence given the nature of the South.[11]

We assume that the secondary debt market is efficient. With Assumption 1, the secondary price of North Korean $q+(1-q)p$. Actions taken by the North and South can influence the average price of North Korean debt; South Korea can engage in an assisted buyback scheme and North Korea can take costly actions for reform success.[12]

Finally, some may argue that this one-period two-stages setup may induce to suffer from the time-inconsistency problem.

For example, suppose that an equilibrium from this model is a positive level of assisted buyback of North Korean debt. Then after the North receives a positive level of assisted buyback, then the North may be able to re-borrow from the rest of the world and intentionally default on its debt, once again. The South may be in the position to finance the buyback, once again. However, in this paper, the North chooses its reform effort prior to the realization of its status given its benefit-cost. Without aid, no reform effort is undertaken by the North. A positive level of reform effort will be taken with a positive level of assisted buyback. As indicated before, the irreversible nature of reforms along with (2.2) cures the time-inconsistency problem. Notice that once the North engages in reform attempt, the success/failure depends on nature. If it fails, then the probability of collapse increases due to (2.2). Hence, it boils down to whether the North starts reforms or not. The role of the assisted buyback here is to make reforms attractive for the North so that it can start reforms. This notion is implicitly based on the fact that the foreign capital will flow in with the positive level of reform effort. The positive level of reform efforts implies that the North attempts to transform itself to a market-oriented economy. In this case, as the external dependency becomes increasingly important, the policy coordination with foreign nations can be crucial to the success of reforms. As a result, "intentional default" is highly unlikely, and time-inconsistency problem may not pose a threat to the assisted buyback scheme as long as the reforms are irreversible.

In order to derive a solution, we solve backward, and hence start with the analysis of North Korea.

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[11] Recently, the South received IMF assistance due to balance of payments deficits. The possibility of moratorium was on the air but it is the last alternative given the high trade dependency ratio and free capital flow. The South can attempt to obtain partial forgiveness. However, Assumption 1 is most likely as long as the South wants to belong to the world capital market.

[12] On the stark contrast to Bulow and Rogoff(1988), Cohen(1991) reported that a change in the amounts of debt does not change discounted (secondary) prices of debt. However, in our setup, the discounted price of the North Korean debt may be increased of reform success. As it will be specified below, an assisted buyback scheme by the South may start the North's reform and thus increases its discounted price substantially.

2.1. North Korea

This subsection describes the North Korea's choice by utilizing the probability of reform success, (2.1). Notice that the adjustment effort for reform success must be costly for the current North Korean regime. Instead of incorporating a cost function for reform effort explicitly, this paper expresses the adjustment effort in terms of the increments of collapse probability. In solving this problem, the North is to select y given x. Hence, the North maximizes the following expected payoff function with respect to y:

$$MAX_{y\in[0,1]}\ U_N = qV_1 + (1-q)(1-p)V_2. \tag{2.3}$$

U_N indicates the current North Korean regime's expected payoff. Denote V_1 the current North Korean regime's payoffs from reform success and V_2, the payoffs from status quo. Also we assume that in case of collapse the North's payoff is zero.

The solution to the North Korea's problem is,

$$y=\begin{cases} 1 & \text{if } x\geq 1-\left[\dfrac{V_1}{V_2}\dfrac{1}{1-\bar{p}}\right] \\ 0 & \text{otherwise.} \end{cases} \tag{2.4}$$

Suppose that the ratio of returns from the reform to status quo, $\frac{V_1}{V_2}$ is one, then y is 1 if x is greater than or equal to $\frac{1-2\bar{p}}{1-\bar{p}}$. Then as $\bar{p}$ increases, the range that the North will supply the reform effort (1 in this case) increases for given x. That is, as the intrinsic probability of collapse increases, the North is likely to turn to reforms for given amount of aid. If the the current North Korean regime is not to enthusiastic toward reforms, it is because the intrinsic probability of collapse is not too high.

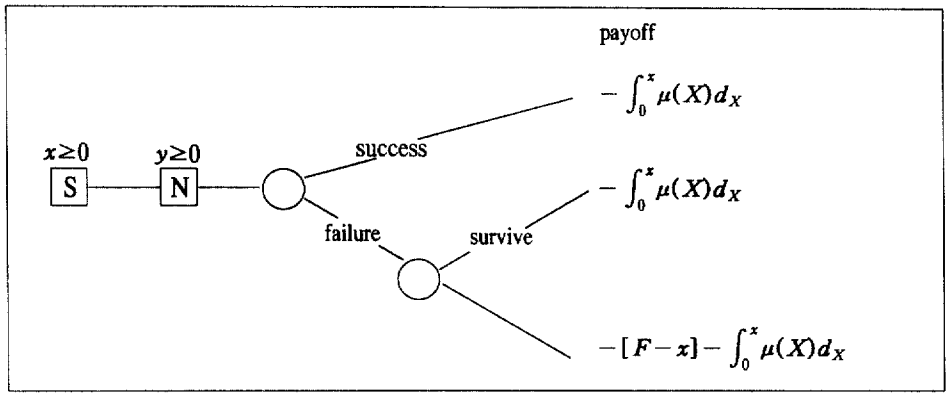
2.2. South Korea

This subsection analyzes the choice of South Korea. In choosing \$x\$, the South should take into account how this choice will affect the North's reform effort level.

The expected payoff for the risk-neutral South is,

$$Max_{x\in[0,1]}\ U_s$$
$$= -[1-q(x,\ y(x))]p(y(x))[\equiv(x)-x] - \int_0^x \mu(X)dX, \tag{2.5}$$

[Figure 2] Payoff of the South



where $\mu(X)$ and $y(x)$ are, respectively, the discounted price of North Korean debt and the North's reaction to the South's decision x. It is given by

$$\mu(x) = [1-q(x,y))]p(y(x)) + q(x,y(x)) \tag{2.6}$$
$$= p(y(x)) + q(x,y(x))[1-p(y(x))]. \tag{2.7}$$

Again, all the variables here are expressed in terms of debt overhang of the North.

$\Xi(x)$ represents the unification cost function. We will simply assume that the unification cost is a constant greater than the amount of the North's debt.

$$\Xi(x) \equiv F > 1 \tag{2.8}$$

Notice that the unification cost, F, can be reduced by the possible action taken (assisted buyback) of the South. The remaining fixed component stresses the inability to reduce a certain portion of unification cost by the South.

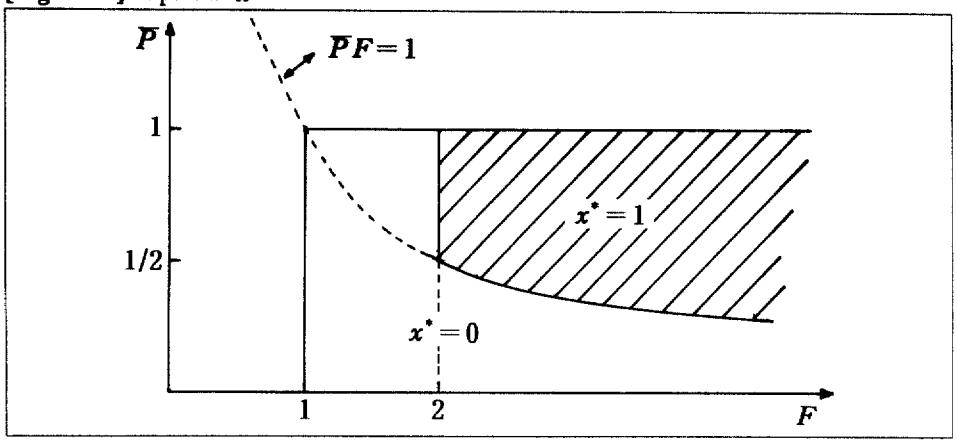
Substituting (2.6) and (2.8) into (2.5), we obtain

$$U_S = -[1-q(x,y(x))]p(y(x))[F-x] - \int_0^x [1-1(X,y(x))]p(y(x)) + q(X,y(x))dX \tag{2.9}$$

This leads to the following Proposition:

Suppose that V_1 is no less than V_2. Then a mutually beneficial assisted buyback arise if the optimal strategy, x^* for the South is

[Figure 3] Optimal x^*



$$x^* = \begin{cases} 1 & \text{if } \bar{p}F > 1 \text{ and } F \geq 2 \\ 0 & \text{if } \bar{p}F \leq 1 \text{ and } F > -2 \\ 0 & \text{if } F < 2. \end{cases} \tag{2.10}$$

Proof of Proposition: See Appendix.

The above Proposition can be illustrated in a two-dimensional plane $(F, \bar{p})$ as in Figure 3.

In Figure 3, the shaded area indicates the region of $x^*=1$. When $\bar{p}$ is greater than $\frac{1}{2}$ and F is greater than equal to 2, x^* (the optimal strategy for the South) is always 1. This implies that if F is greater than or equal to 2, the intrinsic probability of the current North Korean regime determines the aid provision decision by the South. Recognize that F can only affect the South but $\bar{p}$ simultaneously influences the North and South. The following Corollary states how a crisis in the North can invite the assisted buyback.

Corollary 2.3 *Given that the unification cost is reasonably high* $(F \geq 2)$*, the crisis in the North invites the mutually beneficial assisted buyback and thus reform attempt.*

Proof: Appendix and Figure 3.

Even though the most of literature fails to agree on the precise amount of unification cost, they agree that the unification cost can be substantial. Utilizing this notion, we assume that F is reasonably high (greater than or equal to 2). Then, the intrinsic instability of the current North Korean regime (the value of $\bar{p}$) determines the existence of a mutually assisted buyback. "The aid provision" by the South induces the North to undertake reforms due to a crisis. As the probability of collapse of the current regime becomes high, the reforms become an attractive option for the North. This implies that a crisis in the current North

Korean regime may facilitate the introduction of reforms in the North as the South has an incentive to provide aid. Drazen and Grilli(1990) provided the similar intuition in a different setup. They claimed that economic reforms are likely to succeed when an economy suffers from a crisis. They used a war of attrition model to derive this result. In their paper, crises may be necessary to induce structural change because economic participants believe that someone else can be forced to bear the burden. In normal periods, such structural changes are resisted, however, the periods of crises facilitate the introduction of economic reforms. However, our paper argues that the crises in the North may be too costly for the South to do nothing. In return, "the provision of aid" induces the North to undertake reforms to escape from its own crisis.

Both Proposition and Corollary provide a valuable policy prescription for the South. First, the timing of assisted buyback must be contingent on the instability status of the current North Korean regime (intrinsic probability of collapse, $\bar{p}$) given that the unification cost is substantial; the mutually beneficial intervention by the South has to occur when the current North Korean regime suffers from a crisis. Second, our result does not depend on the current secondary debt market price of North Korean debt. A low current debt market price of North Korea does not automatically lead to the intervention by the South. Even if the secondary debt market price were high, the assisted buyback scheme could be a welfare-improving policy for the South if and only if the above-mentioned conditions are met. Finally, as $\bar{p}$ and the unification cost is important in determining the intervention decision, the South needs to allocate greater resources in calculating $\bar{p}$ and the unification cost.

Ⅲ. POSTSCRIPT

Instead of restating the main results derived from this paper, we reexamine a North Korean reform possibility and explore lirections of future research. First, we explore an interesting possibility: what if the current North Korean regime may not be interested in reforms regardless of the provision of foreign aid? This question contradicts (2.1). Some authors claimed that foreign aid does not affect its probability of reform success.[13] Becker and Becker(1997) pointed out that economic aid tends to postpone rather than to contribute the reforms. This depends largely upon the type of an aid package. For example, the food aid provided by the South may not contribute to increase the probability of reform success even though the food aid might have marginally increased the probability of survival of the current regime. Norland(1997) predicted that

"the current regime may not undertake any significant reform (before some rapprochement with South Korea) even though has recently begun some modest

[13] See Dornbusch(1990) for a different perspective.

and hesitant reforms."

An assisted buyback scheme that fully wipes out the defaulted North Korean debts actually acts as the settlement of defaulted North Korean debts. Since the settlement is the prerequisite for new loans, this creates an opportunity for potential investors to reinvest into the North.[14]

This may substantially increase the probability of reform success. Therefore, this scheme helps the North to start reforms.

We now turn to the directions for future research. First, we can examine whether preplay communication between the North and South can arise or not. The investigation of this possibility is relevant to the policy implications since this model can determine the condition of cooperation between the two hostile parties. The previous section demonstrates that an assisted buyback scheme can be mutually beneficial to both parties (North and South) if $\overline{p}$ is reasonably high and the unification cost is ubstantial. If this is the case, then it seems reasonable that replay communication between the two parties can arise before they take any action. A cheap talk model asserts that when preferences are similar, preplay communication between two parties may be possible and beneficial. Notice that the North has an incentive to undertake reforms and the South has interests in provision of aid, then this setting is suitable for a cheap talk.

Second, the aid provision to North Korea can be modelled as a war of attrition game between the South and U.S.[15] Under this setup, three parties (the North, South, and U.S.) play a strategic game. The South and U.S. play a war of attrition game in provision of aid to the North. Notice that both parties' preferences may be generally similar; both parties try to avoid the collapse. However, in case of the collapse, the costs bearing may be different between the two parties due to the unification cost. Then the timing of the aid provision is the choice variable for the South and U.S. since the probability of collapse of the current North Korean regime may increase due to the delay of the aid. The two relevant factors determine the timing of aid provision are the availability of foreign reserve and the costs that may arise from the collapse of the current North Korean regime.

Finally, this paper does not consider an investment scheme (the purchase of North Korean debt via the secondary debt market). Two main reasons may be given for this omission. Since the purpose of this paper is to examine the aid policy by the South Korean government, this paper does not look into a particular aid policy that may lead to a mutually beneficial outcome rather than

[14] When the North invited potential investors to a newly established special economic zone, one of the main reasons that they were reluctant to invest was the unsettlement of the existing defaulted debt. See Emerging Market Debt Research on North Korea(1995).

[15] Alesina and Drazen(1991) developed a war of attrition game to explain why the delay of stabilization policies may occur. Lee(1997B) also considers a similar setup to explain why the aid provision often take time.

the aid policy based purely on the humanitarian reason. Second, as long as it is concerned with the investment scheme, then it should be left to the South Korean private firms (rather than the South Korean government) to produce efficient outcome. Hence, this is beyond the scope of this paper. In the future, however, when political tension between the South and North is removed (and thus it is allowed for private firms to directly and freely invest into the North), the investment scheme as well as debt-equity swap can be extensively analyzed.

APPENDIX

Since $p \equiv p(y) = p + [1-p]y$,

$$U_N = \frac{y}{1-x+y} V_1 + \frac{1-x}{1-x+y}[1-p(y)]V_2 \tag{.11}$$

$$= \frac{y}{1-x+y} V_1 + \frac{1-x}{1-x+y}[1-\bar{p}][1-y]V_2.$$

$$\frac{\partial}{\partial} U_N = \frac{V_1 - [1-\bar{p}][1-x]V_2}{1-x+y} - \frac{yV_1 - [1-\bar{p}][1-x][1-y]V_2}{[1-x+y]^2} \tag{.12}$$

$$= \frac{1-x}{[1-x+y]^2}[V_1 - 2V_2 - 2\bar{p}V_2 - xV_2 + \bar{p}xV_2]$$

$$= \frac{1-x}{[1-x+y]^2}[V_1 - [1-\bar{p}][2-x]V_2].$$

Hence $\frac{\partial}{\partial y} U_N > 0$ if and only if

$$x > 2 - \left[\frac{V_1}{V_2}\frac{1}{1-\bar{p}}\right]$$

Therefore, if we denote by $y(x)$ the North's optimal reaction,

$$y(x) = \begin{cases} 1 & \text{if } x > 2-v \\ 0 & \text{otherwise,} \end{cases} \tag{.13}$$

where, we denote,

$$v \equiv \frac{V_1}{[1-\bar{p}]V_2}.$$

From, (2.1) (2.2) and (.13), we have

$$p(y(x)) = \begin{cases} \dfrac{1}{2-x} & \text{if } x > 2-v \\ p & \text{otherwise,} \end{cases} \tag{.14}$$

and

$$q(x, y(x)) = \begin{cases} \dfrac{1}{2-x} & \text{if } x > 2-v \\ 0 & \text{otherwise.} \end{cases} \tag{.15}$$

Substituting (.14) and (.15) into (.13), we get,

$$U_S = -[1-q(x, y(x))]p(y(x))[F-x] - \tag{.16}$$

$$\int_0^x [1-q(X, y(x))]p(y(x)) + q(X, y(x))dX$$

$$= \begin{cases} -F + \dfrac{x-F}{x-2} & \text{if } x > 2-v \\ -pF & \text{if } x \le 2-v \end{cases}$$

Hence,

$$\frac{\partial}{\partial x} U_S = \begin{cases} \frac{1}{2-x}\left[\frac{x-F}{x-2} - 1\right] & \text{if } x > 2-v \\ 0 & \text{if } x \leq 2-v. \end{cases}$$

Therefore, if $x > 2-v$,

$$\frac{\partial}{\partial x} U_S \geq 0 \Leftrightarrow F \geq 2.$$

Denote

$$g(x) \equiv -F + \frac{x-F}{x-2}.$$

Then it follows that the maximum attainable payoff for the South is,

$$U_S^* = \begin{cases} \text{Max}\{g(1), -pF\} & \text{if } F \geq 2 \\ \text{Max}\{g([2-v]^+), -pF\} & \text{if } F < 2. \end{cases}$$

where, $g(x^+)$ means the value of the right-hand limit of g at x.

Thus when $F \geq 2$, an optimal solution x^* of the South is

$$x^* = \begin{cases} 1 & \text{if } g(1) = -1 \geq -\bar{p}F \\ 0, & \text{othersise.} \end{cases}$$

Note that if $F < 2$, the optimum decision level x^* is not well-defined when $g(2-v) \geq -\bar{p}F$. However, it is easy to show that $g((2-v)) \geq -\bar{p}F$ if and only if

$$\bar{p} \geq 1 - \frac{1}{\left[1 - \frac{V_2}{V_1}\right]F + \frac{2V_2}{V_1}},$$

which implies, in turn, that

$$2 - v = 2 - \frac{V_1}{[1-\bar{p}]V_2} \leq 2 - \frac{V_1}{\left[\frac{1}{1-\frac{V2}{V_1}}F + \frac{2V_2}{V_1}\right]V_2} \leq -\left[\frac{V_1}{V_2} - 1\right]F < 0.$$

Thus the maximum value of U_S is never attained in the region $x > 2-v$ when $F < 2$. In other words, $x^* = 0$ if $F < 2$.

From these observations, we can summarize the optimal strategy of the South as follows:

$$x^* = \begin{cases} 1 & \text{if } pF > 1 \text{ and } F > 2 \\ 0 & \text{if } pF > 1 \text{ and } F \leq 2 \\ 0 & \text{if } F < 2. \end{cases}$$

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