THE KOREAN ECONOMIC REVIEW
Volume 11, Number 1, December 1995.

INTERNATIONAL COORDINATIONS AS A CREDIBLE COMMITMENT DEVICE OF DOMESTIC POLICY

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This paper claims that international monetary coordination eliminates credibility problem of domestic policy. Assuming that coordinative governments are the first movers, the paper shows that the international coordination is beneficial not only because externalities of non-coordinative policies are internalized, but also because government credibility problem is resolved. The coordination itself provides an environment in which the government credibility problem is completely removed.

I. INTRODUCTION

Most of the literature seems to agree that there exist gains from international monetary policy coordination. The reason is that by coordination countries can internalize the externalities that non-coordinated policies generate.

In a 1985 paper, however, Rogoff showed that increased international monetary coordination may actually be counterproductive. He introduces strategic interactions not only between governments but also between government and wage setters. The idea behind this result is based on the following logic: Governments may want to exploit the trade-off relationship between output and inflation to keep employment high when a negative shock occurs. But the governments' temptation to do so is checked by the concern about inflation under a Nash non-coordinative regime because increasing money supply to neutralize the negative shock depreciates the home currency and increases CPI through higher price of imported goods. Governments are interested in keeping inflation rate low as well. But the coordination between two countries removes the constraints on the expansionary monetary policy because they can keep their exchange rate fixed through bilateral expansion. Then governments don't have to worry as much about the side-effect of the expansionary monetary policy. Thus they have stronger incentives to expand under a coordinative regime than in a non-coordinative one. With rational expectations, wage setters recognize the governments' incentives to expand and resulting high inflation. The wage setters therefore set wages at

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es to expand and resulting high inflation. The wage setters therefore set wages at a sufficiently high level in the first place so that at the high wage rate government's marginal benefit from expanding money is exactly offset by marginal cost of inflation. The result is government's poor performance in keeping output level high only with higher inflation than in the non-coordinative regime.

In essence the Rogoff's model suggests that the coordination between countries may exacerbate the credibility problem between government and private sector.

In fact if wage setters are the first mover as in the Rogoff's paper, it is not very surprising that a rational expectations model predicts an 'inflation bias'. The Rogoff's result is an extension of Barro and Gorden (1983), Kydland and Prescott (1977)'s government credibility problem into a two country model. In their papers government's lack of credible commitment device along with rational expectations produces a time-consistent 'inflation bias'.

It should be pointed out that the validity of the Rogoff's result critically depends on the assumption about 'who moves first' from the game theoretic point of view. The whole picture can significantly change if coordinating governments are the first movers. If governments take actions first and they can reach a binding agreement on a policy coordination, the coordination itself becomes a credible commitment device for the monetary policy. In this case shifting to a coordinative regime generates unambiguously higher welfare not only by internalizing the externality but also eliminating the inflation bias of the non-coordinative regime. Thus the gains from international policy coordination may be bigger than traditionally has been thought to be.

To explore the idea this paper adopts first-moving-government assumption and shows an additional source of gains from international policy coordination; reduced inflation bias by solving the credibility problem between government and private sector. No possibility of counterproductive coordination is also shown.

II. MODEL

Consider the following model. There are two symmetric countries. Foreign variables are denoted by a star superscript.

$$m-p=\phi\, y-\beta i \qquad m^*-p^*=\phi\ y^*-\beta i^* \tag{1}$$

$$y=-\lambda(p-e-p)^*-\sigma i \qquad y^*=-\lambda(p^*+e-p)-\sigma i^* \tag{2}$$

$$p^c=\frac{1}{2}p+\frac{1}{2}(p^*+e) \qquad p^{c*}=\frac{1}{2}p^*+\frac{1}{2}(p-e) \tag{3}$$

$$i=i^* \tag{4}$$

$$p = \overline{w} + \alpha y + v \qquad p^* = \overline{w^*} + \alpha y^* + v \tag{5}$$

$$\overline{w} = (1-k)w + kw_{-1} \qquad \overline{w^*} = (1-k)w^* + kw^*_{-1} \tag{6}$$

$$w = p^c \qquad w^* = p^{c*} \tag{7}$$

$$\pi = p^c - p^c_{-1} \qquad \pi^* = p^{c*} - p^{c*}_{-1} \tag{8}$$

where m = nominal money balances
p = price level
y = output
i = interest rate
e = exchange rate defined as the domestic currency price of a unit of foreign currency
p^c = consumer price index
π = inflation rate
$\overline{w}$ = average nominal wage rate
w = wage rate for those who contract in current period
w_{-1} = wage rate for those who contracted in last period
k = portion of wage setters who contracted in last period
v = global real shock assumed positive
All parameters are positive

Subscript '-1' denotes last period. All variables are expressed in the log form. We restrict the analysis to a stationary solution ($e_t = e_{t+1}$, $p_t = p_{t+1}$), and therefore assume that real and nominal interest rates are equal.

Equation (1) is a standard LM curve expressing money demand as a function of real output and interest rate. The IS curve is given in equation (2), where demand for output is a function of the interest rate and the real exchange rate. Equation (3) defines a consumer price index as an average prices of domestic goods and imports. Equation (4) states the interest parity condition. Capital is perfectly mobile across countries and domestic and foreign bonds are perfect substitutes. The economy's aggregate supply schedule is given by equation (5). Two-periods labor contract is assumed so that government policy is effective in a rational expectations model. α measures the slope of the aggregate supply curve (or inverse of price elasticity of supply). Note that a positive v means a negative real shock by construction. In equation (6) average wage rate is defined. For simplicity assume k=1/2. Equation (7) states that current wage setters index the wage rate to CPI. Equation (8) defines inflation rate. Note that the two countries are linked through the perfect capital mobility, real exchange rate, and CPI influenced by price of imports.

Our model is a little bit differs from Rogoff's. Table 1 compares the two models. Although the present model is not as elaborate as Rogoff's it is sufficient to convey key ideas. From our simplified model we can explicitly use money supply as a control variable unlike in Rogoff's model, in which domestic price is treated as the control variable for simplification.

[Table 1] Comparison to Rogoff's Model

	Rogoff's Model	Present Model
Wage	Base wage set one period in advance is partially adjusted by current CPI	Two period wage contract where current wage is fully indexed to current CPI
Aggregate supply	function of price and wage rate	function of price and average wage rate
Money supply	real money stock is measured by nominal money stock divided by CPI	real money stock is measured by nominal money stock divided by domestic price
Goods demand	function of real exchange rate, real interest rate, and domestic and foreign real income	function of real exchange rate and real interest rate

Reduced form solutions of above system are given by equations (9) to (13). We present equations for only domestic variables since similar equations hold for the foreign country due to the symmetricity.

$$y=\beta_1 m+\beta_2 m^*-\frac{1}{2}\beta_1(w+w_{-1})-\frac{1}{2}\beta_2(w^*+w^*_{-1})-(\beta_1+\beta_2)v \tag{9}$$

$$p=\alpha\beta_1 m+\alpha\beta_2 m^*+\frac{1}{2}(1-\alpha\beta_1)(w+w_{-1})-\frac{1}{2}\alpha\beta_2(w^*+w^*_{-1})+(1-r_1-r_2)v \tag{10}$$

$$p^c=r_1 m+r_2 m^*-\frac{1}{2}(r_1-1)(w+w_{-1})-\frac{1}{2}r_2(w^*+w^*_{-1})+(1-r_1-r_2)v \tag{11}$$

$$\pi=r_1 m+r_2 m^*-\frac{1}{2}(r_1-1)(w+w_{-1})-\frac{1}{2}r_2(w^*+w^*_{-1})+(1-r_1-r_2)v-p^c_{-1} \tag{12}$$

$$e=(\alpha+0.5\lambda)(\beta_1-\beta_2)(m-m^*)$$
$$+\frac{1}{2}\{1-(\alpha+0.5\lambda)(\beta_1-\beta_2)\}\{(w-w_{-1})-(w^*-w^*_{-1})\} \tag{13}$$

where

$$\beta_1 = \frac{1}{2\theta}\left(1 + \frac{\theta}{\alpha+\phi}\right) > 0$$

$$\beta_2 = \frac{1}{2\theta}\left(1 - \frac{\theta}{\alpha+\phi}\right) < 0$$

$$\theta = \alpha + \phi + \beta/\sigma > 0$$

$$r_1 = \alpha\beta_1 + \frac{1}{4\lambda}(\beta_1 - \beta_2) > 0$$

$$r_2 = \alpha\beta_2 - \frac{1}{4\lambda}(\beta_1 - \beta_2) < 0$$

Note

$$1 - \alpha\beta_1 = \frac{\alpha\beta + 2\phi\sigma\theta}{2\sigma\theta(\alpha+\phi)}$$

$$1 - r_1 - r_2 = \frac{\theta - \alpha}{\theta} > 0$$

$$1 - \alpha\beta_1 > -\alpha\beta_2$$

Equation (9) says that increasing money supply has a negative effect on foreign country's output while positive effect on own country. The negative transmission effect of money supply on foreign output comes from 'interest rate channel' (Canzoneri and Gray (1985)): decreasing domestic interest rate by monetary expansion induces capital outflows to foreign country which pushes up the foreign exchange rate. Higher exchange rate then makes foreign goods more expensive relative to domestic goods and so demand for the foreign goods decreases.

Domestic output decreases as the average wage rate of home country increases, but foreign country's high wage rate increases home output because demand for foreign goods shifts to domestic ones due to high price of foreign goods. Note that the global shock, v, reduces output ($\beta_1 + \beta_2 > 0$).

Equation (10) says that home country's money supply, and wage rates of the two countries have positive effects on domestic price level, while foreign country's money supply has a negative effect ($\alpha\beta_2 < 0$). Higher domestic wage rate shifts up the aggregate supply curve given by equation (5), increasing the price level. Higher foreign wage rate also increases the domestic price level because demand shifts to domestic goods due to higher foreign price. Expansion of foreign money

supply decreases domestic price through reduced demand for domestic goods, which comes from appreciation of domestic currency. The real shock, v, pushes up the domestic price.

As shown in equation (11) home country's CPI (and inflation rate in equation (12)) increases with money supply and v. The effect of foreign money supply on domestic CPI, r_2, is negative. When foreign money supply increases there are two factors that move in opposite directions to affect the domestic CPI; increasing foreign price level, and decreasing domestic price and exchange rate (appreciation of domestic currency). In our model the latter dominates the former, resulting in net negative effect of foreign monetary expansion on domestic CPI.

Domestic (average) wage rates has an ambiguous effects on the domestic CPI. When domestic wage increases, both domestic and foreign prices increase (shown in equation (10)) while foreign exchange rate, e, may decrease (domestic currency may appreciate as shown in equation (13)). Whether the foreign exchange rate increases or decrease depends on the relative distances LM and IS curves shift with increasing domestic price level. If LM curve shifts up more than IS shifts down, domestic interest rate increases, inducing capital inflows and thus appreciation of domestic currency. Since the appreciation of the domestic currency could makes foreign goods cheaper, it is possible that the net effect of increasing wage results in lower CPI. Increasing foreign wage rate unambiguously increases the domestic CPI.

Equation (13) says that the foreign exchange rate is an increasing function of relative size of money supplies of the two countries. As mentioned earlier, the effect of increasing wage rate on the exchange rate depends on the relative distances IS and LM curves shift due to the increasing domestic price level induced by the increasing wage rate. One can show that the condition of positive effect on the exchange rate of wage rate, $1-(\alpha+\frac{1}{2}\lambda)(\beta_1-\beta_2)>0$, is a sufficient condition for $-\frac{1}{2}(r_1-1)>0$ in equation (11)[1]

It is assumed that each government minimizes its loss function which depends on deviations of own-country output and inflation from their desire levels.

$$L=(y-y_0)^2+\mu\pi^2 \tag{14}$$

$$L^*=(y^*-y^*_0)^2+\mu\pi^{*2} \tag{15}$$

y_0, y^*_0 are desired output levels and μ stands for the relative weight which government places on inflation stabilization versus output stabilization. Throughout

[1] $1-(\alpha+0.5\lambda)(\beta_1-\beta_2)>0 \Leftrightarrow \theta(1-2\lambda\phi)-2\lambda(\alpha+\phi)(\phi-\alpha)<0$ and $-(1/2)(r_1-1)>0 \Leftrightarrow \theta\ 1-2\lambda\phi<0$

the analysis assume that $y_0 = y^*_0$, $p^c_{-1} = p^{c*}_{-1}$, and $w_{-1} = w^*_{-1}$. The symmetricity greatly reduces the burden of algebraic calculations without affecting main results.

Ⅲ. NON-COORDINATION SOLUTION

Consider a non-coordination result first. The non-coordination result is a benchmark case against which two regimes of following sections are compared. In a non-coordinative regime, wage setters are assumed to be the first mover since the government does not have a credible commitment device for monetary policy. Although the government may announce a money supply target in advance to wage setting, the announcement is not credible.

To obtain a subgame perfect Nash equilibrium, we start with the government's problem. Given w, w^*, w_{-1}, w^*_{-1}, home government's problem is to minimize its loss function (14) subject to equations (9) and (13). The first order condition is given by

$$(y - y_0)\frac{\partial y}{\partial m} + \mu\pi\frac{\partial \pi}{\partial m} = 0 \tag{16}$$

From equation (16) one obtains home country's reaction function.

$$m = -\frac{1}{\beta_1^2 + \mu r_1^2}\left\{(\beta_1\beta_2 + \mu r_1 r_2)m^* - \frac{1}{2}(\beta_1^2 + \mu r_1^2 - \mu r_1)(w + w_{-1})\right.$$
$$\left. -\frac{1}{2}(\beta_1\beta_2 + \mu r_1 r_2)(w^* + w^*_{-1}) - \frac{1}{\theta}(\beta_1 - \mu r_1\theta + \alpha\mu r_1)v - \beta_1 y_0 - \mu r_1 p^c_{-1}\right\} \tag{17}$$

The reaction function says that home country's money supply is positively related to the foreign country's money supply. The reason of the positive relationship between the two countries' money supplies is that the home country's expansionary monetary policy becomes less costly as foreign money supply increases because the home country's currency does not depreciate as much as otherwise. Recall that depreciation of the home currency increases CPI.

Since countries act independently in the non-coordinative regime a government's temptation to expand money supply with a (negative) global shock is checked by the concern about the currency appreciation. It may be expected therefore that the monetary policy would be more expansionary in the coordinative regime. As will be shown later, in fact, the policy coordination between countries results in more expansionary monetary policy in Rogoff-type coordination. But our model in section Ⅴ will show that it is not necessarily the case.

The reaction function also shows that whether money supply should be increased or decreased with increasing wage rate depends on parameters. The increasing wage rate reduces output level and pushes up price. If government is more concern about the output level (inflation), it should increase (decrease) money supply at the expense of higher inflation (lower output).

Since the same argument applies to the real shock, v, the sign of the coefficient on v in the reaction function is also ambiguous.

Throughout the analysis assume that the coefficient on v in the reaction function is positive;

$$\beta_1 - \mu r_1 \theta + \alpha \mu r_1 > 0 \qquad \text{(A1)}^{2)}$$

The assumption says that economy in question is in a state where it is government's best interest to increase money supply in the presence of a (negative) real shock. The assumption requires that μ be not too big (If μ is sufficiently large, decreasing money supply should be the best action with a negative real shock).

The home money supply negatively reacts to the foreign wage rate because increasing foreign wage rate increases foreign price (thus domestic consumer price index) and domestic output as can be seen in equation (9). Neutralizing the foreign shock therefore requires home money supply to contract.

Similar equation holds for the foreign country. Solving the two reaction functions, one obtains uncoordinated money supply rule as a function of wage rate, economic shock, output target, and price level of last period.

$$m = \frac{0.5(\beta_1 + \alpha\mu r_1 - \theta\mu r_1)(w + w_{-1}) + (\beta_1 + \alpha\mu r_1 - \theta\mu r_1)v + \theta\beta_1 y_0 + \theta\mu r_1 p^c_{-1}}{\beta_1 + \alpha\mu r_1} \qquad (18)$$

Substituting the money supply rules of the two countries into (11) yields equation (19).

$$p^c = \frac{1}{\beta_1 + \alpha\mu r_1} \left\{ \frac{1}{2}\beta_1 (w + w_{-1}) + \beta_1 v + \alpha\beta_1 y_0 + \alpha\mu r_1 p^c_{-1} \right\} \qquad (19)$$

Now consider wage setters' problem. Understanding the above mechanism, wage setters set $w = p^c$ in the first place. Then the current wage rate is given by

$$w = \frac{\beta_1 w_{-1} + 2\beta_1 v + 2\alpha\beta_1 y_0 + 2\alpha\mu r_1 p^c_{-1}}{\beta_1 + 2\alpha\mu r_1} \qquad (20)$$

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2) $\beta_1 - \mu\theta r_1 + \alpha\mu r_1 > 0 \Leftrightarrow 2\lambda(\alpha + \phi + \theta)[1 - \alpha\mu(\theta - \alpha)] - \alpha\mu(\theta - \alpha) > 0$

Equilibrium wage rate is a increasing function of real shock, output target, CPI and wage rate of last period.

Plugging equation (20) to (18), one obtains equilibrium money supply in the non-coordinative regime.

$$m = \left\{ \frac{\beta_1 - \mu\theta r_1 + \alpha\mu r_1}{2A} \right\} w_{-1} + \left\{ \frac{\beta_1 - \mu\theta r_1 + \alpha\mu r_1}{A} \right\} v + \left\{ \frac{\lambda(\alpha+\theta)(\alpha+\phi+\theta)}{A} \right\} y_0 + \left\{ \frac{(\alpha+\theta)(\mu\theta+2\mu\alpha\lambda(\alpha+\phi+\theta))}{2A} \right\} p^c_{-1} \quad (21)$$

where

$$A \equiv \alpha\mu\theta + \lambda(1+2\alpha^2\mu)(\alpha+\phi+\theta) > 0$$

The equation (21) shows that the equilibrium money supply is positively related to wage rate and CPI of last period, current real shock, and output target.

Using (21) and (20) in Equations (9) and (12) yields the Nash non-coordination solution for output and inflation rate.

$$y = -\left\{ \frac{\mu\theta+2\mu\alpha\lambda(\alpha+\phi+\theta)}{2A} \right\} w_{-1} - \left\{ \frac{\mu\theta+2\mu\alpha\lambda(\alpha+\phi+\theta)}{A} \right\} v + \left\{ \frac{\lambda(\alpha+\phi+\theta)}{A} \right\} y_0 + \left\{ \frac{\mu\theta+2\mu\alpha\lambda(\alpha+\phi+\theta)}{2A} \right\} p^c_{-1} \quad (22)$$

$$\pi = \left\{ \frac{\lambda(\alpha+\phi+\theta)}{A} \right\} w_{-1} + \left\{ \frac{2\lambda(\alpha+\phi+\theta)}{A} \right\} v + \left\{ \frac{2\alpha\lambda(\alpha+\phi+\theta)}{A} \right\} y_0 - \left\{ \frac{\lambda(\alpha+\phi+\theta)}{A} \right\} p^c_{-1} \quad (23)$$

The welfare in the non-coordinative regime can be evaluated by loss function using (22) and (23).

$$L^{Nash} = (y^{Nash} - y_0) + \mu(\pi^{Nash})^2$$

IV. ROGOFF'S RESULT

Here we present the Rogoff's result that international monetary policy coordination can be counterproductive.

Consider following joint objective function for coordination.

$$MIN_{m,m^*} \quad L^J = \frac{1}{2}\{(y-y_0)^2 + \mu\pi^{*2}\} + \frac{1}{2}\{(y^*-y^*_0)^2 + \mu\pi^{*2}\} \quad (24)$$

In Rogoff it is assumed that wage setters take action before governments set a coordinated policy. The wage setters set wage rate at the first stage understanding government's minimization problem of the joint objective function. As in non-coordination case, we work backwards; starting with government problem.

From the first order conditions of the minimization problem, one obtains coordinated money supply schedule, given wage rate.

$$m = \frac{1}{1+\mu\alpha^2}\{\frac{1}{2}(1-\mu\alpha(\theta-\alpha))(w+w_{-1})+(1-\mu\alpha(\theta-\alpha))v$$

$$+\theta y_0+\mu\alpha\theta p^c_{-1}\} \tag{25}$$

Comparing coordinated money supply rule given by equation (25) with the non-coordinated money supply rule in equation (18), one can see that the governments have stronger incentives to expand money supply in the coordinative regime than in the non-coordinative regime[3], given a wage rate and a shock.

Substituting (25) into (11) yields equation (26).

$$p^c = \frac{1}{1+\mu\alpha^2}\left\{\frac{1}{2}(w+w_{-1})+v+\alpha y_0+\mu\alpha^2 p^c_{-1}\right\} \tag{26}$$

Comparison of (26) with (19) indicates that the consumer price index in the coordination regime is greater than that in the Nash regime, given a wage rate and a global shock.

Knowing equation (26), wage setters set $w=p^c$. Then equilibrium wage rate in the coordinative regime is given by equation (27).

$$w = \frac{1}{1+2\mu\alpha^2}\{w_{-1}+2v+2\alpha y_0+2\mu\alpha^2 p^c_{-1}\} \tag{27}$$

Substituting equation (27) into (25) yields equilibrium money supply in the coordinative regime.

$$m = \frac{1}{1+2\mu\alpha^2}\{(1-\mu\alpha(\theta-\alpha))w_{-1}+2(1-\mu\alpha(\theta-\alpha))v$$

$$+(\alpha+\theta)y_0+\mu\alpha(\alpha+\theta)p^c_{-1}\} \tag{28}$$

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[3] $\frac{1-\mu\alpha(\theta-\alpha)}{1+\mu\alpha^2}-\frac{\beta_1+\alpha\mu\gamma_1-\theta\mu\gamma_1}{\beta_1+\alpha\mu\gamma_1}=\frac{\mu\theta(\beta_1-\beta_2)}{4\lambda(1+\mu\alpha^2)(\beta_1+\alpha\mu\gamma_1)}$

Using equation (27) and (28) in equation (9) and (12) one obtains the coordination solution for output and inflation rate.

$$y = \frac{1}{1+2\mu\alpha^2}\{-\mu\alpha w_{-1} - 2\mu\alpha v - y_0 + \mu\alpha p^c_{-1}\} \tag{29}$$

$$\pi = \frac{1}{1+2\mu\alpha^2}\{w_{-1} + 2v + 2\alpha y_0 - p^c_{-1}\} \tag{30}$$

Let's compare equilibrium m, y, and π in the two regimes. For simplicity assume $w_{-1}=y_0=p^c_{-1}=0$, $v=1$. From equations (21) through (23), and (28) through (30) it can be shown that

$$m^{Nash} < m^{Rogoff} \tag{31}$$

$$y^{Nash} < y^{Rogoff} \tag{32}$$

$$\pi^{Nash} < \pi^{Rogoff} \tag{33}$$

The superscript 'Rogoff' refers to the coordinative regime where wage setters move first as assumed by Rogoff.

With presence of a (negative) real shock, international policy coordination results in more expansion of money supply, less loss in output level and higher inflation rate than non-coordination.

Now compare the loss functions of the two regimes.

$$L^{Nash} - L^{Rogoff} = (y^{Nash} - y_0)^2 + \mu(\pi^{Nash})^2 - (y^{Rogoff} - y_0)^2 - \mu(\pi^{Rogoff})^2$$

$$= \frac{\theta\mu^2\{\theta - 4\alpha\lambda(\alpha+\phi+\theta)(1+2\alpha^2\mu)\}}{(1+2\alpha^2\mu)^2\{\alpha\mu\theta + \lambda(1+2\alpha^2\mu)(\alpha+\phi+\theta)\}^2} \tag{34}$$

Expression (34) shows the possibility of counterproductive policy coordination[4]: the higher μ and/or λ, the more possible it becomes that $L^{Rogoff} > L^{Nash}$. The intuition behind the result is following; High μ implies high marginal cost of money expansion given other country's money supply in the non-coordinative regime. Since countries can reduce the marginal cost through a bilateral money expansion, the incentive to coordinate increases with μ. But rational wage setters understands the stronger government incentives in the coordinative regime, high μ ma-

[4] $L^{Rogoff} > L^{Nash} \Leftrightarrow \mu > \frac{(\alpha+\phi+\beta/\sigma) - 4\alpha\lambda(2\alpha+2\phi+\beta/\sigma)}{8\alpha^3\lambda(2\alpha+2\phi+\beta/\sigma)}$ or $\lambda > \frac{\alpha+\phi+\beta/\sigma}{4\alpha(1+2\alpha^2\mu)(2\alpha+2\phi+\beta/\sigma)}$

kes the credibility problem even worse.

V. CORDINATION AS A COMMITMENT DEVICE OF DOMESTIC MONETARY POLICY

Suppose two governments reach an agreement on monetary policy coordination and announce it before wage setters act. The international agreement on monetary policy may convince the wage setters that the announced monetary policy is credible. Then the coordination is beneficial not only because externalities of non-coordinative monetary policies are internalized, but also government credibility problem is resolved. The contrasting feature of the present model to Rogoff's is that the credibility problem is completely fixed through coordination rather than gets worse. In this framework this section shows that the policy coordination never can be counterproductive.

To obtain a subgame perfect equilibrium, we start from the second-mover's problem. Given m, m^*, wage setters set $w=p^e$, $w^*=p^{e*}$. By solving for w, w^* after setting $w=p^e$, $w^*=p^{e*}$ in equation (11) and corresponding equation for foreign country, one obtains wage setters' desired wage rate as function of m, m^*, and v.

$$w=\frac{2(\gamma_1^2+\gamma_1-\gamma_2^2)m+2\gamma_2 m^*-(\gamma_1^2-\gamma_2^2-1)w_{-1}-2\gamma_2 w^*_{-1}+2\{(1-\gamma_2)^2-\gamma_1^2\}v}{B} \quad (35)$$

$$w^*=\frac{2(\gamma_1^2+\gamma_1-\gamma_2^2)m^*+2\gamma_2 m-(\gamma_1^2-\gamma_2^2-1)w^*_{-1}-2\gamma_2 w_{-1}+2\{(1-\gamma_2)^2-\gamma_1^2\}v}{B} \quad (36)$$

where $B=(1+\gamma_1)^2-\gamma_2^2 > 0$

The wage rate is an increasing function of money supply, real shock and a decreasing function of foreign money supply. The reason that the wage falls with increasing foreign money supply is that appreciation of domestic currency (or depreciation of foreign currency) due to the foreign money expansion reduces the domestic CPI to which the wage is indexed.

Understanding that increasing money supply increases the wage rate and the increasing wage rate, in turn, reduces output, coordinating countries will take it into consideration in deciding money supplies. Note that this feature is not present in the non-coordinative regime nor in Rogoff-type coordinative regime because wage rate is set before government takes action in those regimes.

Using (35) and (36) in equation (9), output can be expressed as a function of government control variable, m, m^* and predetermined variables, w_{-1}, w^*_{-1}, and v.

$$y=\left\{\frac{\beta_1(1+\gamma_1)-\beta_2\gamma_2}{B}\right\}(m-w_{-1})+\left\{\frac{\beta_2(1+\gamma_1)-\beta_1\gamma_2}{B}\right\}(m^*-w^*_{-1})$$

$$-\left\{\frac{2(\beta_1+\beta_2)(1+\gamma_1-\gamma_2)}{B}\right\}v \tag{37}$$

Equation (37) says that output is positively related to money supply and negatively related to the real shock[5]. However, the effect of foreign money supply on the domestic output is ambiguous[6]. Note that in equation (9) the foreign money supply has unambiguously negative effect on domestic output. The possibility of a positive transmission of foreign money expansion to the domestic output in this coordinative regime comes from the fact that increasing m^* reduces w in equation (35), which increases the domestic output.

By the same way, using (35), (36) in equation (12) yields equation for inflation rate as function of government control variable, m, m^* and predetermined variables, w_{-1}, w^*_{-1}, and v.

$$\pi=2\left\{\frac{\gamma_1+\gamma_1^2-\gamma_2^2}{B}\right\}m+\left\{\frac{2\gamma_2}{B}\right\}m^*+\left\{\frac{1-\gamma_1^2-\gamma_2^2}{B}\right\}w_{-1}$$

$$-\left\{\frac{2\gamma_2}{B}\right\}w^*_{-1}+2\left\{\frac{1-\gamma_1-\gamma_2}{1+\gamma_1+\gamma_2}\right\}v-p^e_{-1} \tag{38}$$

Equation (38) shows that inflation rate is an increasing function of m and v[7], and a decreasing function of foreign money supply ($\gamma_2 < 0$). As in the section Ⅳ, assume that governments of the two countries minimize the joint loss function given by (24).

$$Min_{m,m^*} L^J=\frac{1}{2}\{(y-y_0)^2+\mu\pi^2\}+\frac{1}{2}\{(y^*-y^*_0)^2+\mu\pi^{*2}\} \tag{24}$$

From the first order conditions one obtains coordinated money supply schedules.

$$m = m^* = \frac{\{1-2\alpha\mu(\theta-\alpha)\}w_{-1}+2\{1-2\alpha\mu(\theta-\alpha)\}v+(\theta+\alpha)y_0+2\alpha\mu(\theta+\alpha)\}p^e_{-1}}{1+4\alpha\mu^2} \tag{39}$$

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[5] $\frac{\beta_1(1+\gamma_1)-\beta_2\gamma_2}{B} > 0$, $\frac{2(\beta_1+\beta_2)(1+\gamma_1-\gamma_2)}{B} > 0$

[6] $\beta_2(1+\gamma_1)-\beta_1\gamma_2 = \frac{\sigma-2\beta\mu\lambda}{4\sigma\theta\mu\lambda(\alpha+\phi)}\mu$

[7] $\gamma_1^2+\gamma_1-\gamma_2^2 = \gamma_1+\alpha(\beta_1+\beta_2)(\beta_1-\beta_2)+2(\beta_1-\beta_2)/4\lambda > 0$

$1-\gamma_1-\gamma_2 = (\theta-\alpha)/\theta > 0$

In equation (39) the effect of a negative real shock, v, on the equilibrium money supply is ambiguous even with the assumption (A1). This means that under a certain condition governments may reduce money supplies with presence of the negative real shock although they would have increased in non-coordinative or Rogoff-type coordinative regime.

Substituting (39) into equation (37) and (38) yields the equilibrium output and inflation rate.

$$y = \frac{-2\alpha\mu w_{-1} - 4\alpha\mu v + y_0 + 2\alpha\mu p^c_{-1}}{1+4\alpha\mu^2} \tag{40}$$

$$\pi = \frac{w_{-1} + 2v + 2\alpha y_0 - p^c_{-1}}{1+4\alpha\mu^2} \tag{41}$$

Now let's compare the coordination result with non-coordination result in section 3. Assume $w_{-1}=y_0=p^c_{-1}=0$, $v=1$ for simplicity. From equations (21) through (23), and (39) through (41) one can show that[8].

$$sign\,[m^{Nash} - m^{coordination}] = sign\,[2\alpha\lambda(\alpha+\phi)+\theta(2\alpha\lambda-1)] \tag{42}$$

$$sign\,[y^{Nash} - y^{coordination}] = sign\,[2\alpha\lambda(\alpha+\phi)+\theta(2\alpha\lambda-1)] \tag{43}$$

$$sign\,[\pi^{Nash} - \pi^{coordination}] = sign\,[2\alpha\lambda(\alpha+\phi)+\theta(2\alpha\lambda-1)] \tag{44}$$

The superscript 'coordination' refers to the coordinative regime where governments move first. Expression (42) through (44) says that money supply, output and inflation rate in the coordinative regime could be either greater or smaller than in the non-coordinative regime. This is a contrasting to Rogoff's result. In the Rogoff world, coordinative money supply, output and inflation rate are always greater than in the non-coordinative one. The different result of this section comes from that the coordination removes the credibility problem so that coordinating countries can weigh the benefit and cost of changing money supplies without any wage hike from the wage setters[9].

Expression (42) says that if λ is sufficiently small $m^{Nash} < m^{coordination}$. A possible

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[8] $2\alpha\lambda(\alpha+\phi)+\theta(2\alpha\lambda-1) > 0$ means

$$\alpha > \frac{-(4\lambda\phi+2\lambda\beta/\sigma-1)+\{(4\lambda\phi+2\lambda\beta/\sigma-1)^2+16\lambda(\phi+\beta/\sigma)\}^{1/2}}{8\lambda} \quad \text{or} \quad \lambda > \frac{\alpha+\phi+\beta/\sigma}{2\alpha(2\alpha+2\phi+\beta/\sigma)}$$

[9] Comparing the Rogoff's regime to the coordinative regime of this section, it can be shown that

$$m^{Rogoff} - m^{coordination}$$
$$y^{Rogoff} - y^{coordination}$$
$$\pi^{Rogoff} - \pi^{coordination}$$

explanation of this is that sufficiently small λ generates a positive spillover (in equation (37)) of one country's money supply to the other country's output level, and the externality is taken into consideration in the coordinative regime.

Under a (sufficient) condition, $\alpha\lambda > 1/2$, one can see that

$$m^{Nash} > m^{coordination}$$

$$y^{Nash} > y^{coordination}$$

$$\pi^{Nash} > \pi^{coordination}$$

This is an opposite result to Rogoff (expression (31)-(33)). Comparing non-coordinative, Rogoff-type coordinative and (first-moving-government) coordinative regime, the coordination regime is more contractionary (under the sufficient condition) and the Rogoff-type coordination is more expansionary than the coordinative regime.

Comparison of loss functions shows that there exists no possibility of counterproductive policy coordination.

$$L^{Nash} - L^{coordination}$$
$$=(y^{Nash}-y_0)^2+\mu(\pi^{Nash})^2-(y^{coordination}-y_0)^2-\mu(\pi^{coordination})^2$$
$$=\frac{\theta^2\mu^2+(\alpha+\phi+\theta)\{4\alpha^3\mu^2\lambda^2+4\alpha^2\mu^2\lambda^2\phi+4\alpha\mu^2\lambda\theta(\alpha\lambda-1)\}}{A^2(1+4\alpha\mu^2)} > 0 \qquad (45)^{10}$$

where $A \equiv \alpha\mu\theta+\lambda(1+2\alpha^2)(\alpha+\phi+\theta) > 0$

VI. CONCLUDING REMARKS

We have demonstrated that the Rogoff's result -the possible counterproductive international policy coordination- critically depends on the assumption that wage setters move before governments act, and that the result can be reversed if an announcement of internationally agreed monetary policy comes before the wage setters act.

Assumptions about who moves first significantly affect the nature of the game between government and wage setters. In our model the policy coordination eliminates government credibility problem while exacerbates it in the Rogoff's world.

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[10] The lowest possible value of $\alpha\lambda$ is zero. Substituting $\alpha\lambda=0$ into the expression still yields a positive sign of the expression.

An implication of the result is that gains from the international policy coordination could be bigger than have been thought to be. Countries can benefit by policy coordination not only from internalization of policy externalities but also from eliminating the credibility problem of policy.

In section 8 of his paper, Rogoff suggests a solution to the exacerbated credibility problem; "optimally-designed cooperative regime". He says "if the central banks were able credibly to guarantee that they would not systematically try to raise employment, and would only use monetary policy to offset disturbances, then it would be possible to achieve a superior and truly cooperative outcome".

It is not clear how the new institution can be made. But it seems that the "optimally-designed" institution is supposed to convince the wage setters that government would not exploit the tradeoff relationship between employment and inflation. Under such environment wage setters do not hike wage as much, nor governments exploit the tradeoff relationship when coordinate, with the result of elimination of inflation bias.

Three points are worth mentioning about the Rogoff's suggestion : First, wage setters continue to be assumed as first mover. Second, the governments' actions under the "optimally-designed cooperative regime" are not optimal in the sense that the governments do not exploit the tradeoff relationship, given the first mover's wage rate, to minimize the social loss. Third, according to his argument we need to seek an special institution outside of the economy to make sure the coordination produce a desired result.

The point made in this paper is that we may not need the institutional arrangement at all if governments are the first mover. The inflation bias is eliminated through coordination not for the reason that wage setters believe governments not to exploit the tradeoff relationship as in Rogoff's solution, but for the reason that first-moving governments take the wage setters' responses into consideration when they coordinate. The essence is that the coordination itself provides an environment in which the government credibility problem is completely removed.

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