Optimal Reserve Requirements and Price Stability: Taiwan's Case Study

Chau-Jung Kuo and Sode D. Shyu

This paper presents a stochastic financial model from which one can derive the optimal reserves ratio for stabilizing price level. It is shown that the optimal reserves ratio is a function of the structure of unanticipated shocks to a liquid asset market and a high-powered money market. An important policy implication, drawn from this model, suggests that it may help the stabilization of price level if a lower level of the reserve requirements is adopted by the central bank when the shock exists solely in a liquid asset market. An application of the presented model to the financial assets in Taiwan suggests that the optimal reserves ratio for stabilizing the price level is approximately 5.7717 percent, in the case of the 2-SLS estimation, and 4.2442 percent, in the case of the SUR estimation, below the weighted average of the actual 7.7575 percent up to the end of 1997. The empirical findings further suggest Taiwan's monetary authority would thus have to accept a lower level of the reserve requirements in order to reduce the

price fluctuations.

I. INTRODUCTION

Reserve requirements have become a common institutional feature of

our monetary system since the system was first introduced in the 19th

Chau-Jung Kuo and Sode D. Shyu, Department of Finance, National Sun Yat-sen University, Kaohsiung, Taiwan.

century. Reserve requirements are generally defined as a system mandating banks and other depository institutions to maintain vault cash of deposits held with a central bank balance as a reserve at a fractional percentage (reserve ratio) against their liabilities. Since the 1940s, the use of reserve requirements as a monetary policy instrument has been widely adopted by most of the countries in the world. Up to the recent decade, however, the use of reserve requirements has undergone two significant and substantial changes.

First, with regard to the reforms of the reserve requirement system, it appears to have converged in the direction of simplification and reduction in order to reduce the regulatory burdens on subjected banks arising from reserve requirements. For example, the central banks in the major industrialized countries (e.g., Canada, France, Germany, Italy, Japan, United Kingdom, and United States) have reduced their reserve ratios as well as simplifying reserve ratio trenches over the past decade in an attempt to lighten the burden they placed on banks. This convergence suggests that a market-based policy strategy for the reserve requirement system is now likely to be a general trend.

Second, since the 1980s, due to financial liberalization and

innovation along with regulatory and technological change, the relationship between the growth rate of monetary aggregates and economic growth in some countries has become less stable. It has led to a reconsideration of the usefulness of money supply as the policy objectives and has altered the operating philosophy for a central bank's policy tools. For example, to date during the 1990s, a number of countries, (e.g., Australia, Canada, Finland, Israel, New Zealand, Spain, Sweden and United Kingdom) have instead begun directly targeting the inflation rate. Indeed, because almost all central banks now identify price stability as the primary objective of monetary policy, in classifying policy framework it is probably more helpful to look at how specific a country's inflation objective is, rather than to distinguish between intermediate and final-target countries. Particularly, in March of 1995, the Bank of England pioneerly held a conference for central banks from those countries currently using inflation targets.

There appeared to be little agreement among researchers for a long time on either the optimal level of reserves or the criteria for setting such reserves in order to achieve macroeconomic stability. (See, e.g., Aschhein[2], Bryant[9], Carson[10], Friedman [13,14], Sellon, Gordon

and Weiner[18], Van Hoose[22]) Several issues arose, and the literature is somewhat limited to conceptual and technical issues. One of the most issues is that the countries with inflation targets are often said to pursue final-target strategies because the end product of monetary policy actions are inflation outcomes. The literature are thereby distinguished from countries pursuing intermediate-target strategies — using either the exchange rate, of some measure of money or credit. However, the distinction is probably more semantic than economic. Any country adhering to a monetary target, for example, must implicitly have a price objective embedded within this target, just as implicit assumptions have to be made about trends in the velocity of circulation of money and in real activity. So, in terms of the objectives of policy, final and intermediate-target approaches have clear similarities — though no central banks have yet settled on a definitive statement of price stability. Whatever the issues may be existed in the literature, the increased focus on the need to form a forward-looking inflation assessment associated with a market-based reserves policy is now a notable common theme across the major industrialized countries. Discussing this theme, as presented in this paper, allows us to derive the minimum price

fluctuations as functions of the reserves ratio, some disturbances shock against the anticipated portfolio behavior in the financial assets market, and the other analytic parameters in the model. Thus, it is possible to study the price stability as it varies with different levels of the reserves.

The composition of this paper is as follows: Section 2 firstly describes a simple financial infrastructure and formulates a basic model for financial equilibrium; and section 3 presents a reduced model, which was derived from the preceding section; section 4 attempts to solve the optimal reserves ratio for the price stability by randomizing this basic model; empirical results for Taiwan's case are presented in section5; while in the last section we make a summary and conclusions.

II. BASIC MODEL FOR FINANCIAL EQUILIBRIUM

The basic framework employed in the model is an adaptation of Santomero and Siegel's[17] and Siegel's[19] version of the general equilibrium framework of the financial markets proposed by Tobin and Brainard (1963). It might be taken for granted that a prescribed description for the financial infrastructure in the model seems to be required in order to lighten the inter-relationships among the economic

agents and financial assets embodied by this model.

A. A description of the financial infrastructure

Along with five financial assets markets, there are three types of agents operating in the financial infrastructure: the central bank, banking or financial institutions (*b*), households (*h*) and firms (*f*). The central bank issues nominal high-powered money (H^s) in the forms of currency and bank reserves and carries out policy by choosing the instrument of the reserve requirements to attempt the stabilization of the price of output (*P*) in terms of nominal high-powered money, whose return is assumed fixed at zero. Banks issue deposits (D^s) and hold deposit reserves (H_b^d) and securities; those are in the forms of bonds (B_b^d) and equities (E_b^d), and loan to firms and households in local markets (L^s). Households hold asset portfolios and borrow from banks, while firms obtain funds from issuing securities in the forms of bonds (B_f^s) and equities (E_f^s) to maintain their fixed physical capital (*K*), borrow from banks, and hold asset portfolios. With regard to the asset portfolios for firms and households, it is composed of the real demand for currency (C^d),

deposits (D^d), bonds ($B^d_{h\&f}$), and equities ($E^d_{h\&f}$).

The financial infrastructure describing the inter-relationships among the three agents and financial assets, as mentioned above, may summarily be shown as in Table1[1].

B. The behavioral formulations and market clearing

The approach here is to formulate a symmetric behavior for all economic agents that concentrates on demands for and supplies of financial assets in five financial markets. In accordance with most of the literature in this area, it is assumed that each private agent's demands and supplies satisfy balance sheet constraints and substitution properties. That is, within the five financial markets, each private agent is constrained by a budget constraint limiting assets purchases, and the assets are all gross substitutes. For the banking system, banks are internally financed institutions that loan to firms and households, holding equity, bond and deposit reserves as assets against their deposit issues. The bank's asset portfolios must sum to zero in real value so that the bank's budget constraint may be written as $H^d_b + L^s + B^d_b + E^d_b = D^s$. While for the

households   and   firms   agent,   its   constraint   is

$C^d + D^d + E^d_{h\&f} + B^d_{h\&f} - L^d = W \equiv H^s / P + K$, and, $B^s_f + E^s_f = K$, where W

indicates total wealth, defined as total firm physical capital plus real

high-powered money. Finally, there is no budget constraint for the

central bank because it simply carries out the policy for the price

stabilization by controlling the issues of base money.

Table 1

Threefold financial infrastructure

Central Bank	
	high-powered money (H^s / P)

Banking System	
Deposit reserves (H^d_b)	deposits (D^s)
loans (L^s)	
bonds (B^d_b)	
equities (E^d_b)	

<center>Households and Firms</center>

currency (C^d)	loan borrowing (L^d)
deposit holdings (D^d)	bond issues (B_f^s)
bond holdings $(B_{h\&f}^d)$	capital (K)
equity holdings $(E_{h\&f}^d)$	equity issues (E_f^s)

It will be convenient to suppose that the excess reserves of the banking system is initial zero so that $H_b^d = \rho D^s$, where ρ is the required reserves ratio. Furthermore, with an assumption of full employment in the real sector, the equilibrium conditions for a corresponding commodity market, which is not explicitly used in the model, can be eliminated with the help of Walras's Law. Thus, a general model of financial equilibrium may be constructed as the following five-equation system of equilibrium conditions:

High-powered money market

$$C^d\left(\overset{-}{r_b}, \overset{-}{r_e}, \overset{-}{r}, \overset{-}{r_d}, \overset{+}{W}\right) + \rho D^s\left(\overset{+}{r_b}, \overset{+}{r_e}, \overset{+}{r}, \overset{-}{r_d}\right) = H^s / P \qquad (1)$$

Deposit market

$$D^d\left(\overset{-}{r_b}, \overset{-}{r_e}, \overset{-}{r}, \overset{+}{r_d}, \overset{+}{W}\right) = D^s\left(\overset{+}{r_b}, \overset{+}{r_e}, \overset{+}{r}, \overset{-}{r_d}\right) \tag{2}$$

Loan market

$$L^d\left(\overset{+}{r_b}, \overset{+}{r_e}, \overset{-}{r}, \overset{+}{r_d}, \overset{+}{W}\right) = L^s\left(\overset{-}{r_b}, \overset{-}{r_e}, \overset{+}{r}, \overset{-}{r_d}\right) \tag{3}$$

Bond market

$$B^d_{h\&f}\left(\overset{+}{r_b}, \overset{-}{r_e}, \overset{-}{r}, \overset{-}{r_d}, \overset{+}{W}\right) + B^d_b\left(\overset{+}{r_b}, \overset{-}{r_e}, \overset{-}{r}, \overset{-}{r_d}\right) = B^s_f\left(\overset{-}{r_b}, \overset{+}{r_e}, \overset{+}{K}\right) \tag{4}$$

Equity market

$$E^d_{h\&f}\left(\overset{-}{r_b}, \overset{+}{r_e}, \overset{-}{r}, \overset{-}{r_d}, \overset{+}{W}\right) + E^d_b\left(\overset{-}{r_b}, \overset{+}{r_e}, \overset{-}{r}, \overset{-}{r_d}\right) = E^s_f\left(\overset{+}{r_b}, \overset{-}{r_e}, \overset{+}{K}\right) \tag{5}$$

where the arguments (r_b, r_e, r, r_d) are the rate of return on bond, equity, loan, and deposits, respectively, and the sign above the arguments in the demand and supply functions stand for the signs of the partial derivatives. Given exogenous variables (ρ, K, W, H^s), and using implicit function theorem, five endogenous variables (P, r_b, r_e, r, r_d) in the model may be simultaneously determined. It follows that a market clearing for all real balances $(H/P, D, L, E, B)$ in five financial markets is also determined.

III. REDUCED MODEL FOR FINANCIAL EQUILIBRIUM

In order to be accurate on the purpose of this paper with the equilibrium solution, it may be simplified considerably if two assumptions are further made. First, the solution of the model is evaluated at the point where the rate of return on equity r_e is equal to the fixed marginal product of capital. This will be appropriate since the model is a comparative static full-employment framework. Second, it will be assumed that the supply of deposits for the banking system exhibits constant returns to scale in high-powered money and bonds so that the market rate of deposit is $r_d = (1 - \rho)r_b$ if there exists only institutional cost; i.e., the reserve ratio ρ, in a competitive financial market. This assumption further reduces the solution for the rate of return on bank loans, which is simply determined by "marking up y" so that $r = r_d + y$, once the rate of return on bond r_b is determined.[2]

Formally, using the conditions of budget constraint for all private agents, the reduced model for the financial equilibrium containing these assumptions can be written by the following two excess demand equations:

HH: $C^d(r_b, r_e, r, r_d, W) + \rho D^d(r_b, r_e, r, r_d, W) - H^s / P = 0$ (6)

AA: $C^d(r_b, r_e, r, r_d, W) + D^d(r_b, r_e, r, r_d, W) + E^d_{h\&f}(r_b, r_e, r, r_d, W) + B^d_{h\&f}(r_b, r_e, r, r_d, W)$

$- L^d(r_b, r_e, r, r_d, W) - H^s / P - B^s_f(r_b, r_e, K) - E^s_f(r_b, r_e, K) = 0$ (7)

Equation (6) stands for the market for high-powered money in equilibrium, while equation (7) represents the market for liquid assets in equilibrium. Each of them is respectively denoted by the notations of *HH* and *AA*, which was first used in Santomero and Siegel[17]. By assuming both these equations are linearly homogeneous and using Euler's theorem, it can be shown that equilibrium in the system is obtained for a unique set of $p*$ and r_b^*. Specifically, the equilibrium solution is

$$\ln P^* = \frac{A_B S_H - H_B S_A}{H_P A_B - H_B A_P}$$

$$r_b^* = \frac{H_P S_A - A_P S_H}{H_P A_B - H_B A_P}$$ (8)

where $H_B \equiv \dfrac{\partial C^d}{\partial r_b} + \rho \dfrac{\partial D^d}{\partial r_b} < 0$

$H_P \equiv \dfrac{H^s}{P}\left[1 - \left(\dfrac{\partial C^d}{\partial W} + \rho \dfrac{\partial D^d}{\partial W}\right)\right] > 0$

$$A_B \equiv \frac{\partial C^d}{\partial r_b} + \frac{\partial D^d}{\partial r_b} + \frac{\partial B_{h\&f}^d}{\partial r_b} + \frac{\partial E_{h\&f}^d}{\partial r_b} - \frac{\partial L^d}{\partial r_b} - \frac{\partial B_f^s}{\partial r_b} - \frac{\partial E_f^s}{\partial r_b} < 0$$

$$A_P \equiv \frac{H^s}{P}\left[1 - \left(\frac{\partial C^d}{\partial W} + \frac{\partial D^d}{\partial W} + \frac{\partial B_{h\&f}^d}{\partial W} + \frac{\partial E_{h\&f}^d}{\partial W} - \frac{\partial L^d}{\partial W}\right)\right] < 0$$

$$S_H \equiv -\left[\frac{\partial C^d}{\partial r_e}r_e + \frac{\partial C^d}{\partial r}r + \frac{\partial C^d}{\partial r_d}r_d + \rho\left(\frac{\partial D^d}{\partial r_e}r_e + \frac{\partial D^d}{\partial r}r + \frac{\partial D^d}{\partial r_d}r_d\right)\right]$$

$$S_A \equiv -\left[\frac{\partial C^d}{\partial r_e} + \frac{\partial D^d}{\partial r_e} + \frac{\partial B_{h\&f}^d}{\partial r_e} + \frac{\partial E_{h\&f}^d}{\partial r_e} - \frac{\partial L^d}{\partial r_e} - \frac{\partial B_f^s}{\partial r_e} - \frac{\partial E_f^s}{\partial r_e}\right]r_e + \left[\frac{\partial B_f^s}{\partial K} + \frac{\partial E_f^s}{\partial K}\right]K$$

$$-\left[\frac{\partial C^d}{\partial r} + \frac{\partial D^d}{\partial r} + \frac{\partial B_{h\&f}^d}{\partial r} + \frac{\partial E_{h\&f}^d}{\partial r} - \frac{\partial L^d}{\partial r}\right]r - \left[\frac{\partial C^d}{\partial r_d} + \frac{\partial D^d}{\partial r_d} + \frac{\partial B_{h\&f}^d}{\partial r_d} + \frac{\partial E_{h\&f}^d}{\partial r_d} - \frac{\partial L^d}{\partial r_d}\right]r_d$$

As indicated in Figure 1, the system described by equations (6) and (7) can be represented in two-dimensional space for a given value of r_e. Where the slope of locus *AA* is negative and independent to reserve ratio; i.e., $AAslope = -A_P / A_B < 0$, while the slope of locus *HH* is not only positive but also a function of the required reserves ratio ρ. That is,

$$HHslope(\rho) = -\frac{H_P}{H_B} \equiv -\frac{\gamma + \lambda\rho}{\alpha + \beta\rho} > 0 \tag{9}$$
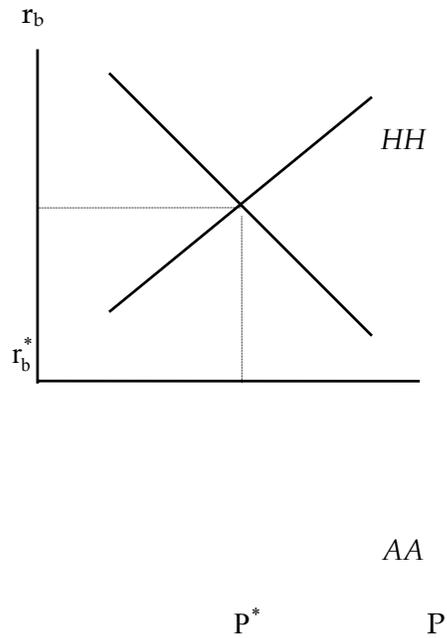
where

$$\alpha \equiv \frac{\partial C^d}{\partial r_b} < 0, \beta \equiv \frac{\partial D^d}{\partial r_b} = \frac{\partial H_B}{\partial \rho} < 0,$$

$$\gamma \equiv \frac{H^s}{P}\left(1 - \frac{\partial C^d}{\partial W}\right) > 0, \lambda \equiv -\frac{H^s}{P}\left(\frac{\partial D^d}{\partial W}\right) = \frac{\partial H_P}{\partial \rho} < 0$$

Figure 1

The equilibrium solution for the deterministic model

IV. STOCHASTIC FORM OF THE MODEL

A. Randomized Model

In order to solve the optimal required reserves ratio under the target of minimizing the price fluctuations, the random characteristics of the model will be attended. Here two sources of stochastic disturbances can be considered. First, there may be unanticipated changes (ε_H) associated with the equation *HH*, either on the demand side or on the supply side in a high-powered money market. For example, a transitory change in the demand for high-powered money by commercial banks or currency by households may be caused. Also, to react to the rise of financial turmoil, any change in money supply by the central bank may be adopted. In Figure 1 this is indicated by shifts in the *HH* curve. Second, there may be unanticipated changes (ε_A) associated with the equation *AA*, a randomness in the demand for liquid assets. For example, changes in the demand for equity at the expense of bonds are captured by this sort of

disturbance as presented by Santomero and Siegel [17]. This is indicated by shifts in the *AA* curve in Figure 1. In general, the random shocks to these two markets are correlated, with the degree of correlation and its sign depending on the specific disturbance. Yet, in practice, so far as this paper concerns the volatile shock for these two markets, there may be a higher volatility in the liquid asset market due to the emergence of financial innovations.

With regard to the random process of disturbances terms described above, we assume $E(\varepsilon_H) = E(\varepsilon_A) = 0$, and $E(\varepsilon_H \varepsilon_A) = \sigma_{AH}$, $E(\varepsilon_H^2) = \sigma_H^2$, and $E(\varepsilon_A^2) = \sigma_A^2$. Furthermore, the assumption that all shock terms are subject to a proportional price level is employed so that the shocks are proportional to the size of the market. This assumption is exact in the high-powered money market and approximate for the liquid asset market. By adding the disturbance terms ε_H and ε_A to the deterministic systems (6) and (7), respectively, and linearizing the system around its initial equilibrium values, the stochastic form of the linear model, in terms of deviations from equilibrium, can be written as

$$HH: \quad H_P \tilde{p} + H_B \tilde{r}_b = \varepsilon_H \qquad\qquad (10)$$

$$AA: \quad A_P \widetilde{p} + A_B \widetilde{r}_b = \varepsilon_A \tag{11}$$

where $p \equiv \ln P$, notation "~" represents deviations from the initial equilibrium values. For any realized value of the stochastic terms ε_H and ε_A, solving (10) and (11) yields the following equilibrium solution for the price level:

$$\widetilde{p} = \frac{A_B}{H_P A_B - H_B A_P} \varepsilon_H - \frac{H_B}{H_P A_B - H_B A_P} \varepsilon_A \tag{12}$$

Note that the first term in (12) is the fraction of shock to the high-powered money market due to shifts in liquid asset demands and supplies, while the second term is the fraction of shock to the liquid asset market due to shifts in high-powered money demands and supply. The variance of (12) is given by the following expression:

$$\sigma_P^2 = \frac{A_B^2 \sigma_H^2 + H_B^2 \sigma_A^2 - 2A_B H_B \sigma_{AH}}{\left(H_P A_B - H_B A_P\right)^2} \tag{13}$$

As noted at the outset, attention will be centered upon the

derivation of the optimal reserves ratio, which minimizes the price variations. This is done in the text by taking a partial derivative of (13) with respect to ρ as shown in the Appendix. The solution of the optimal reserves ratio can be written as

$$\rho^* = \frac{\left(\alpha^2\lambda - \alpha\beta\gamma\right)\sigma_A^2 + \left(\lambda A_B^2 - \beta A_P A_B\right)\sigma_H^2 + \left(\beta\gamma A_B + \alpha\beta A_p - 2\alpha\lambda A_B\right)\sigma_{AH}}{\left(\beta^2\gamma - \alpha\beta\lambda\right)\sigma_A^2 + \left(\beta\lambda A_B - \beta^2 A_P\right)\sigma_{AH}} \quad (14)$$

Given the analytic parameters of the model, the optimal level of reserves is a function of the structure of unanticipated shocks to the liquid asset market and the high-powered money market, as shown in equation (14).

B. Policy Implications

The focus point of the policy implications will be the effect of reserves ratio changes on the price level fluctuations. The effect of a small change in the reserves ratio ρ^* on the variance of the log of the price level is formally equal to

$$\frac{\partial \sigma_P^2}{\partial \rho} = 2 \left\{ \overset{-}{\beta} \, \overset{-}{A}_B \left[\frac{\overset{-}{A}_B \, \overset{-}{A}_P \, \overset{+}{\sigma_H^2} + \overset{-}{H}_B \, \overset{+}{H}_P \, \overset{+}{\sigma_A^2} - \left(\overset{-}{A}_B \, \overset{+}{H}_P + \overset{-}{H}_B \, \overset{+}{A}_P \right) \overset{(?)}{\sigma_{AH}}}{\underbrace{\left(H_P A_B - H_B A_P \right)^3}_{(-)}} \right] - \underbrace{\frac{\overset{-}{\lambda} \, \overset{-}{A}_B \, \overset{+}{\sigma_P^2}}{H_P A_B - H_B A_P}}_{(-)} \right\} \overset{>}{\underset{<}{}} 0(?) \quad (15)$$

The result of the comparative statics from (15) states that a change in the reserves ratio has an ambiguous effect on the variability of price. The reason for this is that the sign of the bracketed term in the numerator of (15) is indeterministic. There exists a correlated shock (σ_{AH}) structure due to the disturbances in both the liquid asset market and the high-powered money market. Again, the effect of the covariance between the shocks depends upon the sign of $(A_B H_P + H_B A_P)$. If the absolute value of the slope of *HH* is greater (smaller) than that of the *AA* locus, then $(A_B H_P + H_B A_P)$ is positive (negative). Hence, the effect of a positive (negative) covariance between the disturbances ε_H and ε_A may increase (decrease) the anticipated variance of the price level associated with the structural change under the consideration. To elaborate the expression in (15), the analysis may be considered the case of a disturbance in each market alone. The following two cases are observed directly from this expression:

Case 1: $\sigma_H^2 = 0$

$$\frac{\partial \sigma_P^2}{\partial \rho} = 2\left\{\beta A_B\left[\frac{H_B H_P \sigma_A^2}{\left(H_P A_B - H_B A_P\right)^3} - \frac{\lambda A_B \sigma_P^2}{\left(H_P A_B - H_B A_P\right)}\right]\right\} > 0 \quad (15\text{-a})$$

This result states that in the case where only the liquid asset market is subject to disturbance, the variance of price unambiguously rises.

Case 2: $\sigma_A^2 = 0$

$$\frac{\partial \sigma_P^2}{\partial \rho} = 2\left\{\beta A_B\left[\frac{A_B A_P \sigma_H^2}{\left(H_P A_B - H_B A_P\right)^3} - \frac{\lambda A_B \sigma_P^2}{\left(H_P A_B - H_B A_P\right)}\right]\right\}\begin{matrix}>\\<\end{matrix}0(?) \quad (15\text{-b})$$

The result indicates that a change in the reserves ratio still has an ambiguous effect on the price fluctuations in the case where only the high-powered money market causes shock.

Taken together, a close examination of the policy implications under this stochastic model discussed above unambiguously reveals the following proposition:

Proposition. *The effect of a change in reserves ratio to the price fluctuations is*

in general ambiguous when both the liquid asset market and the high-powered money market experience an unanticipated shock and when the high-powered money market is subject to an unanticipated shock. But an increase (or a decrease) in the reserves ratio will rise (or reduce) the price fluctuations only when the disturbance shock exists solely in the liquid asset market.

It may be pointed out that only when the liquid asset market is subject to disturbance, the central bank always has "perfect foresight" of the shock on the high-powered money market. Thus, the central bank can simply operate the reserve policy to minimize the price fluctuations by changing the slope of locus *HH*. This result is exact , so fas as our model is concerned, since the slope of locus *AA* is independent to the reserves ratio so that a changed reserves ratio only changes the slope of locus *HH*. Specifically, the effect of changing the reserves ratio to the slope of *HH* curve is

$$\frac{\partial \text{HHslope}\left(\rho\right)}{\partial \rho} = \frac{\beta\gamma - \alpha\lambda}{\left(\alpha + \beta\rho\right)^2} < 0 \tag{16}$$
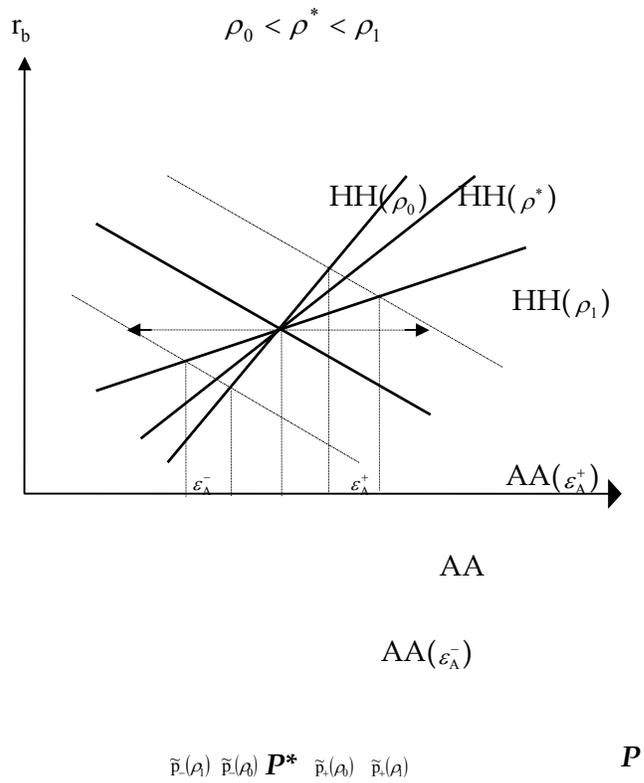
A further understanding for the effect of changing the reserve

policy when the central bank has perfect knowledge for high-powered money can be depicted by Figure 2. An increase (or a decrease) in the reserves ratio from an initial level ρ^* to an adjusted level ρ_1 (or ρ_0) will flatten (or steepen) the initial $HH(\rho^*)$ curve to $HH(\rho_1)$ (or $HH(\rho_0)$) but leave unchanged the AA curve. Once the disturbances in the liquid asset market become relevant, the price level ρ^* (associated with bond rate) will be responsive to change along a new HH curve, which is corresponding to an adjusted reserves ratio ρ_1 (or ρ_0), say $HH(\rho_1)$ (or $HH(\rho_0)$). The new equilibrium is reached until the value of random disturbance ε_A^+ (or ε_A^-) in the liquid asset market is realized so that it shifts outwards (or inwards) the initial AA curve to $AA(\varepsilon_A^+)$ (or $AA(\varepsilon_A^-)$). As a result, the new level of price deviations from its initial equilibruim under a lower reserves ratio, $\widetilde{p}_+(\rho_0)$ and $\widetilde{p}_-(\rho_0)$, is smaller than those of $\widetilde{p}_+(\rho_1)$ and $\widetilde{p}_-(\rho_1)$ under a higher reserves ratio, respectively.

Figure 2

The relationship between the change in reservses

ratio and price fluctuations

r_b $\rho_0 < \rho^* < \rho_1$

HH(ρ_0) HH(ρ^*)

HH(ρ_1)

AA(ε_A^+)

ε_A^- ε_A^+

AA

AA(ε_A^-)

$\tilde{p}_-(\rho_1)$ $\tilde{p}_-(\rho_0)$ P^* $\tilde{p}_+(\rho_0)$ $\tilde{p}_+(\rho_1)$ P

Of course, it is not so easy for the central bank to have a perfect

knowledge for the high -powered money market. However, it doesn't

mean that nothing can be done by the central bank. After all, in today's enviornment of the financial innovations which emerged on most of the liquid asset market, to predict the variability of the high-powered money market for the central bank seems no more difficult than to predict that of the liquid asset market. Hence, a more important implication behind this proposition suggests that a lower reserves ratio may be helpful to stabilize the price fluctuations when the volatility arising from the high-powered money market is smaller than that of the liquid asset market.

V. EMPIRICAL RESULTS

A. A Simultaneous Regression Model

The empirical work presented in this section set forth a simultaneous regression model that may be available for Taiwan. According to this empirical model, the required reserves ratio that minimizes price level instability is estimated. This empirical model requests a determination of not only the variance-covariance structure of unanticipated shocks to the demands for currency, deposit, equity, bond, and loan equations, but

also the asset demands of themselves along with the determinations of bond rate and price level to be estimated simultaneously. First of all, our empirical work was done by estimating an econometric structure form that is cmposed of 7 equations with 7 endogenous variables (*C. D.E.B.L.r_b.p*) and 12 predetermined variables. This can be specified as follows:

Currency equation:

$$C = a_0 + a_1 r_b + a_2 p + a_3 r_d + a_4 W + a_5 C_{-1} + a_6 DV_C + \varepsilon_C \qquad (17)$$

Deposit equation:

$$D = b_0 + b_1 r_b + b_2 p + b_3 r_d + b_4 W + b_5 D_{-1} + \varepsilon_D \qquad (18)$$

Equity equation:

$$E = c_0 + c_1 r_b + c_2 p + c_3 r_e + c_4 W + c_5 LSP_{-1} + \varepsilon_E \qquad (19)$$

Bond equation:

$$B = d_0 + d_1 r_b + d_2 p + d_3 r + d_4 W + \varepsilon_B \qquad (20)$$

Loan equation:

$$L = e_0 + e_1 r_b + e_2 p + e_3 r + e_4 W + e_5 L_{-1} + \varepsilon_L \qquad (21)$$

Bond rate equation:

$$r_b = f_0 + f_1 p + f_2 B + f_3 E + f_4 L + f_5 \rho + f_6 K + f_7 \ln H + \varepsilon_{r_b} \qquad (22)$$

Price equation:

$$p = g_0 + g_1 r_b + g_2 C + g_3 D + g_4 \rho + g_5 \ln H + \varepsilon_p \qquad (23)$$

where DV_C = a seasonal dummy variable of the demands for currency

and the value equals to unit, if the first quarter occurred,

and equals to zero, otherwise.

LSP_{-1} = the nature log value of the Taiwan Stock Exchange Index

lagged one period.

C_{-1} = one period of lagged currency balances.

D_{-1} = one period of lagged deposit balances.

L_{-1} = one period of lagged loan balances.

And the remainder variables listed in the regression system (17)~(23) represent all the same symbol's description as the previous sections.

A sample of quarterly data covering the period from the beginning of 1980 to the end of 1997, totally 18 quarters, 72 observations is used. All of the data sources are drawn from the EPS/AREMOS database, which was built and sponsored by the Ministry of Education, R.O.C., and Taiwan Economic Journal (TEJ) database, respectively. In addition, to compare an empirically consistent result, two alternative estimating methods, two-stage least square (2-SLS) and seemingly unrelated regressions (SUR) , are employed.

The estimates of regression coefficients in the model of structure

form are listed in Panel A ~ Panel G of Table 2. Aside from intercept
terms, of the 37 estimated coefficients in the model, the number of
significant variables have totally 28 terms for the 2-SLS and totally 25
terms for the SUR. Furthermore, the signs associated with all of these
significant terms between the method of the 2-SLS and that of the SUR
are shown by a consistent result.

B. An Estimation for the Optimal Reserves Ratio

The second stage of this empirical work was done by estimating the
optimal reserves ratio for Taiwan. This needs firstly to determine the
estimated value of parameters $(\hat{H}_B, \hat{H}_P, \hat{A}_B, \hat{A}_P)$ generating from the
structure form of the regression model. In addition, in order to calculate
the estimated value of variance-covariance $(\hat{\sigma}_A^2, \hat{\sigma}_H^2, \hat{\sigma}_{AH})$, two reduced
forms of the bond rate equation and the price level equation, which are
derived from Panel F and Panel G of Table 2,[3] are also required. When
these two processes become relevant, using equation (14), this paper
leads to a final result for the estimation of the optimal reserves ratio. All
of these results are summarized in Table 3.

As can be seen from Table 3, the optimal reserves ratio for stabilizing the Taiwan price level is approximately 5.7717 percent in the case of the 2-SLS estimation and 4.2442 percent in the case of the SUR estimation, both below the weighted average of actual 7.7575 percent up to the end of 1997. Substituting both into (13), respectively, indicates that the minimized standard deviation of the price level is

$$2\text{-SLS}: \ \hat{\sigma}_P^* = 0.208122 \qquad \text{SUR}: \ \hat{\sigma}_P^* = 0.30422 \qquad (24)$$

This indicates that, for Taiwan's case, if reserves ratio were set optimally to stabilize the price level, unexpected financial asset shock would cause almost 20.8 percent (or 30.4 percent) standard error in the quarterly price level estimates. If reserves on deposits are zero, it can be estimated from (13) that the standard deviation of the price level would approximately be 21 percent for 2-SLS (or 30.5 percent for SUR) higher than (24). As ρ increases to 15 percent, the standard deviation of price level is approximately 21.2 percent for 2-SLS (or 30.7 percent for SUR) higher than (24). At a reserve level of 100 percent, the standard deviation is more than double the value of (24) in the case of the 2-SLS estimation.

Figure 3 displays the variance of the price level for differing levels of the reserves ratio, ranging from zero to 15 percent. As can be seen from the asymmetry of the price variability curve, a reserve level above the optimal level causes a greater increase in price variation than an equivalent decrement below the optimal level does.

Finally, it is worthy to note that, from Table 3, the estimated value of variance $\hat{\sigma}_H^2$ for both estimating methods is apparently smaller than that of $\hat{\sigma}_A^2$. This empirical finding indicates that the feasibility for predicting the environmental changes to Taiwan's liquid asset market for the Central Bank of China seems more unavailable than that of the high-powered money market. This may further have an important implication for Taiwan's reserve policy.

VI. SUMMARY AND CONCLUSIONS

Although setting reserves to stabilize monetary aggregates has always been the primary concern of most past research, it seems more available for stabilizing price fluctuations when inflation targets have posed a new set of issues for those central banks pursuing them. On the other hand, that reserve regulations set reserves themselves has substantially

undergone a reformation due to financial innovations. Some issues behind these two tendencies in the 1990s are somewhat limited to the conceptual and technical. Foremost among these is perhaps to find a research framework that is both theoretically meaningful and empirically workable so that optimal reserves for the price stability can be determined.

Table 2

Regression results for an econometric structure form model: a

comparison with methods of the 2-SLS and the SUR

Panel A: $C = a_0 + a_1r_b + a_2p + a_3r_d + a_4W + a_5C_{-1} + a_6DV_C + \varepsilon_C$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values[a]	Estimated Coefficients	t-Values
intercept	394.9115	2.230**	414.1465	2.600**
r_b	-6.6244	-4.055***	-5.5333	-4.550***
p	-83.3226	-1.933*	-88.9383	-2.298**
r_d	-8.1656	-4.160***	-6.5096	-4.082***
W	0.1138	4.888***	0.1013	5.229***
C_{-1}	0.4853	4.129***	0.5554	5.847***
DV_c	15.5793	2.767***	12.8044	2.786***
	$\overline{R}^2$=0.9812;F=610.172***; DW=1.544		$\overline{R}^2$=0.9817;F=627.572***; DW=1.742	

Panel B: $D = b_0 + b_1r_b + b_2p + b_3r_d + b_4W + b_5D_{-1} + \varepsilon_D$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values
intercept	17523	2.654***	-450.6357	-0.162
r_b	-73.9230	-3.568***	-34.1401	-2.799***
p	-4219.4488	-2.681***	-58.2292	-0.088
r_d	130.1201	4.715***	71.9716	4.435***
W	0.0178	0.125	0.3320	3.075***
C_{-1}	1.1452	17.836***	0.9637	33.583***
	$\overline{R}^2$=0.9979;F=6804.991***; DW=2.175		$\overline{R}^2$=0.9983;F=8258.914***; DW=2.032	

Table 2 (Continued)

Panel C: $E = c_0 + c_1 r_b + c_2 p + c_3 r_e + c_4 W + c_5 LSP_{-1} + \varepsilon_E$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values
intercept	-72587	-4.917***	-70169	-5.841***
r_b	-170.3425	-3.125***	-93.9441	-3.997***
p	-12362	-3.793***	-11799	-4.379***
r_e	59.7701	1.210	66.7587	1.617
W	3.2263	2.870***	2.9633	3.322***
LSP_{-1}	3212.3895	7.670***	3152.6926	9.438***
	$\overline{R}^2$=0.8414;F=75.281***; DW=1.289		$\overline{R}^2$=0.8432;F=76.259***; DW=1.258	

Panel D: $B = d_0 + d_1 r_b + d_2 p + d_3 r + d_4 W + \varepsilon_B$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values
intercept	-128.9497	-11.213***	-132.8157	-14.643***
r_b	0.6055	3.585***	0.2470	3.157***
p	-30.6065	-11.097***	-31.2450	-14.315***
r	-0.5813	-0.5813***	-0.1273	-1.471
W	0.3374e-4[b]	0.059	0.3393e-4	0.073
	$\overline{R}^2$=0.9237;F=212.866***; DW=1.141		$\overline{R}^2$=0.9335;F=246.703***; DW=0.435	

Panel E: $L = e_0 + e_1 r_b + e_2 p + e_3 r + e_4 W + e_5 L_{-1} + \varepsilon_L$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values

intercept	7811.2340	-1.722*	-2033.0148	-1.183
r_b	-55.6375	-1.940*	-2.1219	-0.227
p	-1919.2064	-1.770*	-439.7725	-1.073

Table 2 (Conituned)

r	71.0681	2.406**	16.1000	1.535
W	0.1064	1.550	0.1769	3.423***
L_{-1}	1.1115	16.851***	0.9636	38.472***
	$\overline{R}^2$=0.9977;F=5997.812***; DW=1.343		$\overline{R}^2$=0.9983;F=8281.716***; DW=1.262	

Panel F: $r_b = f_0 + f_1 p + f_2 B + f_3 E + f_4 L + f_5 \rho + f_6 K + f_7 \ln H + \varepsilon_{r_b}$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values
intercept	85.4217	0.806	64.9785	1.626
p	-10.2526	-0.390	-5.4847	-0.545
B	-1.9238	-1.045	0.3998	0.753
E	0.1547e-4	0.039	0.3693e-4	0.184
L	0.0050	1.223	0.0013	1.231
ρ	0.4883	1.007	1.1624	4.387***
K	0.0161	1.583	0.0142	1.847*
$\ln H$	-7.9771	-4.415***	-8.7924	-6.918***
	$\overline{R}^2$=0.4205;F=8.256***; DW=1.516		$\overline{R}^2$=0.4521;F=9.253***; DW=1.988	

Panel G: $p = g_0 + g_1 r_b + g_2 C + g_3 D + g_4 \rho + g_5 \ln H + \varepsilon_p$

Regressors	2-SLS		SUR	
	Estimated Coefficients	t-Values	Estimated Coefficients	t-Values
intercept	3.2069	13.994***	3.8314	27.622***
r_b	0.0040	2.231**	0.0002	0.183
C	-0.0012	-5.246***	-0.0007	-4.814***
D	0.2858e-4	5.840***	0.3482e-4	9.530***
ρ	-0.0107	-2.735***	-0.0070	-2.393**
$\ln H$	0.2314	4.517***	0.0988	3.170***

$\overline{R}^2$=0.9573;F=315.105***; $\overline{R}^2$=0.9597;F=334.317***;
DW=1.951   DW=1.527

a : * stands for the significant at the 10 percent level, ** stands for the significant at the 5 percent level, and *** stands for the significant at 1 percent level. b : e-4=10^{-4}

Table 3

Summary results for the estimation of the optimal reserves ratio:

a comparison with methods of the 2-SLS and the SUR

	$\hat{H}_B(\rho)$	$\hat{H}_P(\rho)$	$\hat{A}_B$	$\hat{A}_P$	$\hat{\sigma}_A^2$	$\hat{\sigma}_H^2$	$\hat{\sigma}_{AH}$	$\hat{\rho}^*$
2-SLS	-6.6244-73.9230ρ	0.8862-0.0118ρ	-194.6469	-2.2455	1.666231	0.038814	-0.004236	5.7717%
SUR	-5.5333-34.1401ρ	0.8987-0.3220ρ	-131.2485	-2.2097	1.955447	0.088976	0.013855	4.2442%

Figure 3

The variance of the price level for differing levels of reserves ratio

in Taiwan's case

price variance (%)

reserve ratio %   reserve ratio %
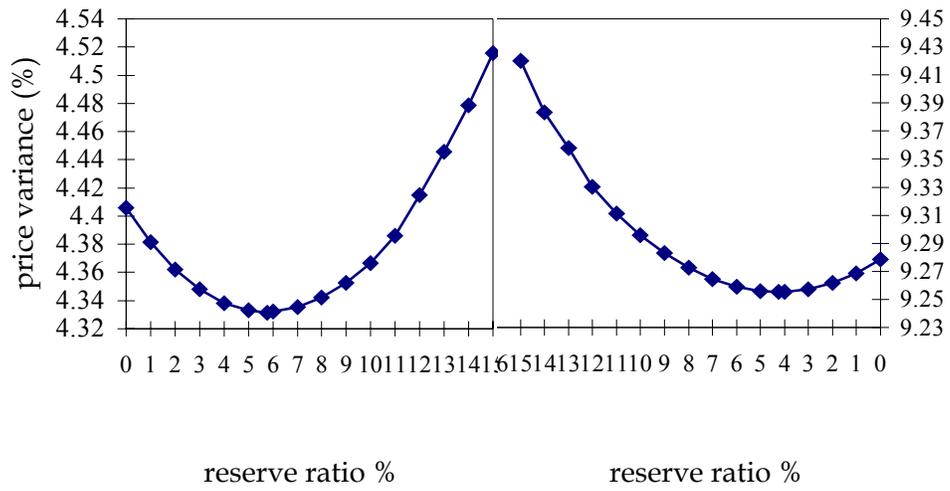
2-SLS: σ_P^2 SUR: σ_P^2

This paper presents a stochastic financial model from which one can derive the optimal reserve requirements that minimize price level fluctuations. It is shown that the optimal reserves ratio is a function of the structure of unanticipated shocks to the financial assets market, given the analytic parameters of the model. Two types of the shocks arising from the liquid asset market and high-powered money market in the model are analyzed. In general, the random shocks to these two markets are correlated so that the effect of a change in the reserves ratio to the price fluctuations is ambiguous. However, when the shock exists solely in the liquid asset market, a change in the reserves ratio will have a positive effect for the price stability. An important implication drawn from this analysis suggests that it may help for the price stability if a lower level of the reserve requirements was adopted by the central bank.

By setting forth simultaneous regressions and utilizing two estimating methods, the 2-SLS and the SUR, an application of the presented model to the financial assets in Taiwan suggests that the optimal reserves ratio for stabilizing price level is approximately 5.7717 percent in the case of the 2-SLS estimation and 4.2442 percent in the case of the SUR estimation. Both cases were lower than the weighted average

of the actual 7.7575 percent up to the end of 1997. Furthermore, both cases of these two estimating results show that the volatility of shocks arising from the high-powered money market is apparently smaller than that of the liquid asset market. These empirical results suggest Taiwan's monetary authority would thus have to accept a lower level of the reserve requirements in order to reduce the price fluctuations.

ACKNOWLEDGMENTS

NOTES

1. All variables on Table 1 are measured in real terms. Since the price
    level of output P is measured in terms of nominal high-powered
    money, it can be viewed as a linking variable between the real
    sector and financial sector.

2. It is appropriate since a structural relationship between the rate of
    return on deposits and loans may more or less exist on the grounds
    it has usually been considered by most literature.

3. The reduced form of the bond rate equation and the price level
    equation, derived from Panel F and Panel G of Table 2, can be
    expressed as the following:

2-SLS :

$$r_b = 38.2465 + 0.1508r_d + 0.0035W + 0.0143C_{-1} + 0.4581DV_c - 0.0008D_{-1} +$$

$$0.4586r - 0.0003r_e + 0.0155LSP_{-1} + 0.0017L_{-1} + 0.4085\rho + 0.0050K - 8.0392\ln H$$

$$P = 3.5411 - 0.0047r_d - 0.0001W - 0.0004C_{-1} - 0.0142DV_c + (0.2441e-4)D_{-1} +$$

$$0.0045r - (2.8301e-6)r_e + 0.0002LSP_{-1} + (0.1695e-4)L_{-1} + 0.0065\rho + (0.4919e-4)K + 0.1482\ln H$$

SUR :

$$r_b = 42.2183 - 0.0192r_d + 0.0004W - 0.0037C_{-1} - 0.0861DV_c + 0.0003D_{-1} -$$

$$0.0335r - 0.0028r_e + 0.1334LSP_{-1} + 0.0015L_{-1} + 1.2639\rho + 0.0163K - 9.10631\ln H$$

$$P = 3.8975 - 0.0021r_d - (0.6336e - 4)W - 0.0004C_{-1} - 0.0096DV_c + (0.3681e - 4)D_{-1} -$$

$$0.0001r - (8.5752e - 6)r_e + 0.0004LSP_{-1} + (4.5080e - 6)L_{-1} - 0.0036\rho + (0.4932e - 4)K + 0.0777\ln H$$

REFERENCES

[1] Aschhein, J., 1959. "Open Market Operations Versus Reserve Requirement Variations," *Economic Journal*, (Dec.), 697-704.

[2] Aschhein, J., 1965. "Restrictive Open-Market Operations Versus Reserve Requirement Variations: A Reformulation," *Economic Journal*, (June), 254-266.

[3] Baltensperger, E., 1982. "Reserve Requirements and Economic Stability," *Journal of Money, Credit, and Banking*, Vol. 14, (May), 205-215.

[4] Bank of Japan, 1995. "Reserve Requirement Systems and Their Recent Reforms in Major Industrialized Countries : A Comparative Perspective," *Quarterly Bulletin*, (May).

[5]   Bank of Japan, 1995. "Inflation Targeting in Selected Countries," *Quarterly Bulletin*, (May).

[6]   Black, F., 1970. "Banking and Interest Rates in a World Without Money," *Journal of Bank Research*, 1, 8-20.

[7]   Black, F., 1975. "Bank Fund Management in an Efficient Market," *Journal of Financial Economics*, 2, 323-339.

[8]   Bernanke, B. S. and A. S. Blinder, 1988. "Credit, Money, and Aggregate Demand," *American Economic Review*, (May), 435-439.

[9]   Bryant, J., 1980. "A Model of Reserves, Bank Runs, and Deposit Insurance," *Journal of Banking and Finance*, 4, 335-344.

[10] Carson, D., 1964. "Is the Federal Reserve System Necessary? " *Journal of Finance*,19, (Dec.), 652-661.

[11] Dothan, U. and J., Williams, 1980. "Banks, Bankruptcy, and Public Regulation," *Journal of Banking and Finance* ,4, 65-87.

[12] Feinman, J. N., 1993. "Reserve Requirements: History, Current Practice, and Potential Reform," Federal Reserve Bulletin, (June), 569-589.

[13] Friedman, M., 1959. *A Program for Monetary Stability*, Fordham University Press, New York City.

[14] Friedman, M., 1959. "Statement of 21 August 1978," Submitted to the Committee on Banking, Housing, and Urban Affairs.

[15] Mitchell, D.W., 1982. "The Effects of Interest-Bearing Required Reserves on Bank Portfolio Riskiness," *Journal of Financial and Quantitative Analysis*, 17, (June), 209-216.

[16] Osborne, D.K. and T. S. Zaher, 1992. "Reserve Requirements, Bank Share Prices, and the Uniqueness of Bank Loans," *Journal of Banking and Finance* 16, 799-812.

[17] Santomero, A.M. and J.J. Siegel, 1981. "Bank Regulation and Macro-Economic Stability," *American Economic Review*, 71, 1, 39-53.

[18] Sellon, Jr., H. Gordon, and S. E. Weiner, 1996. " Monetary Policy Without Reserve Requirements : Analytical Issues," *Federal Reserve Bank of Kansas City Economic Review*, Fourth Quarter, 5-24.

[19] Siegel, J. J., 1981. "Bank Reserves and Financial Stability," *Journal of Finance*, 5, (Dec.), 1073-1084.

[20] Slovin, M., E. Sushka, and Y. Bendeck, 1992. "The Market Valuation Effects of Reserve Regulation," *Journal of Monetary Economics*, 25, 1-17.

[21] Tobin, J., 1969. " A General Equilibrium Approach to Monetary

Theory," *Journal of Money, Credit and Banking*, (Feb.), 15-29.

[22] Van Hoose, D. D., 1983. "Monetary Policy Under Alternative Bank Market Structures," *Journal of Banking and finance*, 7, 383-404.

[23] Weiner, S., 1992. "The Changing Role of Reserve Requirements in Monetary Policy," *Federal Reserve Bank of Kansas City Economic Review*, Fourth Quarter.

APPENDIX

$$\text{Minimize}_{\rho^*} \sigma_P^2 = \frac{A_B^2 \sigma_H^2 + H_B^2 \sigma_A^2 - 2A_B H_B \sigma_{AH}}{\left(H_P A_B - H_B A_P\right)^2}$$

where both $H_B \equiv \alpha + \beta\rho$ and $H_P \equiv \gamma + \lambda\rho$ are linear in reserves ratio ρ. Taking partial derivative of this objective function with respect to ρ, the first-order necessary condition for this minimization can be written as

$$\frac{\left(\beta H_B \sigma_A^2 - \beta A_B \sigma_{AH}\right)\left(H_P A_B - H_B A_P\right)^2}{\left(H_P A_B - H_B A_P\right)^4} - \frac{\left(H_P A_B - H_B A_P\right)\left(\lambda A_B - \beta A_P\right)}{\left(H_P A_B - H_B A_P\right)^2} \sigma_P^2 = 0 \quad (A1)$$

Since $H_P A_B - H_B A_P \neq 0$ and $\sigma_P^2 \neq 0$, the first-order necessary condition in equation (A1) must be satisfied with

$$\beta\left(H_B \sigma_A^2 - A_B \sigma_{AH}\right)\left(H_P A_B - H_B A_P\right) - \left(\lambda A_B - \beta A_P\right)\left(A_B^2 \sigma_H^2 + H_B^2 \sigma_A^2 - 2A_B H_B \sigma_{AH}\right) = 0 \quad (A2)$$

when $H_B \equiv \alpha + \beta\rho$ and $H_P \equiv \gamma + \lambda\rho$ are substituted into (A2); it can be rewritten as

$$\left[\left(\beta^2\gamma - \alpha\beta\lambda\right)\sigma_A^2 + \left(\beta\lambda A_B - \beta^2 A_P\right)\sigma_{AH}\right]\rho = \left(\alpha^2\lambda - \alpha\beta\gamma\right)\sigma_A^2 +$$

$$\left(\lambda A_B^2 - \beta A_P A_B\right)\sigma_H^2 + \left(\beta\gamma A_B + \alpha\beta A_P - 2\alpha\lambda A_B\right)\sigma_{AH} \tag{A3}$$

The solution of the optimal reserves ratio ρ^*, as shown in equation (14),

is obtained by (A3).