Volume Title: Macroeconomic Linkage: Savings, Exchange Rates, and Capital Flows, NBER-EASE Volume 3

Volume Author/Editor: Takatoshi Ito and Anne Krueger, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-38669-4

Volume URL: http://www.nber.org/books/ito_94-1

Conference Date: June 17-19, 1992

Publication Date: January 1994

Chapter Title: Money, Output, Exchange Rate, and Price: The Case of Taiwan

Chapter Author: Chung-Shu Wu, Jin-Lung Lin

Chapter URL: http://www.nber.org/chapters/c8532

Chapter pages in book: (p. 185 - 202)

7 Money, Output, Exchange Rate, and Price: The Case of Taiwan

Chung-Shu Wu and Jin-Lung Lin

7.1 Introduction

Does a high growth rate of the money supply necessarily cause a high inflation rate? From table 7.1, it can be shown that from 1981 to 1989, the average annual growth rate of the money supply (M_2) was 22.40 percent. Though the average annual growth rate of real GNP was 8.36% in the same period, there still existed a large gap between the growth rates of nominal GNP and money supply. This puzzling phenomenon was especially apparent during the period 1986–88. Then, the annual growth rates of M_{1b} were extremely high, 33.55, 45.66, and 29.45 percent for each year, respectively. Nevertheless, during the same period, price indexes were either stable or trended downward; among them, the annual growth rates of the CPI were 0.70, 0.51, and 1.29 percent, respectively, and annual growth rates of the WPI were −3.34, −3.25, and −1.56 percent. This strange phenomenon has caused people to wonder whether there *is* a specific relationship between money supply and price.

Many papers have been written on the relationship between money supply and prices. However, the conclusions of these papers are not uniform. For example, Perry (1980) and Saini (1982) find no evidence that money supply has a significant impact on prices. In contrast, Bordo and Choudhri (1982), Burger (1978), Yu (1977), and Wu (1989) do find such evidence. Moreover, little of the existing empirical literature explicitly takes into account the role the exchange rate plays in the relationship between money supply and prices. From

Chung-Shu Wu is research fellow of the Institute of Economics, Academia Sinica. Jin-Lung Lin is associate research fellow of the Institute of Economics, Academia Sinica.

The authors are grateful to Takatoshi Ito for his constructive criticism and helpful suggestions. We are also indebted to two referees, Maria Gochoco and Khee Glap Tan, for clarifying discussions and valuable advice. Finally, we have benefited from comments by Anne Krueger, Koichi Hamada, Rachel McCulloch, and the participants in the conference.

Table 7.1 **Annual Growth Rates of Money Supply, Real GNP, and Prices in Taiwan, 1971–91 (percentage change)**

Year	*M1B*	*M2*	CPI	WPI	PGDP
1971	—	—	2.79	0.02	—
1972	28.97	28.33	2.97	4.47	5.84
1973	52.12	37.52	8.20	22.85	14.80
1974	20.34	21.07	47.46	40.58	32.70
1975	24.24	31.56	5.23	−5.07	2.27
1976	21.09	21.82	2.49	2.77	5.37
1977	29.63	30.99	7.04	2.76	6.26
1978	36.61	31.14	5.77	3.54	5.26
1979	19.27	17.24	9.75	13.83	11.50
1980	19.42	18.14	19.01	21.54	16.19
1981	14.50	18.89	16.33	7.62	12.14
1982	15.53	23.03	2.96	−0.18	3.47
1983	17.92	26.25	1.36	−1.18	1.95
1984	14.07	23.33	−0.03	0.47	0.86
1985	8.19	21.29	−0.16	−2.59	0.62
1986	33.55	23.31	0.70	−3.34	3.36
1987	45.66	26.57	0.51	−3.25	0.53
1988	29.45	22.06	1.29	−1.56	1.05
1989	12.75	16.83	4.41	−0.37	3.10
1990	−3.31	10.96	4.13	−0.61	3.80
1991	6.62	15.70	3.62	0.17	3.97

Year	RGNP	RX	PM	JUVM1	JUVM2	JUVM 3&4
1971	13.01	0.00	3.61	—	—	—
1972	13.38	0.00	7.07	—	—	—
1973	12.78	−4.47	19.17	45.68	5.47	22.39
1974	1.16	−0.68	49.06	56.49	206.25	33.53
1975	4.44	0.00	−5.58	−13.02	−1.42	−2.09
1976	13.70	0.00	1.16	−4.19	8.32	−3.82
1977	10.25	0.00	7.77	2.53	6.75	9.20
1978	13.99	−2.74	9.19	−2.11	−0.70	17.16
1979	8.45	−2.59	16.35	17.07	27.83	17.05
1980	7.12	−0.01	20.29	66.42	74.57	12.53
1981	5.76	2.35	8.64	−24.38	14.36	9.58
1982	4.05	6.19	−0.70	−10.44	0.66	−2.19
1983	8.65	2.41	−1.47	−6.71	−9.27	−5.70
1984	11.59	−1.17	−0.38	9.90	−4.22	1.78
1985	5.55	0.58	−1.25	−13.51	−2.96	−7.76
1986	12.57	−4.99	−10.06	−13.11	−38.36	−4.11
1987	11.87	−16.12	−7.58	−12.03	−9.6	−8.17
1988	7.84	−9.93	−0.69	6.08	−19.17	4.06
1989	7.33	−7.63	−2.24	−11.13	1.45	−2.40
1990	5.02	1.84	2.87	1.68	21.08	−6.68
1991	7.32	−0.29	−0.85	−1.16	−5.23	−0.61

Notes: M_{1b} = currency in circulation + checking accounts + passbook deposit; $M_2 = M_{1b}$ + quasi money; CPI-consumer price index; WPI-wholesale price index; PGDP-GDP deflator; RGNP = real GNP at 1986 constant prices; RX = exchange rate (*NT/US*); PM = import price index; JUVM1 = import unit value index (agriculture, forestry, fishery, livestock, and hunting products); JUVM2 = import unit value index (minerals); JUVM3&4 = import unit value index (manufacturing products).

the traditional quantity theory of money we know, under the assumption of constant transaction velocity, that the nominal money supply has a positive relationship and real transactions a negative relationship with the price level. With the long-run income elasticity of money demand being 1.6, this high growth rate of real GNP can partly explain why we had only a moderate price fluctuation in the 1970s and early 1980s.[1] However, high growth of real GNP can not explain the case in the late 1980s. Though, in that period growth rates of real GNP were indeed very high, the average inflation rate was much lower than in the 1970s or early 1980s. In addition, if we take a close look at the fluctuation of the exchange rate (see table 7.1) we find that during the period 1985–89, the New Taiwan (NT) dollar appreciated from 39.83 to 26.41 to the U.S. dollar, an appreciation rate of 33.69 percent. Because of this appreciation of the NT dollar, the import price index was decreasing in the late 1980s—during the period 1985–89 the average annual growth rate of the import price index was −4.36 percent—and most of the group import unit value indexes were decreasing as well (see table 7.1).

From these statistics we can see that it may be important to take into account the fluctuation of exchange rates when we discuss the relationship between money supply and inflation rate. If we neglect the impact of the exchange rate as do most traditional empirical studies, we might not be able to explain fully the behavior of price movement and might obtain incorrect predictions of future inflation rates. Therefore, the main purpose of this paper is to reexamine the long-run equilibrium relationship between money supply, output, and price by appropriately taking into account the exchange rate.

Recognizing the importance of stationarity in regression analysis, economists often take the difference of a series to remove the stochastic trend and then proceed with the regression analysis using the differenced series. However, as should be clear from section 7.3, the existence of a long-run equilibrium imposes linear constraints on the long-run components of those variables and taking differences would result in the loss of this precious information. Cointegration analysis—the technique we employ—allows long-run components to obey equilibrium constraints while short-run components have a flex-

1. An equation in Wu (1987) shows that the short-run money demand function of Taiwan can be expressed as

$$\underset{}{m_t} = \underset{(-1.854)}{-1.175} + \underset{(2.105)}{0.393Y_t} - \underset{(-3.825)}{0.092r_t} + \underset{(6.544)}{0.750(M_{t-1}-P_t)} - \underset{(6.948)}{0.879\Delta P_t} + \underset{(3.239)}{0.029Q3}$$

$$+ \underset{(3.180)}{0.035Q4} + \underset{(6.642)}{0.061Q1},$$

$$\rho = 0.252(1.66),\ \bar{R}^2 = 0.993,\ \text{D-W} = 1.996,\ \text{SEE} = 0.022,$$

$$LM1 = 0.0004,\ LM2 = 0.900,\ LM3 = 1.332,$$

where m = real money supply, Y = real GNP, r = interest rate, M = nominal money supply, P = price level, ΔP = change of price, Qi = seasonal dummy, ρ = first order serial correction coefficient, $\bar{R}^2 = R^2$, LM = Lagrangian multiplier jth order serial correlation test. It can be calculated from this equation that the long-run income elasticity of money demand is about 1.6 which is very similar to the results found by Chiu (1992), Chiu and Hou (1992), and Shih (1988).

ible dynamic specification. The estimation method adopted here is Johansen's high-powered maximum likelihood procedure (Johansen 1988; Johansen and Juselius 1990).

The remaining sections of the paper are organized as follows. In section 7.2 we use a simple model to illustrate the relationship between money, output exchange rate, and price. Section 7.3 discusses the statistical method used to analyze the cointegrated systems, section 7.4 offers some empirical results, and section 7.5 contains some concluding remarks.

7.2 Money, Output, Exchange Rate, and Prices

Assuming a two-goods small open economy, the general price index, π, is mainly composed of the domestic price of domestic output, P, and the domestic price of the foreign good, Q, i.e., the general price index can be defined as

$$\pi_t = \theta p_t + (1 - \theta)q_t, 0 \leq \theta \leq 1, \tag{1}$$

where lower-case letters represent the natural logarithm of the values of upper-case letters and θ is the domestic consumption share of the domestic good.[2]

Suppose that the currency of this country can only be used as an exchange medium for domestic transactions and there is no transaction friction in this economy. From the well-known quantity theory of money, the increase of prices of domestic goods would be proportionate to the increase in the domestic money supply. Written in a logarithm form, the old quantity theory can be expressed as

$$m + v = p + y, \tag{2}$$

where m is the logarithm of domestic money supply, v is the logarithm of the velocity with which domestic money circulates, and y is the logarithm of the level of total domestic transaction. If v is constant or growing at a steady rate and y is also growing at a steady rate, changes in p would be directly related to changes in m.

If the goods markets are determined through arbitrage, then the domestic price of the foreign good is the foreign price of the foreign good multiplied by the exchange rate. Written in a logarithm form, this relationship can be expressed as

$$q_t = q_t^* + e_t, \tag{3}$$

where q_t^* is the logarithm of the foreign price of the foreign good and e_t is the logarithm of the spot exchange rate (defined as the price of a unit of foreign money in terms of domestic money).

2. The cost of living is best measured by a price index when the utility function is of Cobb-Douglas form.

Combining equations (1), (2), and (3), the relationship among money, total transaction exchange rate, and prices can be stated as

$$\pi_t = \theta(m + v - y) + (1 - \theta)(q_t^* + e_t). \tag{4}$$

For analytical convenience, we assume the velocity of transactions and the foreign-currency price of foreign goods are constant and are normalized to zero. Therefore, it can be seen from (4) that the domestic money supply and the exchange rate should have a positive relation with the domestic general price index, i.e., the increase of domestic money supply and the depreciation of domestic currency would raise the domestic general price index. In contrast, the increase of total transactions would decrease the domestic general price index.

The above deduction might explain why the high growth rates of money supply in Taiwan in the 1980s did not coincide with high inflation rates. From 1981 to 1989, the average annual growth rate of the money supply (M_2) was 22.40 percent. However, the average growth rate of real GNP, which is a proxy for total domestic transaction, was 8.36 percent. In addition, during the same period, the NT dollar appreciated from 37.79 NT/U.S. dollar to 26.12, an appreciation rate of 29.7 percent. The implication is that, though the growth rate of the money supply had a positive effect on inflation rates, high real output growth and the appreciation of the exchange rate resulted in low inflation rates in the 1980s. Thus, we investigate the relationship between money, output, exchange rate, and prices in Taiwan and try to find out whether there is a long-run relationship among them.

7.3 Statistical Analysis of a Cointegrated System

Traditional least squares regression analysis usually suffers the problem of nonstationarity of the time series. Phillips (1986) showed that, in least squares regressions with nonstationary regressors, coefficient estimates might not converge in probability as the sample size increases, and the distribution of t-statistics diverge. Therefore, in this paper we adopted Johansen's maximum likelihood cointegration analysis to discuss the relationship between money, output, exchange rate, and prices in Taiwan.

Before we do the empirical analysis, we define the order of integration and cointegration (Granger 1981).

Definition: A series X_t is said to be *integrated of order d,* denoted $X_t \sim I(d)$, if $(1 - B)^d X_t = Z_t$, where $a_p(B)Z_t = b_q(B)\varepsilon_t, \varepsilon_t$, is white noise, and the roots of $a_p(B)$ and $b_q(B)$ lie outside the unit circle with no common factor. The components of the vector X_t are said to be *cointegrated of order (d, b),* denoted $X_t \sim CI(d, b)$ if

(1) all components of $X_t \sim I(d)$, and

(2) there exists a vector β ($\neq 0$) such that $Z_t = \beta' X_t \sim I(d - b)$, where $b > 0$. The vector β is called the cointegrating vector.

The definition states that certain linear combinations of the components of the vector process are integrated of lower order than the process itself. As an immediate consequence, each variable can be nonstationary and can fluctuate rapidly whereas certain linear combinations of them fluctuate smoothly and rarely drift away from the attraction domain.

Granger (1983) and Granger and Weiss (1983) proved that any cointegrated vector system, X_t, has the error correction (EC) representation and vice versa. This result was later coined as the Granger Representation Theorem:

$$(5) \qquad A^*(B)(1 - B)X_t = -\alpha\beta' X_{t-k} + \varepsilon_t ,$$

where $A^*(0) = I_p$ and α and β are $p \times r$ matrices with $r \leq p$.

It is this representation theorem which endows cointegration with an economic equilibrium interpretation that has attracted economists' attention. To illustrate the main idea, assume $d = b = 1, p = 2$, and $r = 1$. Then after some rearrangement, (5) becomes

$$(6) \quad \Delta y_t = a_1\Delta y_{t-1} + \ldots + a_{k-1}\Delta y_{t-k-1} + b_1\Delta\chi_{t-1} + \ldots + b_{k-1}\Delta\chi_{t-k-1} + \alpha(y_{t-k} - \beta\chi_{t-k}) + \varepsilon_t.$$

Note that all terms in this difference are $I(0)$, and for the equation to be "consistent," the only term in level, $y_{t-k} - \beta\chi_{t-k}$ has to be $I(0)$ too. This term is called the cointegration error and measures the disequilibrium effects of the last k periods on the adjustment path of y_t. All other terms in the difference capture the short-run dynamics of the economic system. When the economy converges to a steady state all terms, including the cointegration error, approach zero. In other words, in equilibrium, y_t and x_t tend to stay in the equilibrium region, a linear line $y = \beta\chi$, in our case.

As the cointegrated system contains integrated regressors, the traditional asymptotic distribution results for regression parameters no longer hold. The t and F statistics do not follow the t and F distributions, respectively, even when the sample size is large. To tackle the estimation and testing issue, Engle and Granger (1987) suggest the two-step regression procedure.[3] Johansen (1988, 1991) makes an important contribution by (1) extending the bivariate system to a multivariate one and (2) deriving the maximum likelihood estimator and the asymptotic distribution of the likelihood ratio statistic, to which we now turn.

A vector autoregressive process is used to model the given series X_t:

$$(7) \qquad X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \varepsilon_t,$$

3. This two-step estimator has been investigated by Stock (1987), Phillips (1988a, 1988b), Phillips and Durlauf (1986), Phillips and Park (1988), Phillips and Quliaris (1990), and Stock and Watson (1987).

where $t = 1, \ldots, T$, X_t has p elements, $\varepsilon_1, \ldots, \varepsilon_T$ are *i.i.d.* $N_p(0, \Lambda)$, and $X_{-k+1}, \ldots, X_0$ are given. Denoting the lag operator by B and setting $\Delta = 1 - B$, we rewrite the model as

(8) $$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Gamma X_{t-k} + \varepsilon_t,$$

where

(9) $$\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i,\ i = 1, \ldots, k-1,$$

and

(10) $$\Gamma = -I + \Pi_1 + \ldots + \Pi_k.$$

Information about the long-run equilibrium is embedded in the coefficient matrix Γ. If the Γ is of full rank, then X_t is stationary. If Γ is the null matrix, then X_t is the traditional p-dimensional multivariate ARIMA(k, 1, 0) process. Finally, if $0 < \text{rank}(\Gamma) = r < p$, then there are r cointegration vectors. That is, there are $p \times r$ matrices α and β such that $\Gamma = \alpha\beta'$ and $\beta' X_t$ is stationary. Thus, the issue of testing a cointegration system is equivalent to testing the rank of Γ. More specifically,

(11) $$H_0: \Gamma = \alpha\beta',$$

where α and β are $p \times r$ matrices with full column rank and $r \leq p$.

Johansen (1988, 1991) proved that under the null hypothesis, $\Gamma = \alpha\beta'$, the maximum likelihood estimator of β is the first r eigenvectors, $\hat{v}_1, \ldots, \hat{v}_r$, corresponding to the r largest eigenvalues, $\hat{\lambda}_1 > \ldots > \hat{\lambda}_r$, of $S_{k0} S_{00}^{-1} S_{0k}$ with respect to S_{kk}, where

(12) $$S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R'_{jt},\ i,j = 0, k\ ,$$

and R_{0t} and R_{kt} are the regression residuals of ΔX_t and X_{t-1} on lagged differences $\Delta X_{t-1}, \ldots, \Delta X_{t-k-1}$, respectively.

The likelihood ratio test statistic that there are at most r cointegration vectors is

(13) $$-2\ln(Q) = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i)\ ,$$

and its asymptotic distribution is

(14) $$\text{tr}\left[\int_0^1 dBB' \left(\int_0^1 BB' du\right)^{-1} \int_0^1 dB'B\right],$$

where B is a $(p - r)$-dimensional Brownian motion with covariance matrix I.

The likelihood ratio test statistic for testing $H_0(r)$ against $H_0(r + 1)$ is given by

(15) $$-2\ln(Q; r/(r+1)) = -T\ln(1 - \hat{\lambda}_{r+1})\ ,$$

with asymptotic distribution

$$(16) \qquad \lambda_{\max}\left\{\int_0^1 dBB'\left(\int_0^1 BB'du\right)^{-1}\int_0^1 dBB'\right\},$$

where $\lambda_{\max}\{M\}$ denotes the maximal eigenvalue of M.

Equations (14) and (16) are referred to as trace and λ-max statistics, respectively. However, they are too complicated to have an analytical expression of their critical values, and hence we have to rely on a simulation experiment. The critical values can be found in Johansen and Juselius (1990).

7.4 Empirical Results

The data used in this paper is monthly data from January 1981 to January 1992.[4] Industrial production is used as a proxy for income, which is unavailable on a monthly basis. Money supply is measured by M_2 rather than M_{1b},[5] the exchange rate by the exchange rate of the U.S. dollars in terms of NT dollars, and prices by the CPI.[6] All variables are measured in logarithms and their graphs appear in figure 7.1.

It can be seen from figure 7.1 that the series are either increasing or decreasing through time, i.e., they are not stationary. To investigate the existence of a unit root, Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests with lags set to 4 are used. The t-statistics of ρ in the following regression are compared with the 95 percent quantile, 3.37 for DF and 3.17 for ADF.

$$(17) \qquad \text{DF Test: } \Delta Y_t = -\rho Y_{t-1} + \varepsilon_t .$$

$$(18) \qquad \text{ADF Test: } \Delta Y_t = -\rho Y_{t-1} + \alpha_1 \Delta Y_{t-1} + \ldots \alpha_4 \Delta Y_{t-4} + \varepsilon_t .$$

All variables overwhelmingly pass the test and we cannot reject the null hypothesis that each series has a unit root. The results are reported in table 7.2.

Equation (8) including a constant and 11 monthly dummies with $k = 3$ is fitted to the data. The Box-Pierce statistic with 12 degrees of freedom is computed for each equation to check the remaining serial correlation in the residuals. The critical value of chi-square distribution with size 0.05 is 21.026. As is obvious from table 7.3, all equations pass the test of no serial correlation in the residual. As for normality, we compute the Jarque and Bera (1980) statistics. All except money fail the test. However, since all four variables are fairly symmetrically distributed, this nonnormality should not cause serious prob-

4. Though the Taiwanese government adopted the floating exchange rate system in July 1978, it was not until March 1980 that the Central Bank in Taiwan eliminated the fluctuating range limit of the NT dollar.

5. M_2 is a broader definition of the money supply and is more appropriate than M_1 for explaining the fluctuation of prices. In their study of the Danish economy, Johansen and Juselius (1990) also use M_2 to measure the money supply.

6. The source of this data is the Taiwan EPS data bank, Ministry of Education.

Table 7.2 **Unit Root Test of Four Series**

Series	Dickey-Fuller	Augmented Dickey-Fuller
JQIND	2.377	0.632
M_2	1.315	1.835
RX	−1.485	0.055
CPI	−1.098	−1.074

Note: JQIND = industrial production; M_2, RX, and CPI as in Table 7.1.

Table 7.3 **Summary Statistics for Four Residuals**

Series	Skewness	Kurtosis	Normality ($\chi^2(2)$)	B.P.-Q ($\chi^2(12)$)
JQIND	−0.7030	2.460	43.491	8.538
M_2	−0.0756	0.599	2.067	17.352
RX	−0.8480	2.285	43.875	9.357
CPI	0.2400	1.293	10.306	12.380

Note: All series as defined in tables 7.1 and 7.2.

lems. The robustness of the maximum likelihood estimation (MLE) procedure is still an open question.

We have summarized in table 7.4 the estimated eigenvectors and eigenvalues and λ-max and trace test statistics. Using the trace test procedure for the hypothesis $r \leq 1$, the likelihood ratio statistic

$$-2\ \ln(Q) = -T \sum_{i=2}^{3} \ln(1 - \hat{\lambda}_i) = 30.372 \tag{19}$$

is insignificant as compared with the 95 percent quantile, 35.07. For the hypothesis $r = 0$, the test statistic is 58.79, which is greater than the 95 percent quantile, 53.35.

Using the λ-max test procedure for the hypothesis $r \leq 1$, the likelihood ratio statistic

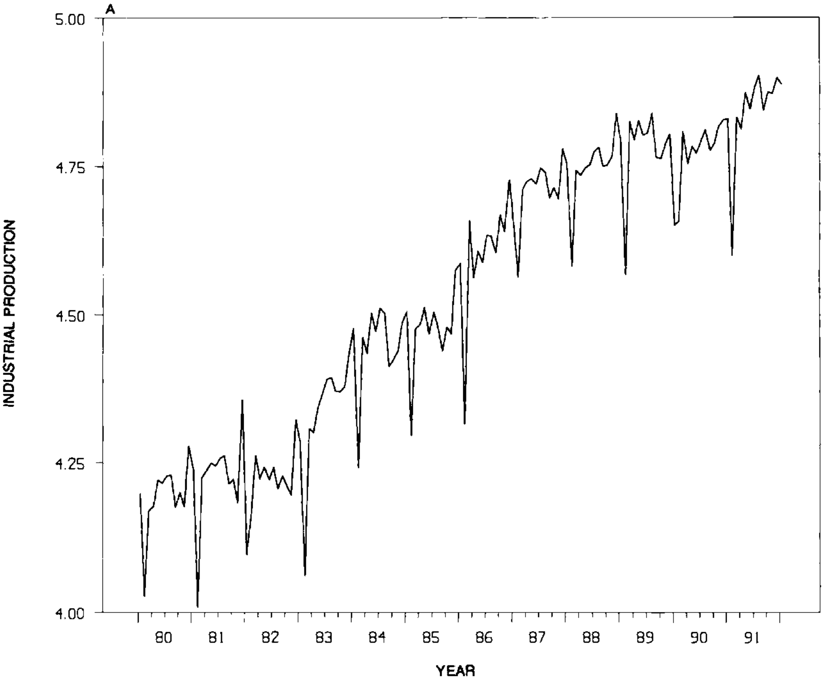
$$-2\ \ln\ (Q{:}\ r = 0 | r = 1) = 28.39 \tag{20}$$

is barely greater than the 95 percent quantile, 28.17. All these together strongly indicate that the rank of cointegration is 1.

The estimated long-run equilibrium relationship is

$$\pi_t = -3.771Y_t + 1.277m_t + 0.691e_t\,. \tag{21}$$

All the signs are exactly the same as predicted by the theory: money supply and exchange rate have positive effects on price, and output has a negative effect. The graph of all three cointegration relationships appear in figure 7.2. For comparison, we also include cointegration relationship 4, though it is not statistically significant.



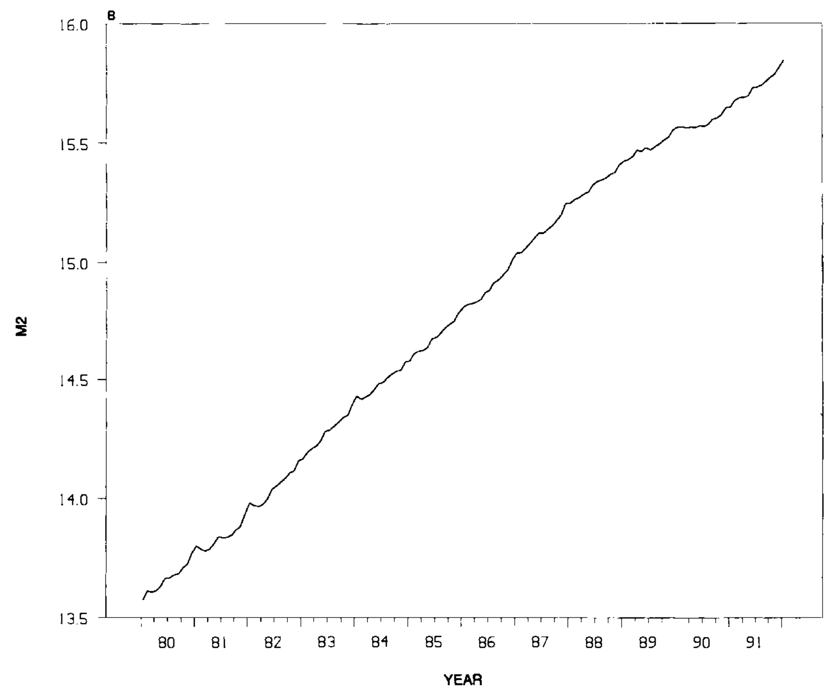
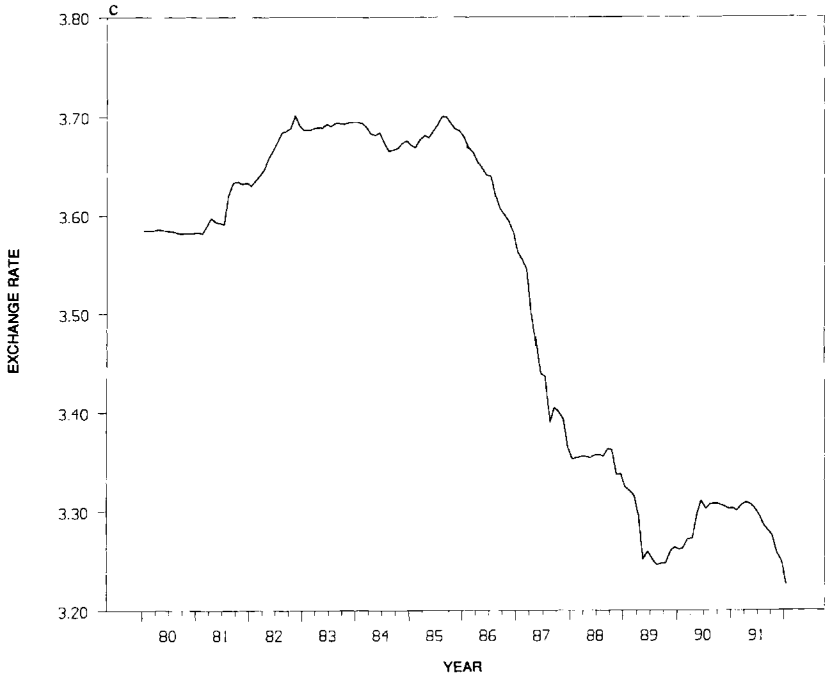


Fig. 7.1 A, Industrial production in Taiwan; B, M2 in Taiwan; C, exchange rate in Taiwan; D, consumer price index in Taiwan



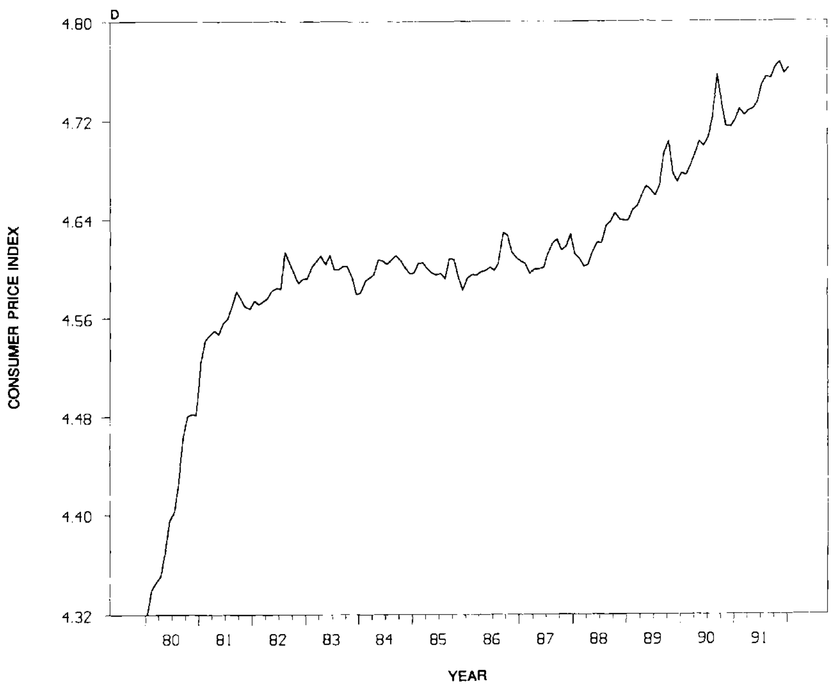


Fig. 7.1 (continued)

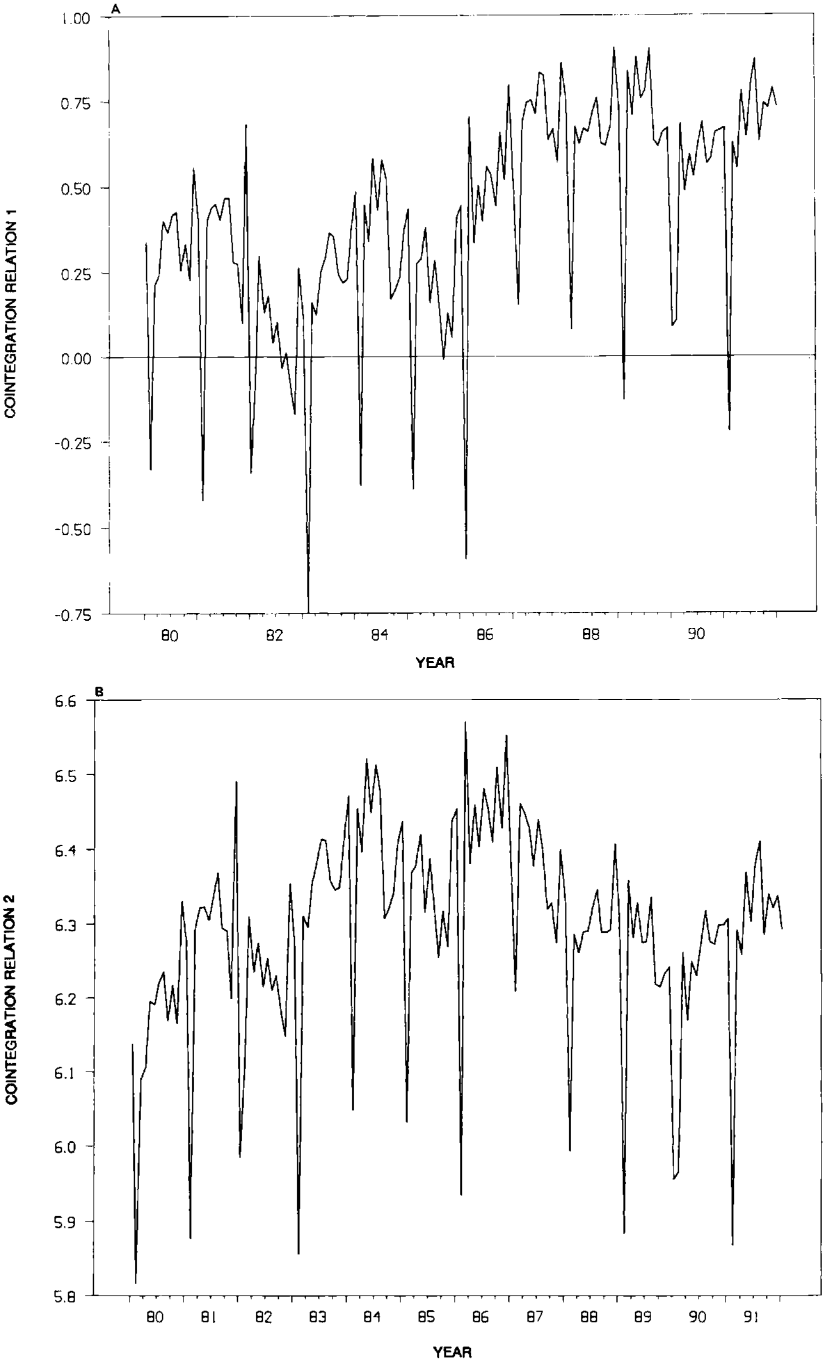


Fig. 7.2 A, Cointegration relation 1; B, cointegration relation 2; C, cointegration relation 3; D, cointegration relation 4

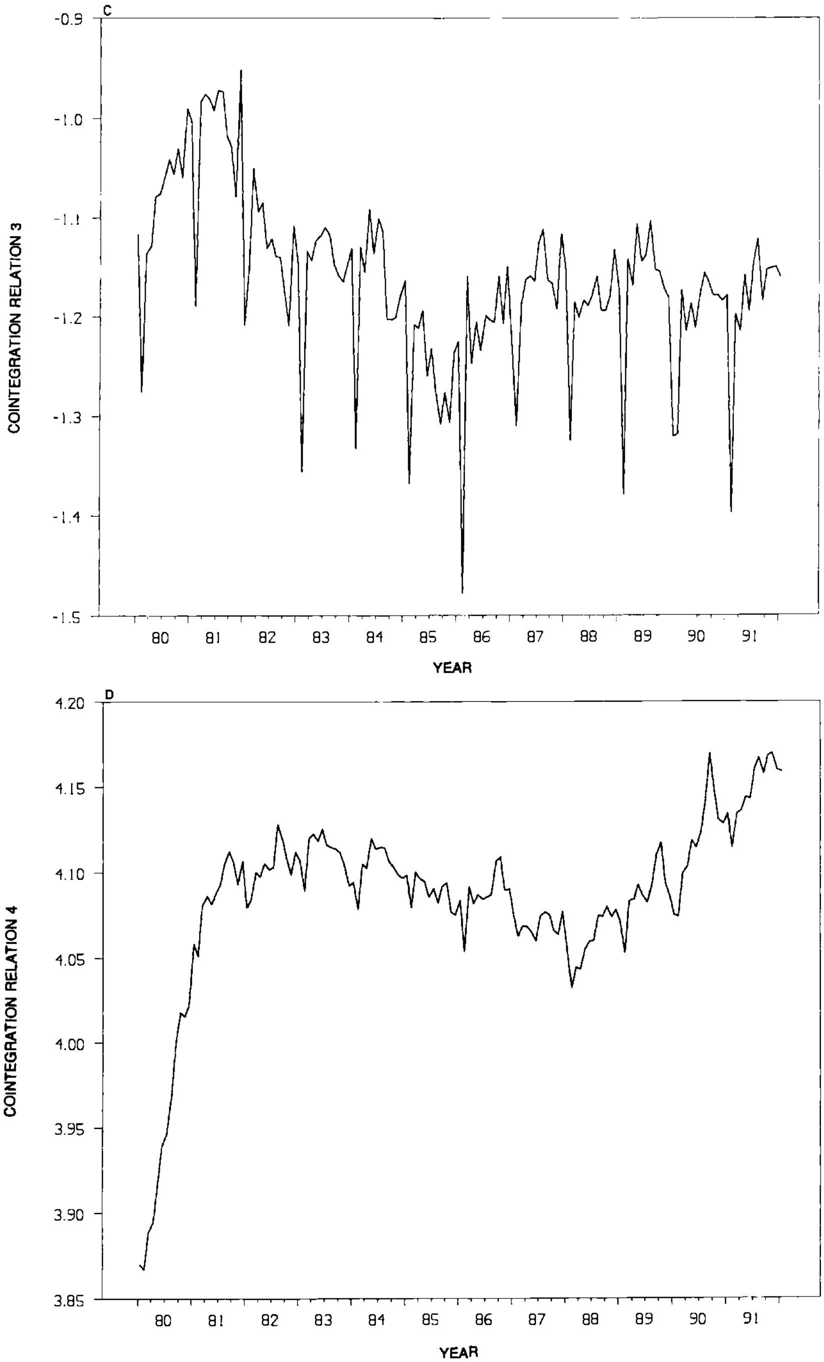


Fig. 7.2 (continued)

Table 7.4 **Estimated Eigenvalues and Eigenvectors, λ-Max Test, and Trace Test.**

Eigenvalues and λ-Max and Trace Test Statistics			
0.19623	0.14667	0.07100	0.00153
28.39719	20.61971	9.57369	0.19917
0.19917	9.77285	30.39257	58.78976
Eigenvectors			
20.842	−30.485	−15.534	4.833
7.057	9.800	9.505	−3.783
−3.819	−9.699	7.609	3.274
5.527	−16.338	−16.776	42.726

Note: In upper half, first row lists eigenvalues in descending order, second row the λ-max test statistics, and third row the trace test statistics. In lower half, each column vector is the eigenvector corresponding to the eigenvalue above in the same column.

For short-run dynamics, the error correction equation for price (monthly dummies not reported here) can be expressed as follows.[7]

$$
\begin{aligned}
\Delta\Pi_t = &- \underset{(-\,0.582)}{0.004} + [\,\underset{(2.155)}{0.015} * (\,\Pi_{t-1} + 0.377\ Y_{t-1} - 1.277\ m_{t-1} \\
&- 0.691\ \mathrm{e}_{t-1})] + [\,-\underset{(-\,2.053)}{0.055}\ \Delta Y_{t-1} - \underset{(-\,1.931)}{0.052}\ \Delta Y_{t-2} \\
&- \underset{(-\,2.154)}{0.057}\ \Delta Y_{t-3} - \underset{(-\,2.425)}{0.064}\ \Delta Y_{t-4} - \underset{(-\,2.366)}{0.060}\ \Delta Y_{t-5} - \underset{(-\,2.576)}{0.063}\ \Delta Y_{t-6} \\
&- \underset{(-\,4.645)}{0.106}\ \Delta Y_{t-7} - \underset{(-\,3.919)}{0.093}\ \Delta Y_{t-8} - \underset{(-\,2.278)}{0.048}\ \Delta Y_{t-9} - \underset{(-\,0.771)}{0.011}\ \Delta Y_{t-10} \\
&- \underset{(-\,0.869)}{0.068}\ \Delta m_{t-1} - \underset{(-\,0.206)}{0.015}\ \Delta m_{t-2} - \underset{(-\,2.111)}{0.169}\ \Delta m_{t-3} - \underset{(-\,0.784)}{0.062}\ \Delta m_{t-4} \\
&- \underset{(-\,1.703)}{0.132}\ \Delta m_{t-5} - \underset{(-\,0.293)}{0.022}\ \Delta m_{t-6} + \underset{(1.927)}{0.139}\ \Delta m_{t-7} + \underset{(2.604)}{0.194}\ \Delta m_{t-8} \\
&+ \underset{(1.775)}{0.137}\ \Delta m_{t-9} + \underset{(2.047)}{0.157}\ \Delta m_{t-10} + \underset{(2.542)}{0.198}\ \Delta m_{t-11} - \underset{(-\,0.172)}{0.013}\ \Delta m_{t-12} \\
&+ \underset{(0.168)}{0.014}\ \Delta e_{t-1} + \underset{(0.140)}{0.012}\ \Delta e_{t-2} + \underset{(0.237)}{0.019}\ \Delta e_{t-3} + \underset{(0.080)}{0.007}\ \Delta e_{t-4} \\
&- \underset{(1.050)}{0.086}\ \Delta e_{t-5} + \underset{(0.511)}{0.040}\ \Delta e_{t-6} + \underset{(1.049)}{0.083}\ \Delta e_{t-7} + \underset{(0.477)}{0.037}\ \Delta e_{t-8} \\
&+ \underset{(2.784)}{0.215}\ \Delta e_{t-9} + \underset{(1.487)}{0.120}\ \Delta e_{t-10} - \underset{(-\,2.361)}{0.262}\ \Delta\Pi_{t-1} - \underset{(-\,3.671)}{0.392}\ \Delta\Pi_{t-2}
\end{aligned}
\tag{22}
$$

7. We delete terms which are not significant; such elimination does not significantly affect the magnitude or the significance of other coefficients (Leamer 1978).

$$- 0.254\,\Delta\Pi_{t-3} - (0.129\,\Delta\Pi_{t-4}] + \varepsilon_t\,,$$
$$(-\,2.465) \qquad (-1.248)$$
$$\bar{R}^2 = 0.420,\ \mathrm{SEE} = 0.007,\ \text{D-W} = 2.015,\ Q(30)_{S.L.} = 0.981\ .$$

While the term in the first bracket captures the long-run adjustment effect, terms in the second bracket reflect the short-run dynamics. As can be expected, disequilibrium factors push inflation high, and growth of real income has a negative effect on the inflation rate, while an increase in the money supply and a depreciation of the exchange rate have positive effects. We also note that, for short-run adjustment, the negative effect of real output on price can last as long as nine months, and the positive effect of money supply on price may not show up until six months later. Moreover, though the exchange rate has a positive effect on price in the long run, for short-run adjustment, this positive effect becomes significant only eight months later.

7.5 Conclusion

This paper has examined the relationship between money supply, real output, exchange rate, and price using recently developed cointegration techniques. We adopted the maximum likelihood method developed by Johansen. Only by using this sophisticated statistical technique can a multivariate cointegrated system be properly analyzed.

Our empirical results using Taiwan monthly data over the period January 1981 to February 1992 show that money supply (M_2), real output, exchange rate, and price (CPI) are cointegrated with rank one. The estimated equilibrium and the short-run dynamic relationship shows that, as predicted by the theory, an increase in the money supply and a depreciation of the exchange rate have positive effects on price, while increase of real output has a negative effect. This provides a possible explanation of why the high growth rates of money supply during the 1980s in Taiwan did not cause high inflation rates, i.e., during the same period the growth rate of real GNP was relatively high and the exchange rate was appreciating sharply.

One innovation of this paper is examining the relationship between money, output, and price by appropriately taking into account the exchange rate. However, the approach we adopted using aggregate analysis cannot see the impact of exchange rate appreciation on different sectors. It also cannot help us to understand pass-through effects. All these are interesting topics for future research.

References

Bordo, M. D., and E. V. Choudhri. 1982. The link between money and prices in an open economy: The Canadian evidence from 1971 to 1980. *Review* (Federal Reserve Bank of St. Louis) 64 (7): 13–23.

Burger, A. 1978. Is inflation all due to money? *Review* (Federal Reserve Bank of St. Louis) 60 (12): 8–12.

Chiu, P. C. H. 1992. Money and financial markets: The domestic perspective. In *The Taiwan: From developing to mature economy*, ed. G. Ranis, 121–93. Boulder, Colo.: Westview.

Chiu, P. C. H., and T. C. Hou. 1992. Prices, money and monetary policy implementation under financial liberalization: The case of Taiwan. Paper presented at OECD Development Centre Seminar on Financial Opening: Developing Country Policy Issues and Experience.

Engle, R. F., and C. W. J. Granger. 1987. Cointegration and error-correcting: Representation, estimation and testing. *Econometrica* 55:251–76.

———. 1991. *Long-run economic relationships: Reading in cointegration.* Oxford: Oxford University Press.

Gonzalo, J. 1989. Comparison of five alternative methods of estimating long run equilibrium relationships. Discussion Paper 89–55, University of California, San Diego.

Granger, C. W. J. 1981. Some properties of time series data and their use in econometrica model specification. *Journal of Econometrics* 16:121–30.

———. 1983. Co-Integrated variables and error-correcting models. Discussion Paper 83-13, University of California, San Diego.

Granger, C. W. J., and A. A. Weiss. 1983. Time series analysis of error-correcting models. In *Studies in econometrics, time series, and multivariate statistics*, ed. S. Karlin, T. Amemlya, and L. A. Goodman, 255–78. New York: Academic Press.

Jarque, C. M., and A. K. Bera. 1980. Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economic Letters* 6:255–59.

Johansen, S. 1988. Statistical analysis of cointegrating vectors. *Journal of Economic Dynamics and Control* 12:231–54.

———. 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector regression models. *Econometrica* 59:1551–80.

Johansen, S., and K. Juselius. 1990. Maximum likelihood estimation and inferences on cointegration with applications to demand for money. *Oxford Bulletin of Economics and Statistics* 52:169–210.

Leamer, E. E. 1978. *Specification search: Ad hoc inference with nonexperimental data.* New York: Wiley.

Lin, J. L., and Y. S. Kao. 1992. Long run equilibrium relationship among part-time, full-time female labor force participation rates: An application of cointegration analysis. *Academia Economic Papers* (Taipei: Institute of Economics, Academia Sinica) 20:201–41.

Perry, G. 1980. Inflation in theory and practice. *Brookings Papers on Economic Activity* 1:207–41.

Phillips, P. C. B. 1986. Understanding spurious regressions in econometrics. *Journal of Econometrics* 33:311–40.

———. 1988a. Optimal inference in cointegrated systems. *Cowles Foundation Discussion Paper* 866. New Haven, Conn.: Cowles Foundation, Yale University.

———. 1988b. Spectral regression for cointegrated time series. *Cowles Foundation Discussion Paper* 872. New Haven, Conn.: Cowles Foundation, Yale University.

Phillips, P. C. B., and S. N. Durlauf. 1986. Multiple time series regression with integrated process. *Review of Economic Studies* 53:473–96.

Phillips, P. C. B., and J. Park. 1988. Asymptotic equivalence of ordinary least squares in regression with integrated variables. *Journal of American Statistical Association* 83:111–15.

Phillips, P. C. B., and S. Quliaris. 1990. Asymptotic properties of residual based test for cointegration. *Econometrica* 58:165–93.

Saini, K. G. 1982. The monetarist explanation of inflation: The experience of six Asian countries. *World Development* 10:881–94.

Shih, Yen. 1988. A re-examination of the short-run demand for money in Taiwan. *Quarterly Review* (Taipei: Economic Research Department, Central Bank of China) 10:21–49.
Stock, J. H. 1987. Asymptotic properties of least squares estimators of cointegrated vectors. *Econometrica* 55:1035–56.
Stock, J., and M. Watson. 1988. Testing for common trends. *Journal of the American Statistical Association* 83:1097–1107.
Wu, C. S. 1987. Price expectations, structural change and the specification of Taiwan money demand function. *Academia Economic Papers* (Taipei: Institute of Economics, Academia Sinica) 15:87–113.
———. 1989. The transaction money and prices in Taiwan. Discussion Paper no. 8901. Institute of Economics, Academia Sinica, Taipei.
Yu, Z. S. 1977. An inflation model for Taiwan. *Academia Economic Papers* (Taipei: Institute of Economics, Academia Sinica)5:1–22.

Comment Maria S. Gochoco

Wu and Lin's study examines why there is no apparent proportionate relationship between monetary growth and inflation in Taiwan using monthly data for 1981–92. The reason, as they want to show using cointegration techniques, is that the appreciation by 29.7 percent of the NT dollar between 1981 and 1989 held inflation down to 3.04 percent even as M_2 grew 22.4 percent.

I have several comments: First, on the overall style of the paper, more verbal explanations of the methodology and the empirical results would be useful. For example, the authors could explain why cointegration is a useful procedure by stating that it circumvents the need for each time series in a regression to be stationary—a requirement for standard regression techniques to work.

Second, since cointegration only tells us about the long-run equilibrium relationship between the dependent variable and the independent variables, an error-correction specification can be used to examine their behavior over the short run. Such an error-correction model forces gradual adjustment of the dependent variable toward some long-run values (estimated via cointegration) while explicitly allowing for short-run dynamics.

Third, a better justification for the use of M_2 rather than a narrower monetary aggregate must be made instead of what is stated in footnote 5.

Fourth, the final estimated inflation equation's coefficients have to be explained in light of the theory the paper tests and the statistical significance of these coefficients must also be stated. For example, it does not make sense for the coefficient on monetary growth in the inflation equation to be greater than one.

Fifth, there is hardly any discussion of the conduct of monetary policy in Taiwan. The paper makes no mention of the use by the monetary authorities of

Maria S. Gochoco is an associate professor at the School of Economics of the University of the Philippines.

open market operations, such as the Central Bank's selling its own CDs and savings bonds in 1985 and 1986, changes in the annual rate of domestic credit expansion, the depressing effect on the income velocity of money of the drop in interest rates and price stability between 1974 and 1986, and the liberalization of the foreign exchange market in Taiwan by which capital exports of $1 million to $5 million per year are allowed. These other factors may have had significant roles to play in holding inflation down despite the high rates of growth of money arising from current account surpluses.