# Money, Price Level and Output in the Chinese Macro Economy

by

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CEPS Working Paper No. 98
May 2004

Abstract: After giving a brief monetary history of the Chinese macro-economy, this paper presents an error correction model to explain the inflation rate from 1954 to 2002 by its past change, the change in log (M2/real output) and the deviation in the previous period of log price level from a regression on log(M2/real output). The model passes the Chow test for parameter stability using 1979 as the breakpoint as economic reform started in 1979. A VAR for changes in log price, log M2 and log real output is constructed with the lagged levels of the three variables and their lagged changes as explanatory variables. The coefficient matrix of the lagged levels is found to have rank one, written as ab' where b' is the transpose of the cointegrating vector, estimated previously by regressing log price on log(M2/real output) for the single error-correction equation for inflation. The impulse responses of log price and log output to innovations in log M2 are consistent with Milton Friedman's propositions on the effects of money as summarized by Bernanke (2003). Using the same VAR model and M1 instead of M2, we have found the above impulse responses to be similar for the United States and China.

*I would like to acknowledge with thanks helpful comments from seminar participants at Princeton University and financial support from the Center for Economic Policy Studies at Princeton University in conducting this research.

## I. Introduction

This paper presents an abridged history of China's macroeconomy from the early 1950s to 2004. It is abridged because only three macroeconomic variables, money stock M, real output Y and the price level P are analyzed. The basic hypothesis concerning the co-movements of these three variables is due to the work of Milton Friedman (1994). A major proposition guiding our work is that when money supply increases, whatever the cause, real output will first increase before the price level increases but real output will die down more rapidly than prices. This proposition will be used to explain the changes in the price level and output in relation to the changes in money stock in China's macroeconomic history from the 1950s to 2004. This is done in section II.

In section III we will explain the price level and inflation statistically by first estimating a linear regression of log P on log(M/P). If this regression is interpreted as a long-run equilibrium relation, or a cointegrating relation, between log P, and log (M/Y), the residuals can be interpreted as deviations from equilibrium or errors in the explanation of log P, to be denoted by u. To explain inflation as measured by $\Delta$log P, we use as explanatory variables its own lagged value, $\Delta$log(M/Y) and u(t-1). The coefficient of u(t-1) is expected to be negative because a value of log P above equilibrium in the last period will tend to dampen price increase in the current period in this error-correction equation to explain inflation. This section updates the work of Chow (1987) and follows the methodology of Engle and Granger (1987). One interesting result is that the parameters of this error-correction equation explaining inflation are temporally stable from 1954 to 2002 as confirmed by the Chow (1960) test using 1979, the year economic reform started, as the break point.

We estimate in section IV a VAR to explain the changes in the three variables, log M, log P and log Y, denoted by the vector x. The VAR is a vector regression of $\Delta$x(t) on x(t-1) and $\Delta$x(t-1). By the maximum likelihood method of Johansen (1991), the coefficient matrix of x(t-1) is found to have rank one, to be written as ab'. The vector b'x(t-1) corresponds to the regression of log P on log(M/Y) in section III, and turns out to be similar numerically. Using this VAR we compute the impulse responses of log P and log Y to unexpected changes in M2. The dynamic effects are found to be consistent with the major propositions of Milton Friedman stated above on the effects of money supply on price and output, and as recently summarized in Bernanke (2003).

Section V compares the impulse responses estimated by using US and Chinese data with M1 replacing M2, and finds that the general patterns are quite similar in spite of the institutional differences between these two countries. Section VI concludes.

## II. A Brief Monetary History of the Chinese Macro-economy

In this section we provide a brief explanation of the important movements of price and output in response to changes in money supply where money supply itself can be the result of other factors. This is a simplified economic history but it can be interesting to the extent that money supply changes can be explained and the resulting movements in price and output are consistent with Friedman's proposition as stated at the beginning of this paper. We start with an explanation of the large price changes, and then explain the large output changes.

Table 1 provides five sets of data from 1954 to 2002: General retail price index P at the end of the year (column 2), the inflation rate measured by 100 times P(t)/P(t-1) (column 3), real GDP index

Y (column 4), M2 at the end of the year in 100 million yuan (column 5) and M1 at the end of the year (column 6).

Table 1 Price Level of China and its Determinants

| Year | General retail price index | $P_t/P_{t-1}$ x100 | GDP index | M2 | M1 |
|---|---|---|---|---|---|
| 1952 | 0.8227 | 99.6 | 22 | 74.50314 | 64.6 |
| 1953 | 0.8506 | 103.4 | 25.1 | 82.00875 | 79.0 |
| 1954 | 0.8705 | 102.3 | 26.6 | 90.20963 | 87.4 |
| 1955 | 0.8793 | 101.0 | 28.3 | 94.85521 | 89.9 |
| 1956 | 0.8793 | 100.0 | 32.3 | 132.3043 | 120.0 |
| 1957 | 0.8926 | 101.5 | 33.7 | 139.0515 | 133.9 |
| 1958 | 0.8947 | 100.2 | 41.2 | 194.0242 | 213.5 |
| 1959 | 0.9028 | 100.9 | 44.6 | 226.401 | 257.4 |
| 1960 | 0.9308 | 103.1 | 43.9 | 256.6131 | 289.3 |
| 1961 | 1.082 | 116.2 | 30.9 | 286.1142 | 359.2 |
| 1962 | 1.1229 | 103.8 | 28.9 | 233.48 | 353.5 |
| 1963 | 1.0567 | 94.1 | 32 | 214.0444 | 365.6 |
| 1964 | 1.0177 | 96.3 | 37.2 | 214.5185 | 352.4 |
| 1965 | 0.9904 | 97.3 | 43.5 | 246.5319 | 399.6 |
| 1966 | 0.9875 | 99.7 | 50.9 | 285.2925 | 454.5 |
| 1967 | 0.9801 | 99.3 | 44.5 | 309.5001 | 499.1 |
| 1968 | 0.9809 | 100.1 | 44.2 | 335.6512 | 520.6 |
| 1969 | 0.9698 | 98.9 | 52.7 | 336.8679 | 505.6 |
| 1970 | 0.9676 | 99.8 | 65 | 320.8612 | 506.6 |
| 1971 | 0.9603 | 99.2 | 69.5 | 357.9469 | 553.8 |
| 1972 | 0.9581 | 99.8 | 71.5 | 404.8609 | 586.7 |
| 1973 | 0.9639 | 100.6 | 77.5 | 454.3348 | 681.4 |
| 1974 | 0.9691 | 100.5 | 78.3 | 494.3595 | 769.2 |
| 1975 | 0.9706 | 100.2 | 84.9 | 525.0772 | 845.4 |
| 1976 | 0.9735 | 100.3 | 82.6 | 573.4608 | 900.6 |
| 1977 | 0.9934 | 102.0 | 89 | 595.6617 | 905.6 |
| 1978 | 1.000 | 100.7 | 100 | 668.1896 | 954.7 |
| 1979 | 1.02 | 102.0 | 107.6 | 867.0332 | 1208.1 |
| 1980 | 1.081 | 106.0 | 116 | 1178.303 | 1486.2 |
| 1981 | 1.107 | 102.4 | 122.1 | 1453.783 | 1707.0 |
| 1982 | 1.128 | 101.9 | 133.1 | 1761.087 | 1972.9 |
| 1983 | 1.145 | 101.5 | 147.6 | 2247.387 | 2291.5 |
| 1984 | 1.177 | 102.8 | 170 | 3171.021 | 3233.0 |
| 1985 | 1.281 | 108.8 | 192.9 | 4188.024 | 3450.1 |
| 1986 | 1.358 | 106.0 | 210 | 5460.866 | 4393.8 |
| 1987 | 1.457 | 107.3 | 234.3 | 7154.482 | 5173.1 |
| 1988 | 1.727 | 118.5 | 260.7 | 9378.91 | 6376.4 |
| 1989 | 2.034 | 117.8 | 271.3 | 11836.63 | 6804.6 |
| 1990 | 2.077 | 102.1 | 281.7 | 15293.4 | 6950.7 |

| | | | | | |
|---|---|---|---|---|---|
| 1991 | 2.137 | 102.9 | 307.6 | 19349.9 | 8633.3 |
| 1992 | 2.252 | 105.4 | 351.4 | 25402.2 | 11731.5 |
| 1993 | 2.549 | 113.2 | 398.8 | 34879.8 | 16280.4 |
| 1994 | 3.102 | 121.7 | 449.3 | 46923.5 | 20540.7 |
| 1995 | 3.561 | 114.8 | 496.5 | 60705.5 | 23987.1 |
| 1996 | 3.778 | 106.1 | 544.1 | 76094.9 | 28514.8 |
| 1997 | 3.808 | 100.8 | 592 | 90995.3 | 34826.3 |
| 1998 | 3.709 | 97.4 | 638.5 | 104498.5 | 38953.7 |
| 1999 | 3.598 | 97.0 | 684.1 | 119897.9 | 45837.3 |
| 2000 | 3.544 | 98.5 | 738.8 | 134610.3 | 53147.2 |
| 2001 | 3.516 | 99.2 | 794.2 | 158301.9 | 59871.6 |
| 2002 | 3.47 | 98.7 | 857.4 | 185007 | 70881.8 |

Data Sources: *China Statistical Yearbook (2003),* for general retail price index, 1978 - 2002 (pp.313), GDP index, 1978 – 2002 (pp. 58), M1 and M2, 1990 – 2002 (pp. 704). The 1952 – 1977 data for the indices are also from earlier years of *China Statistical Yearbook* but directly taken from Chow (2002), page 120. The pre-1990 M1 is constructed as currency in circulation plus demand deposits. The pre-1990 M2 is approximated as linking currency plus savings deposits data with the official M2 series, where the linking factor is 1.58 (official M2 of 1990) / (currency + savings deposits in 1990).

To explain inflation we consider a weak form of the quantity theory of money because the functional form of the quantity equation Mv=PY may not be correct empirically. The weak form states that, with Y held constant, P tends to increase as M increases; with M constant, P tends to increase as Y decreases, and P constant, Y tends to increase as M increases. The quantity theory as specified by the particular functional form of the quantity equation may not be empirically valid even in the long run for various reasons. First, interest rate affects v and may not be constant in the long run. Second, interpreted as a demand for money equation (M/P) = Y/v, it implies an income elasticity of unity which may be empirically incorrect. We take from the quantity theory not the exact quantity equation but a weaker proposition as stated above. To explain P we first find out whether the variable M has changed if the relative change in M is much larger than the change in Y. We also examine whether Y has changed and if so it is expected to have a negative effect on P. These basic ideas are used to interpret the major changes in prices and output in China. The explanation is given verbally and informally in this section, and more formally in statistical terms in the next section.

We first examine the major changes in the price index and its relation to changes in M and possibly to Y, the latter asserting a negative effect. The data of Table 1 reveals that all episodes of inflation were associated with substantial increase in the ratio M/Y. In 1961 the price index increased by 16.1 percent while money stock (measured by M2 in this exposition but M1 will do as well) increased from 226.4 in 1959 to 286.1 in 1961, or by 26.4 percent and the real output index decreased dramatically from 43.9 in 1960 to 30.9 in 1961. The dramatic decline in output was a result of the economic failure of the Great Leap Forward Movement that had started in 1958.

In the era of economic reform after 1978 there have been episodes of inflation in 1985, 1988, and 1993-5. Money stock increased from 2247.4 at the end of 1983 to 4188.0 at the end of 1985, or by 86.3 percent in these two years, more in percentage terms than for any previous two years. The

inflation rate in 1985 was 8.8 percent. The reason for the rapid increase in money stock was the banking reform policy introduced in 1982-3 to allow the banks more autonomy to extend credits, perhaps similar to the autonomy introduced for state-owned enterprises in the reform process. From the end of 1986 to the end of 1988 money stock increased from 5460.9 to 9378.9 or by 71.7 percent in these two years. The government did not slow down the fairly rapid increase in money supply perhaps because it did not understand the mechanism of inflation as we specify in section III. The inflation rate in 1988 was 18.5 percent. The reason for this inflation rate to be higher than the rate in 1985 is the delayed effects of the substantial increases in money supply for several years prior to 1988 while the percentage increases in the years prior to 1983 were much smaller. It has been observed that inflation in 1988, together with government corruption, were the two major causes of discontent among the population and indirectly of the tragic Tiananmen Incident on June 4, 1989.

From the end of 1991 to the end of 1996 money stock increased from 19349.9 to 76094.9 or by a factor of 3.93 in 5 years. The inflation rates in 1993, 1994 and 1995 were 13.2, 21.7 and 14.8 percent respectively. The large increases in money stock in these years were the result of Deng Xiaoping's Southern Expedition in February 1992 in which he set forth a policy of further reform and opening and urged rapid development of the economy. Banks received the green light to expand credit for investment projects. It was Zhu Rongji as Governor of the People's Bank or Central Bank and later as Vice Premier who managed to stop the rapid increase in money supply after 1996 (as seen in Table 1). He did so mainly by the administrative means of assigning credit quotas to the People's Banks of different provinces and succeeded in stopping inflation. A provincial People's bank's president would lose his job if the credit quota were exceeded.

We next turn briefly to the effects on output associated with the large increases in money supply in the above episodes. Since the average rate of annual growth of real output was about 9.5 percent from 1979 to 1998, any increase much above that average can be considered large. Output increased by 170/147.6 or 15.2 percent in1984 and by 192.9/170 or 13.5 percent in 1985 when money supply increased very rapidly in 1983-4. It increased by 260.7/234.3 or 11.3 percent in 1988, and by 449.3/398.8 or 12.7 percent in 1994. This is a part of the history of China's economic fluctuations as measured by changes in total output.

The data in Table 1 terminate in 2002, but current events up to the second quarter of 2004 seem to be consistent with the proposition that increase in money supply first leads to increase in output and then to increase in prices. Money supply increased rapidly in 2002-3 mainly as a result of the large inflow of foreign exchanges acquired through large trade surplus and large foreign investment. The foreign exchange was converted into high power money in the banks. This led to rapid expansion of money and credit and to increases in investment and output in 2003, with real GDP increasing by 9.3 percent. Signs of inflation began to show in the last quarter of 2003 as Friedman would have predicted.

In presenting this abridged history of the Chinese macroeconomy we have to be aware of the possible inaccuracy of the Chinese official data on which our exposition is based. Support for the usefulness and reliability of most official Chinese data has been given in Chow (1985; 2002, pp. 90-91, 152-3; 2004, pp. 59-63). The accuracy of the data given in Table 1 can be inferred partly by using them to interpret economic reality based on confirmed economic hypotheses. The above discussion of the effect of money on prices and output is an example, while other examples can be found in Chow (2002). The accuracy of economic data and the validity of well accepted economic

hypotheses in explaining the data help to reinforce each other. The fact that official output statistics in Table 1 show a large reduction of real output in 1961 from 43.9 to 30.9 suggests that official statisticians are willing to report large economic failures of China. We hope that the reader will be able to form a better judgment on the accuracy of these data after reading the remainder of this paper.

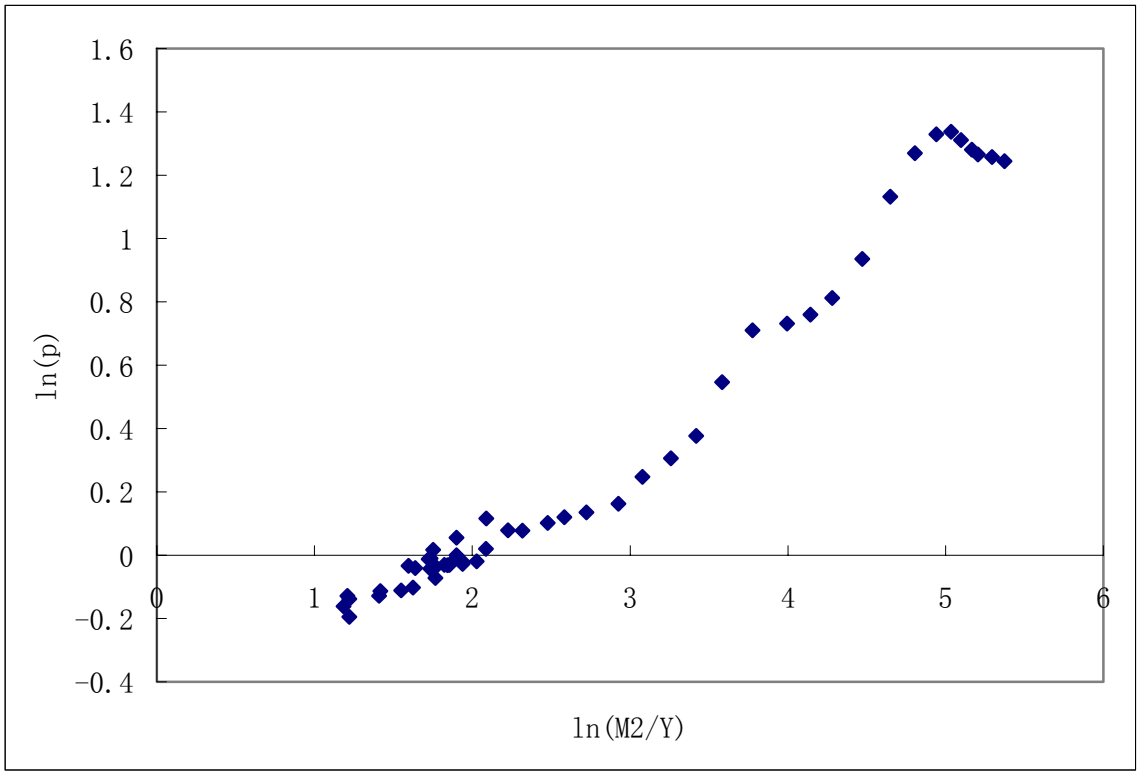
Nevertheless Young (2003) has raised questions on the accuracy of Chinese output data. His main point is that if we deflate output in money terms by its implicit deflator to obtain real output, the estimate of increase in real output is too large if the deflator underestimates the true inflation rate. By replacing the output deflator by another official price index, such as the retail price index shown in his Table 3 for deflating output of the Secondary (industrial) sector, we will get a smaller rate of growth of real output. The most dramatic difference between the two results is found in Young (2003, p. 1233) for the growth of GDP in 1989 when his alternative estimate shows a negative 5 percent and the official estimate shows a positive 4 percent (from Table 1, 271.3/260.7 =1.041). The alternative estimate is grossly in error. First, the retail price index in 1989 was abnormally high according to the explanation given in section III below (see Figures 2 and 3 and Table 2 for the two large positive residuals in 1988 and 1989 and the verbal explanation following Table 2). Second, *China Statistical Yearbook 1990* ( Tables 10-29 and 10-30) provides data on outputs in physical units of individual industrial products and most of them show an increase in 1989 as compared with 1988. Third, China's real GDP was growing at 11.3 percent in 1988 and a reduction to the official rate of 4.1 percent in 1989 was a very large reduction. Peaceful demonstrations did not start until April and the Tiananmen Incident occurred on June 4, 1989. We can reasonably assume that for the first six months of 1989, real GDP was increasing at least at 7 percent annually as compared with 11.3 percent the year before. To get a negative growth of -5 percent for the entire year would require an annual rate of decline in output of about -17 percent (3.5 in the first half and -8.5 in the second half) in the second half of 1989, which is highly unlikely. Much of the revision of output growth given in Young (2003) is due to this very large difference of -9 percent in one year.

## **III.** An error-correction model to explain inflation in China

This section updates the work of Chow (1987) to explain the change in log P by its lagged value, the change in log(M/Y) and an error-correction term, where M denotes money supply and y denotes real output. M2 is used because our simple model fails to include the rate of interest which may affect the demand for M1 more than it affects M2 as an increase in the interest rate would tend to reduce the demand for M1 relative to the interest yielding deposits in the remainder of M2. Results from using M1 for money stock will be reported in section IV for comparison with corresponding results for the United States.

After pointing out in the previous section the relation between changes in the price level and associated changes in money stock or real output in the major inflation episodes (real output being less volatile than the money stock except for the year 1961) we examine the statistical relation between log P and log (M/Y). Figure 1 plots log(P) against log(M2/Y) over the entire sample period. Overall, the plot suggests that in the long run, the relation between log(P) and log(M2/Y) is approximately linear.

Figure 1 Plotting log(P) against log(M2/Y)




The long run relation between log(P) and log(M2/Y) is then estimated by regressing log(P) on log(M2/Y) and a constant:

$$\log(P) = \underset{(0.031)}{-0.7127} + \underset{(0.0102)}{0.3738}\log(M2/Y), \qquad \text{Adjusted } R^2 = 0.9639.$$

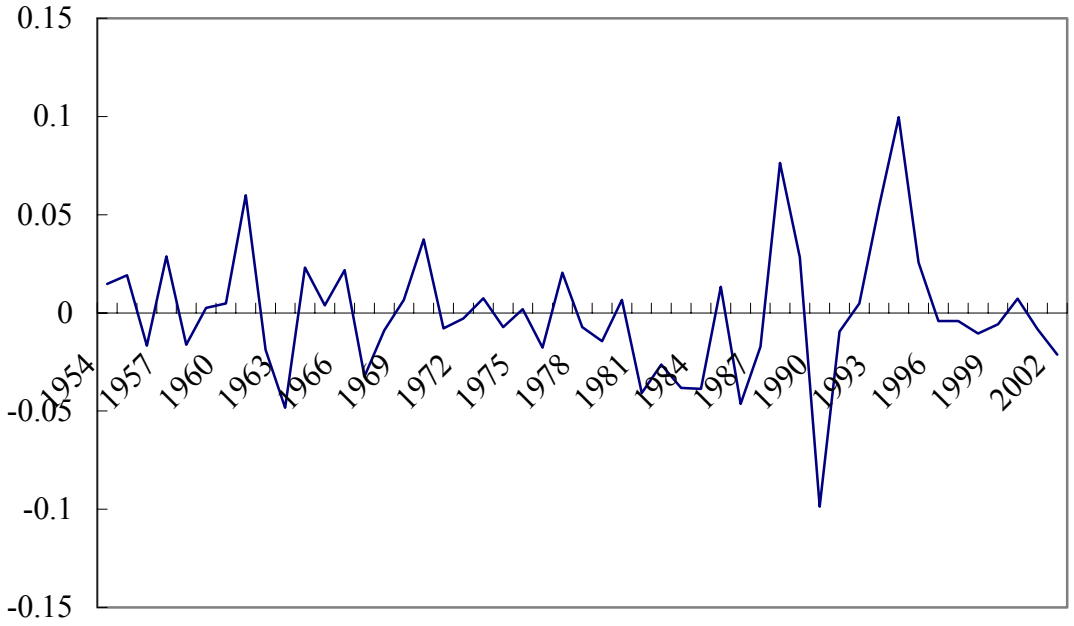
Following Chow (1987; 2002, p. 124), the lagged value of the residual $u_{t-1}$ of the above regression is used as an independent variable representing the error correction term in estimating the equation that explains the inflation rate $\Delta\log(P)$:

$$\Delta\log(P) = \underset{(0.0065)}{-0.0009} + \underset{(0.0429)}{0.1603}\Delta\log(M2/Y) + \underset{(0.108)}{0.55}\Delta\log(P_{-1}) - \underset{(0.052)}{0.031}\Delta\log((M2/Y)_{-1}) - \underset{(0.055)}{0.169}u_{-1}$$

Adjusted $R^2 = 0.6274$.

The residuals of the above model are plotted in Figure 2 to examine how well this model explains the data:

Figure 2 The Residual Plot for Model 1 (including $\Delta\log((M/Y)_{-1})$)




As $\Delta\log((M/Y)_{-1})$ is not significant, it is omitted in the following regression:

$$\Delta\log(P) = \underset{(0.006)}{-0.00017} + \underset{(0.042)}{0.155}\Delta\log(M2/Y) + \underset{(0.0924)}{0.525}\Delta\log(P_{-1}) - \underset{(0.0512)}{0.1575}u_{-1},\ \text{Adjusted } R^2 = 0.6328.$$

Figure 3 plots its residuals and Table 2 presents the data on the residuals from the two models:

Figure 3 Residuals Plot for Model 2 (without $\Delta \log((M/Y)_{-1})$

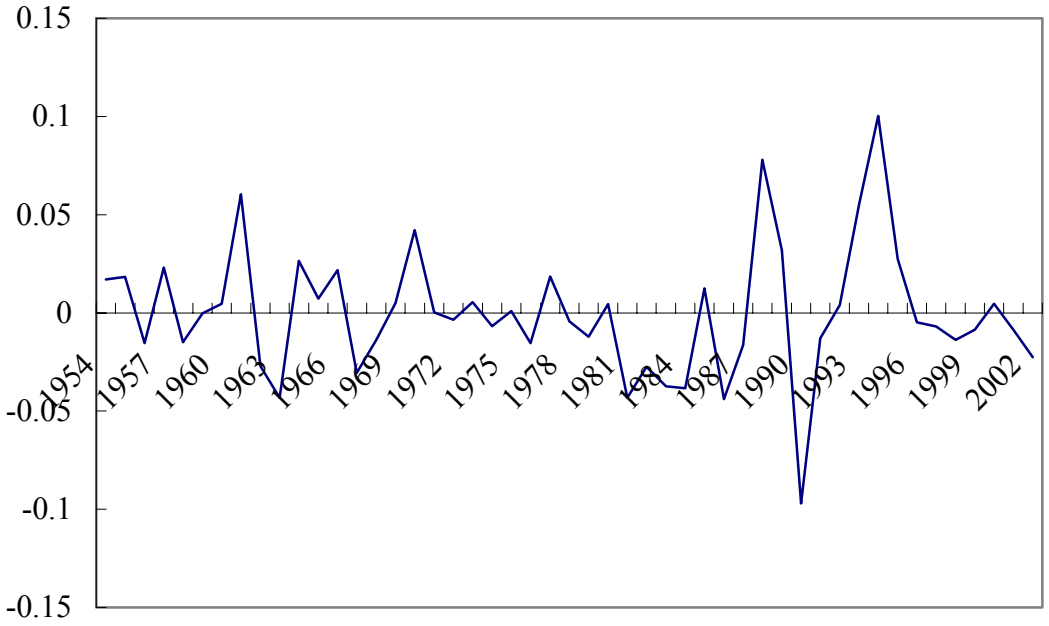



Table 2 Residuals for Model 1 and Model 2

| Year | Model 1 | Model 2 | Year | Model 1 | Model 2 |
|---|---|---|---|---|---|
| 1954 | 0.0147977 | 0.0170414 | 1979 | -0.0144812 | -0.0121256 |
| 1955 | 0.0190982 | 0.0183888 | 1980 | 0.0066371 | 0.0044539 |
| 1956 | -0.0167619 | -0.0154329 | 1981 | -0.0408543 | -0.0431887 |
| 1957 | 0.0286838 | 0.0230097 | 1982 | -0.0263746 | -0.027474 |
| 1958 | -0.0162445 | -0.0149646 | 1983 | -0.0381648 | -0.0373604 |
| 1959 | 0.0025254 | -0.0002004 | 1984 | -0.03873 | -0.038349 |
| 1960 | 0.0047668 | 0.0045939 | 1985 | 0.0132897 | 0.0124603 |
| 1961 | 0.0598597 | 0.060335 | 1986 | -0.0463408 | -0.0438876 |
| 1962 | -0.018769 | -0.0270627 | 1987 | -0.0171425 | -0.0164363 |
| 1963 | -0.0483036 | -0.043342 | 1988 | 0.0764033 | 0.0780104 |
| 1964 | 0.0230726 | 0.0265138 | 1989 | 0.0282354 | 0.0319061 |
| 1965 | 0.0038139 | 0.0072676 | 1990 | -0.0986465 | -0.0970142 |
| 1966 | 0.0217711 | 0.021822 | 1991 | -0.009471 | -0.0130061 |
| 1967 | -0.0323494 | -0.0304916 | 1992 | 0.0048834 | 0.0040563 |
| 1968 | -0.0088929 | -0.0138018 | 1993 | 0.0545428 | 0.0550307 |
| 1969 | 0.006617 | 0.0048992 | 1994 | 0.0996994 | 0.100275 |
| 1970 | 0.0373395 | 0.0421248 | 1995 | 0.0256512 | 0.0273882 |
| 1971 | -0.0079749 | 0.0002567 | 1996 | -0.0041078 | -0.0047449 |
| 1972 | -0.0028541 | -0.0034836 | 1997 | -0.0041265 | -0.0069718 |

| | | | | | |
|---|---|---|---|---|---|
| 1973 | 0.0073827 | 0.0054422 | 1998 | -0.0105428 | -0.0137002 |
| 1974 | -0.007269 | -0.0067967 | 1999 | -0.00578 | -0.008478 |
| 1975 | 0.0018947 | 0.0008898 | 2000 | 0.0071973 | 0.0046898 |
| 1976 | -0.0177193 | -0.0153195 | 2001 | -0.008238 | -0.0087092 |
| 1977 | 0.0205188 | 0.0184406 | 2002 | -0.0212666 | -0.0226344 |
| 1978 | -0.0072758 | -0.0043201 | | | |

The last error correction equation, with the lagged change in log (M2/Y) omitted, explains the data well. All coefficients have the right sign, including the negative sign for the lagged error or residual in the cointegrating equation estimated by least squares. However, we have found very large residuals in the years 1961, 1988 and 1993-4. The 1961 residual was associated with the Great Leap, with a large increase in money supply and a large reduction in real output in 1961 the effect of which is not sufficiently captured by our equation. The 1988 residual can be attributed to the government announcement, for the sake of controlling inflation at the time, that after December 1988 no price increase was to be allowed. Such an announcement had the effect of inducing retailers to raise their prices in the fall of 1988 before the December deadline. The 1993-94 residuals can be attributed to the effect of Deng Xiaoping's Southern Expedition further opening speech in 1992 which was followed by the Chinese people and government officials seizing the opportunity to follow Deng's urge to expand investments, leading to inflationary pressure as demand for investment goods increased, more so than our equation can explain. In general the equation shows that the theory explains the data well and that the residuals can be used to interpret historical events. From 1997 to 2002 China experienced deflation as shown by the price index in Table 1 while the residuals of our error-correction equation presented in Table 2 are small, showing that our model explains successfully price decreases as well as price increases.

It would be of interest to find out whether the parameters of our error-correction equation changed after 1979, the year economic reform started to change a planned economy towards a market-oriented economy. We all agree that changes in Chinese economic institutions took place after 1979. However such changes in economic institutions need not change the relation between changes in log price and the determinants given by our equation. The Chow test for testing the null hypothesis of stability of all parameters in our error-correction equation yields an F(4,41) statistic of only 0.78, as compared with the 5 percent critical level of 2.60 and the one percent critical level of 3.51. Hence the null hypothesis of parameter stability is easily accepted. The result of the stability test further supports the validity of our error-correction model in explaining inflation in China.

## IV. A VAR Model with Cointegration

In this section we report on a VAR explaining the vector $\Delta x$ composed of $\Delta\log$ (P), $\Delta\log$ (M2) and $\Delta\log$ (Y) by x(t-1) and $\Delta x$(t-1). The coefficient matrix of x(t-1) is written as ab' where b' is the transpose of the cointegrating vector. The cointegrating equation b'x was estimated in section III by regressing log (P) on log (M2/Y), as suggested by Engle and Granger (1987) under our assumption that the coefficients of log (M2) and log(Y) are opposite in sign and equal in magnitude. We first apply the method of Johansen (1991) to find the rank of the coefficient matrix of x(t-1). Table 3 reports the trace statistics for the number of cointegrating relations:

Table 3 Johansen Cointegration Test

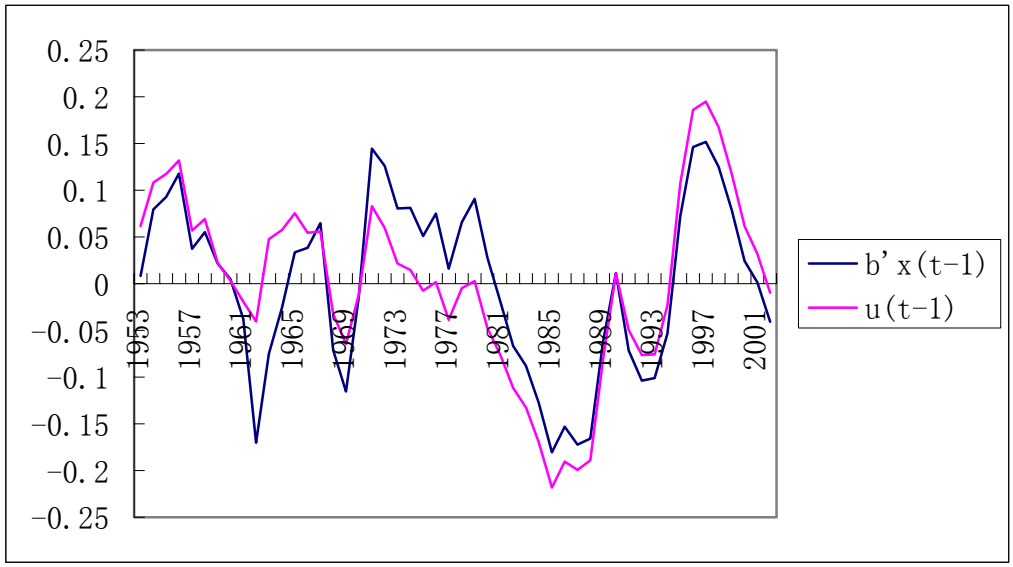
Series: LOG(P) LOG(Y) LOG(M2)

| Eigenvalue | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value | Hypothesized No. of CE(s) |
|---|---|---|---|---|
| 0.27 | 35.34 | 34.91 | 41.07 | None * |
| 0.26 | 19.91 | 19.96 | 24.60 | At most 1 |
| 0.10 | 5.16 | 9.24 | 12.97 | At most 2 |

* Denotes rejection of the hypothesis at 5%(1%) significance level. Critical values are taken from Enders (2003, p. 403), the panel of critical value for the case with a constant in the cointegrating vector.

The result supports using one cointegrating relation among log(P), log( Y) and log(M2). Hence the rank of the coefficient matrix for the lagged dependent variables is one, and the normalized cointegrating equation is $b' x_{t-1} = \log(P_{t-1}) + 0.6509 \log(y_{t-1}) - 0.5 \log(M2_{t-1}) + 0.3498$. Figure 4 compares this cointegrating equation with the residuals $u_{t-1}$ from regressing log(P) on log(M2/Y). It shows that the cointegrating equation and the vector u(t-1) estimated in section 1 exhibit similar behavior.

Figure 4 Plotting the Long-run Relation and Residuals from the OLS Regression



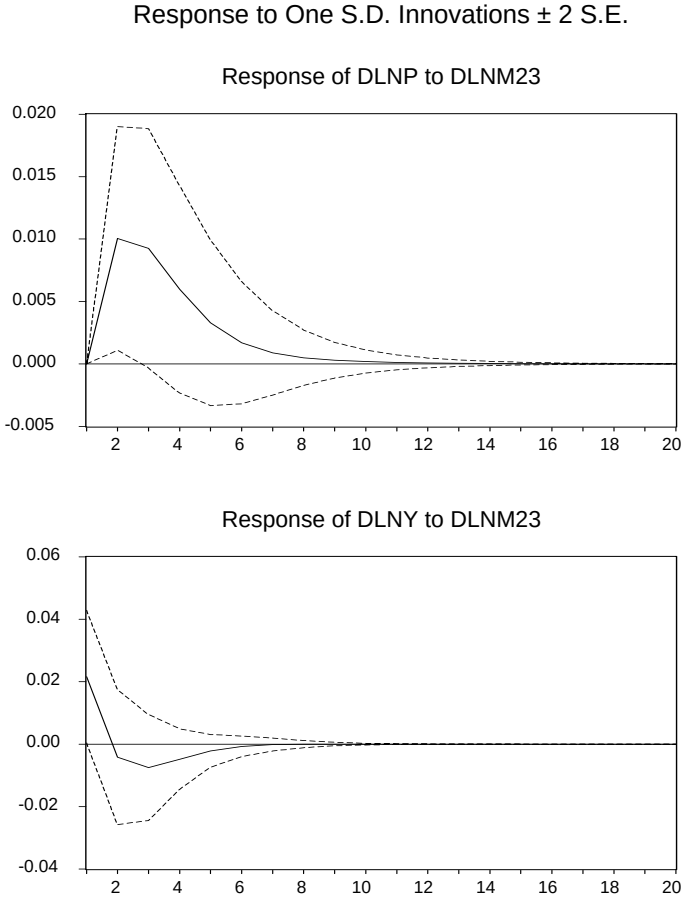

As the Johansen Cointegration Test shows one cointegrating relation, we estimate a vector error-correction VAR assuming one cointegrating relation, numbers in brackets are standard deviations :

$$\begin{bmatrix} \Delta\log(P_t) \\ \Delta\log(y_t) \\ \Delta\log(M2_t) \end{bmatrix} = \begin{bmatrix} \underset{(0.06)}{-0.163} \\ \underset{(0.14)}{-0.24} \\ \underset{(0.15)}{-0.07} \end{bmatrix} b' x_{t-1} + \begin{bmatrix} \underset{(0.11)}{0.54} & \underset{(0.07)}{0.137} & \underset{(0.05)}{0.11} \\ \underset{(0.26)}{0.06} & \underset{(0.16)}{0.46} & \underset{(0.13)}{-0.17} \\ \underset{(0.28)}{0.22} & \underset{(0.17)}{0.53} & \underset{(0.14)}{0.43} \end{bmatrix} \begin{bmatrix} \Delta\log(P_{t-1}) \\ \Delta\log(y_{t-1}) \\ \Delta\log(M2_{t-1}) \end{bmatrix} + \begin{bmatrix} \underset{(0.009)}{-0.015} \\ \underset{(0.02)}{0.064} \\ \underset{(0.02)}{0.045} \end{bmatrix}$$

We are interested in finding out how the price level and real output respond to monetary shocks in the Chinese economy. According to Friedman (1994, p.48), because of price rigidity, the effects of monetary shock will first show up for log output over two to three quarters. Such effects tend to dissipate over time. "The effect on prices, like that on income and output, is distributed over time, but it comes some twelve to eighteen months later, so that the total delay between a change in monetary growth and a change in the rate of inflation averages something like two years". This proposition is confirmed by the studies on US data (Sims (1980), Bernanke and Mihov (1998)) and empirical studies for "virtually all countries" (Bernanke (2003)). However, whether the Chinese data exhibit a similar pattern has not been thoroughly studied. This question is of particular interest since some researchers argue that the institutional differences between the Chinese economy and those of the highly developed economies could make a fundamental difference in explaining the relation between money, price and output (e.g., Peebles (1992)).

We quantify the dynamic effects of monetary shocks on real output and prices by calculating the impulse responses based on the VAR model presented in section 2. Figure 5 plots the impulse responses of log (Y) and log(P) to shocks to M2 over 20 years, respectively. The ordering of these three variables in calculating the impulse responses are P, M, and Y. With this ordering the immediate response of lnP is zero by construction to agree with the prior assumption. Effects of changing the ordering to M, Y, P will be reported in Section V. The result suggests that the dynamic relations between real output, money and price conform Friedman's proposition. In the first year after the expansionary monetary shock, most of the impacts are on real output (the lower panel of figure 5). In the second year, the impact on real output die down quickly, but reaches its maximum for price (the upper panel of Figure 5). The impacts on price then die out over a long horizon.

Figure 5 Impulse Responses for Chinese M2



## V. Comparing the Impulse Responses from US data and Chinese Data

While the impulse response functions for the Chinese data reported in section IV are consistent with Friedman's predictions, the VAR specification is not the same as in empirical studies for other countries. To compare our results with results based on US data, we use the same VAR specification for the US as given in section IV.

The US annual data is extracted from the dataset prepared for the Fair model provided by Ray Fair in the website http://fairmodel.econ.yale.edu/. As only M1 is available in that dataset and it is of interest to reexamine the Chinese impulse responses based on M1 as well, we estimate the VAR model using US M1, real GDP and GDP deflator over the sample period 1966 – 2002 and record the impulse responses of US real output and price level to shocks on US M1 in Figure 6. To make the impulse responses comparable we use Chinese M1 and report the impulse responses in Figure 7.

Figure 6 shows that the general patterns of the responses of real output and price level to monetary shocks agree with Friedman's proposition. The response of output occurs sooner than the response of price but dies down quickly. The response of price peaks at two to three years and dies down much more gradually. Furthermore, by examining the output and price responses using M1 instead of M2, and after changing the ordering of the variables to M, Y, P instead of P, M, Y, we will find that the impulse responses calculated from the US data (Figures 8, 9 and 12) and from the Chinese data (Figures 7, 10 and 11) to be quite similar and to follow the pattern just described.

Figure 6 Impulse Responses of Real Output and Price to US M1 shocks

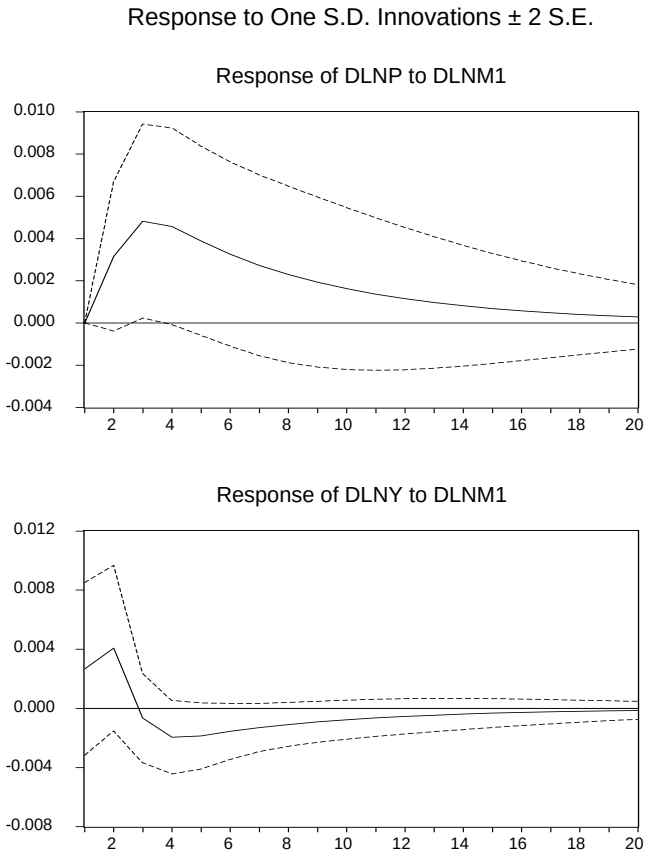
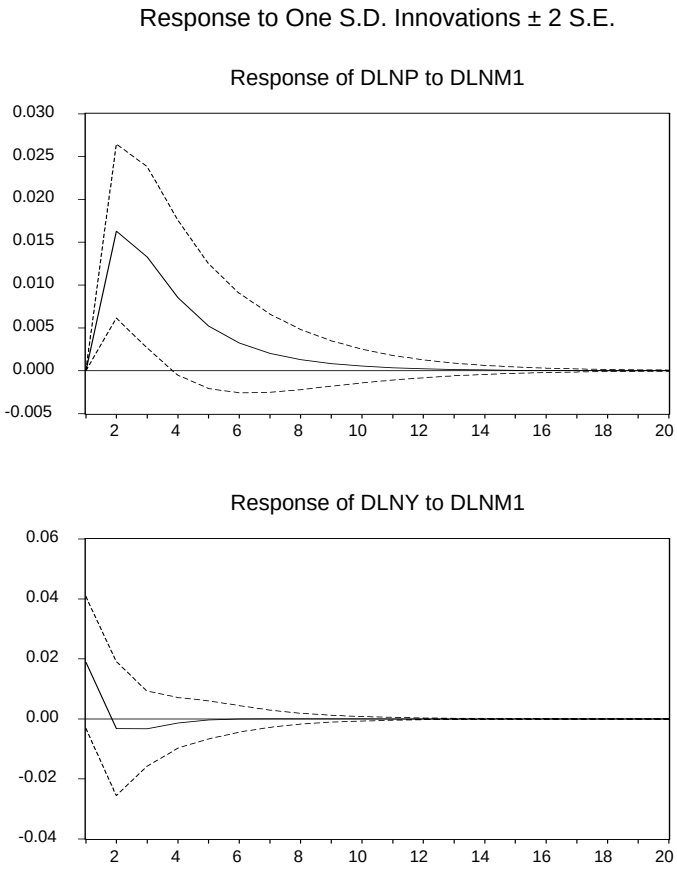


Figure 7 Impulse Responses of Real Output and Price to Chinese M1 shocks




The three-variable VAR may be subjected to omitted-variable bias since some relevant variables such as interest rate are not included. To examine the sensitivity of the above results, we augment the US case with the interest rate to get a four-variable VAR. The interest rate we use is Moody's AAA series downloaded from www.economagic.com. Similar to steps in section III, log(P) is first regressed on a constant, log(M1/Y) and interest rate to get the residuals as a measurement of the equilibrium relation. Then the four-variable VAR system is estimated and the corresponding impulse responses are plotted in Figure 8.

Figure 8 Impulse Responses of Real Output and Price to US M1 shocks
After Adding Interest rate

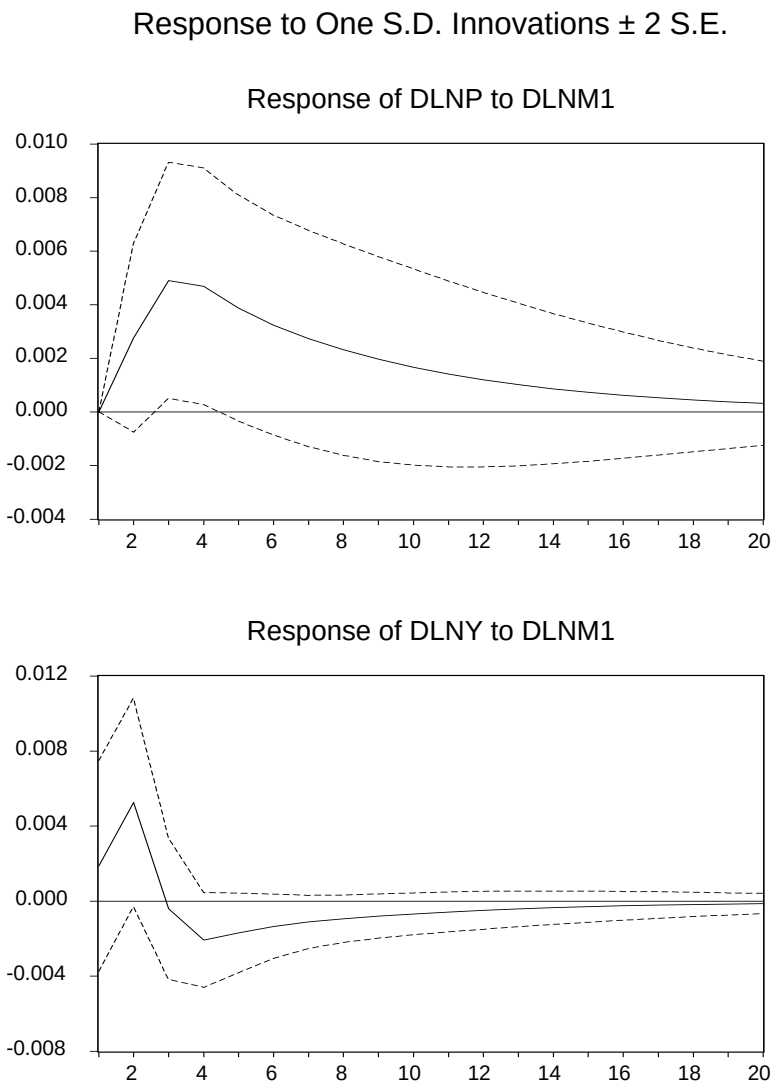


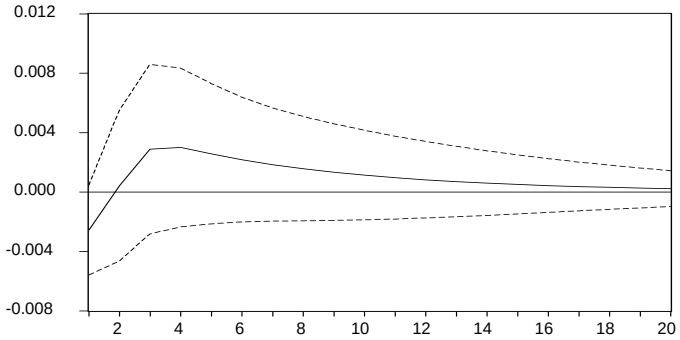

Figure 8 shows that the impulse responses of output and price changes little as compared with Figure 6. It implies that omitting the interest rate does not change substantially the impulse responses of the US data.

To examine the possible effects of the ordering of the variables Figures 9, 10, 11 present respectively the impulse responses based on the US M1, Chinese M1 and Chinese M2 using the ordering M, Y, and P. Figure 12 presents the impulse responses for the US four-variable system in the order of M, Y, P, r. The results show that the general pattern remains the same as before using the ordering P, M, Y. It also shows that the simplified three-variable VAR system is valid in showing the general validity of Friedman's proposition for both China and the US.

Figure 9 Impulse Responses of Real Output and Price to US M1 shocks
Order M, Y, P

Response to One S.D. Innovations ± 2 S.E.

Response of DLNP to DLNM1




Response of DLNY to DLNM1

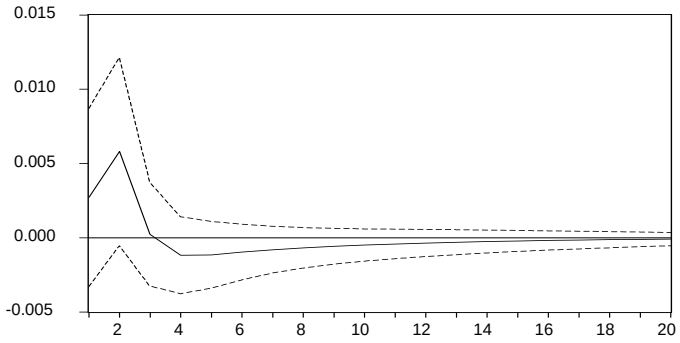


Figure 10 Impulse Responses of Real Output and Price to Chinese M1 shocks
Order M, Y, P

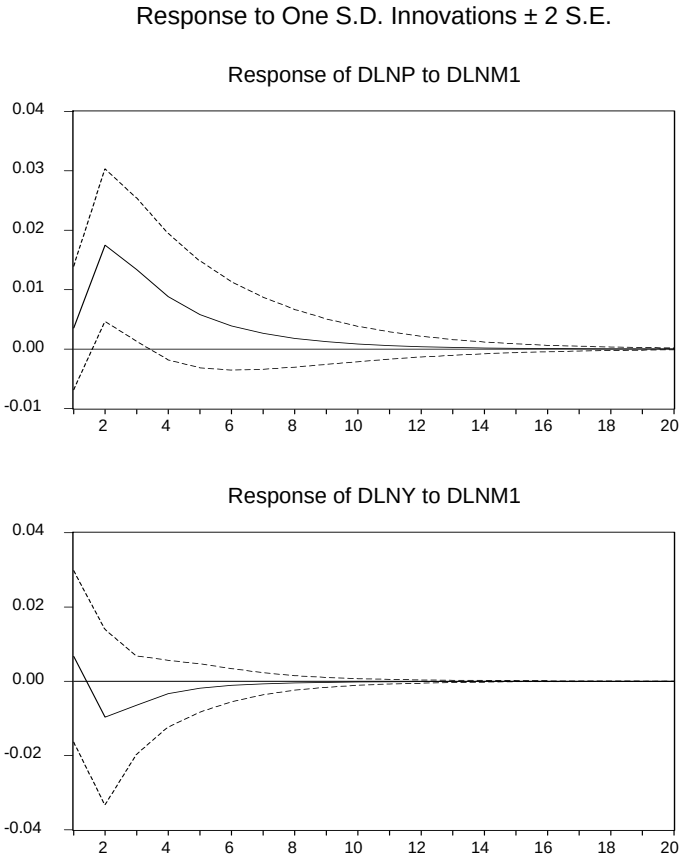


Figure 11 Impulse Responses of Real Output and Price to Chinese M2 shocks
Order M, Y, P

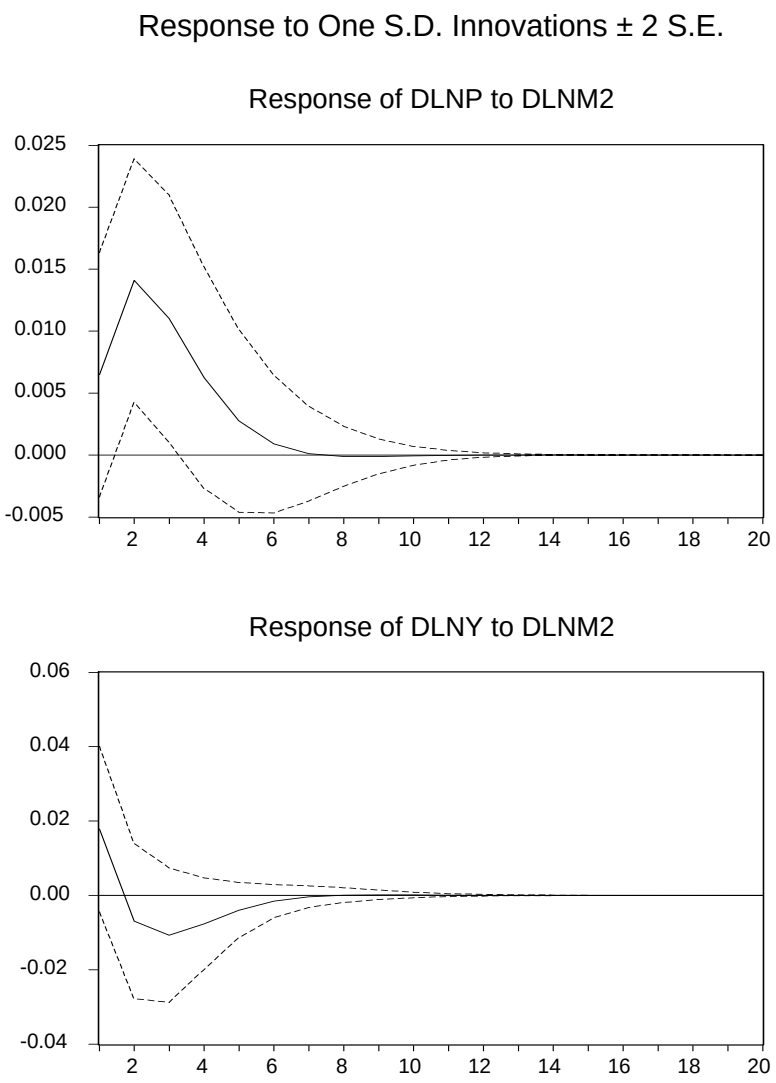
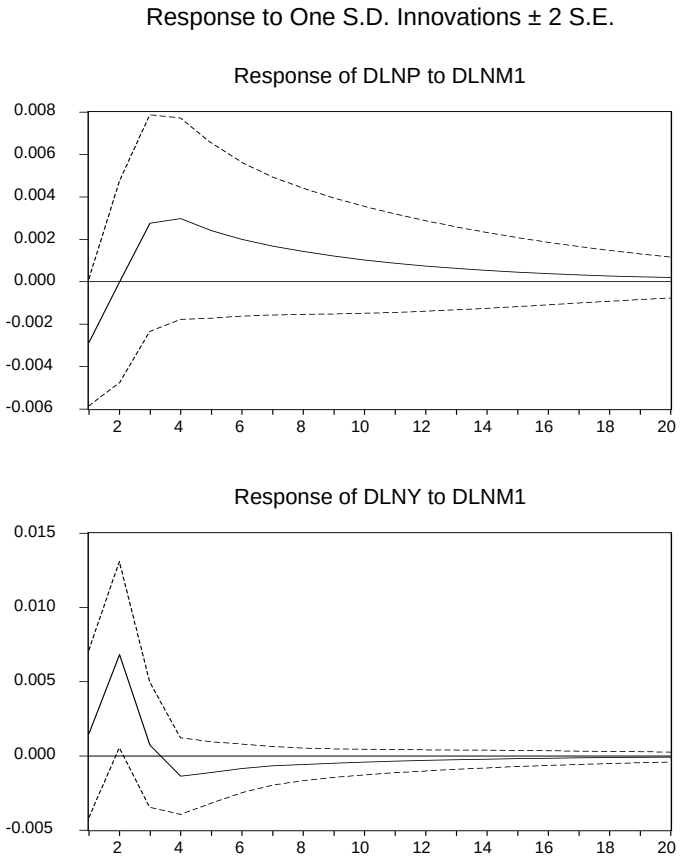


Figure 12 Impulse Responses of Real Output and Price to US M1 shocks
Order M, Y, P, r




## VI. Conclusions

Judging from the estimated error correction equation of section III, we can conclude that our specification of the factors affecting inflation can explain the Chinese data well. The equation passed the Chow test for parameter stability when the sample was divided into the pre- and post-reform periods. Thus institutional changes after major economic reforms did not affect the validity of our equation to explain inflation. In spite of institutional differences between China and the more developed Western economies from which empirical support for Friedman's propositions was drawn, the same theory of inflation and of the effects of monetary shocks on price and output applies. When the first author mentioned the proposed research to Milton Friedman, he responded confidently, "you will find the same effects for China." This paper illustrates the power of economic theory and the stability of economic parameters if the theoretical model is properly specified to explain economic reality, a viewpoint that Milton Friedman has conveyed to his students and the economics profession for over half of a century.

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