The Quantity Theory of Money and the Chinese Puzzle

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Abstract

The Chinese Puzzle refers to economist Mckinnon (1993)'s concept: the growth rate of money supply in China was far more than GDP, while there was not serious inflation. Employing the Ordinary Least Square Regression, Prais-Winsten Regression, Newey-West Standard Errors, Cochrane-Orcutt Standard Errors and Huber-White Errors techniques, we estimated Fisher equation specifications using annual data from 1978 to 2010 and quarterly data from 1996 to 2010 of China. Based on the Quantity Theory of Money, we set up five models to investigate the relationship between money supply, velocity of money, GDP and inflation rate. Breusch-Pagan test, variance inflation factor, Durbin-Watson test and Huber-White sandwich estimators were used as detect and fix violation of classic linear regression assumptions. As a result, we found that M2 is the most relevant money supply variable among M0, M1 and M2. Money supply was unrelated to inflation in the short run but positive related in the long run, i.e. the Chinese Puzzle does exist for a relatively short period and the Quantity Theory of Money held true in the long run. We also found velocity of money is relatively constant and slightly decrease. Therefore, we concluded that change in velocity of money did not cause the Chinese Puzzle. In addition, we found that time-lag, i.e. carryover effects, was the cause of the Chinese Puzzle. Based on these results, we further made some suggestions for the national economic policy regarding the efficiency of China's monetary policy.

Keywords: China, Inflation, Money Supply, velocity of money, Time-lag, economic policy

1. Introduction

The Quantity Theory of Money is an economic theory used to illustrate that the change of money in circulation affects the commodities prices. It shows that money supply has a direct, proportional relationship with the price level. If other factors remain unchanged, the increase in money supply will increase prices proportionally and reduce the value of money inverse proportionally, vice versa.

The early advocates of the Quantity Theory of Money were French thinker Montesquieu and British economist Hume. In the early 20th century, great progress was made in the theory. The American economist Irving Fisher came up with the Cash Transaction Approach. British Alfred Marshall proposed the Cash Balance Theory, and his student Arthur Cecil Pigou invented the Cambridge Equation. The early theory focuses on qualitative analysis on the relationship between money supply, commodities prices and the value of money. Since the 1930s the Quantity Theory of Money has faded as Keynesian theory has become popular. In the 1950s, the Monetarists, such as Milton Friedman, advocated the modern Quantity Theory of Money. They believed that the change of money supply affects both the general price level and the gross domestic product. The modern theory both emphasizes qualitative analysis and quantitative analysis. In its modern form, the quantity theory builds upon the following definitional relationship, $MV = PT$. Among those variables, M is money supply, V is velocity of money, P is price level, T is the total amount of available goods, which also refers to a country's real GDP. This equation is called the Equation of Exchange or the Fisher Equation, and is the basis of the quantity theory. Economist Irving Fisher considered that M is an exogenous variable, and V is decided by social system and spending habits, which are stable in a long period and can be regarded as a constant. Under the condition of full employment, T also remains stable. When V and T are stable, the change of M decides the change of P. That is, the money supply determines the price level.

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The inflation rate has accelerated in China in recent years. In China, consumer prices have rose fivefold from 1978 to 2010. And many economists say the official figures actually understate the rate of inflation, which might in reality be twice as high.[1]The most serious consequence of inflation is the damage of the market mechanism. Inflation results in the distortion of resource allocation and market failure. Therefore, understanding the cause of inflation in China is very urgent and very important. Economists give different explanations for the cause of inflation, while we try to analyze it in the perspective of the Quantity Theory of Money here. The quantity theory suggests that the primary cause of inflation is the excessive supply of money. Controlling money supply is the main mean to tackle inflation. However, facts show that since the late 1980s, the money supply and the price level in China have had an unusual relationship. In the face of fiscal decline, China maintains a high money supply growth rate while the price level remains stable, which is called the Chinese Puzzle by economic scholars. "How did China succeed in containing this inflatinary pressure better than the socialist countries in Eastern Europe, which faced similar revenue declines?"(Mckinnon, 1993)[11] Although extensive empirical analyses substantiate the Chinese Puzzle, economists does not reach consensus on its existence. In addition, whether the Chinese Puzzle is a counter-example of the Quantity Theory of Money also needs to be analyzed.

We estimated the Fisher equation specifications using regression techniques. First, we used regression with Newey West standard error technique to decide the relevance of three definitions of money supply, M0, M1 and M2. Second, we use ordinary least square regression, Huber-White errors and Cochrane-Orcutt standard errors to demonstrate the existence of the Chinese Puzzle. Third, we used the Prais-Winsten regression to estimate the effect of money supply and real GDP towards the inflation, therefore further demonstrating the existence of the Chinese Puzzle. Fourth, we used residual analysis to determine the change in velocity of money, and demonstrated if the change in velocity of money is a cause of the Chinese Puzzle. Fifth, we used lag term as a variable of regression and tried to find out if there is a time-lag between the money supply and the price level. Newey-West standard errors are used.

The paper proceeds as follows. Section 2 reviews the related literature. Section 3 presents the theoretical intuition that underlies our estimation strategy, introduces our baseline and the Quantity Theory of Money-specific econometric specifications, and discusses the data and the variables employed in the analysis. Section 4 presents and discusses our estimation results. Section 5 is the conclusion.

2. Literature Review

A lot of literature has emerged with thorough details about the Chinese Puzzle and the Quantity Theory of Money in China. However, the literature does not hold the same view. There are two broad categories into which prior studies can be classified.

The first category studies admit the strong positive relationship between the money supply and the inflation rate; and deny the existence of the Chinese Puzzle. Chow(1987) found that between 1952 and 1983, the money supply and inflation had a positive relationship and inflation in China could be explained by the quantity theory[2]. Hasan(1999) used samples from 1952–1993, and drew the same conclusion as Chow's[5]. But Peebles thinks that due to China's special economic system, the RMB is not free currency and the price cannot adjust freely; therefore, it is not reasonable to use the quantity theory to explain the relationship between the money supply and the price level. Wang (2004) used the Granger causality test to examine samples from 1978-1994 and believed that the excess money supply was the primary cause of inflation[13]. Li Jun found that money supply and inflation don't have a positive relationship in the short term, but have a positive relation in a 5-year period[6]. Liu et al(2004) found that the growth rate of money supply and the inflation rate have an equilibrium relationship in the long term, and also have an error correction mechanism in the short term[8]. Zhu & Zhang(2005) used the ECM model and found that money supply in different levels has a co-integration relationship with the inflation rate. They believed that M2 can best explain inflation[18]. Chen(1997) suggested that to control inflation under 10% in China, the targeted M2 growth rate should not exceed 28–29%[1]. The author think if the M2 growth rate exceeds 30%,

[1]"Rising Chinese Inflation to Show Up in U.S. Imports", the New York Times, Jan 11, 2011

the inflation rate cannot be limited to 10%. Feltenstein(1991) thought that CPI cannot reveal real effect of inflation. The research provided a method to calculate the 'true' inflation rate. The result is that the annual rate of inflation of the 'true' price index is approximately 12.4 percent higher than that of the official price index over the 10-year period[3].

The second category studies admit the existence of the Chinese Puzzle. However, their explanations for the causes of the paradox differ. When analyzing the inflation predictive power of some indices, Ron found that the turning point signals M1 gives sometimes have nothing to do with the inflation cycle, and M2 does no more better. We cannot conclude that an increase in the money supply speeds up the inflation or reduces the inflation. They tend to deny the stable relationship between the two. Monetarists, Friedman & Kuttner (1992), found the causal relationship between the two disappeared when examining the causality of the money supply and the inflation[4]. Liu & Jin (2005) analyzed statistics from 1978–2003 and didn't find evidence that supports that an increase in the money supply could cause inflation in the long term[9], which supports Yi Gang's statement. Yi(1994) found that, from 1979–1984, China's money supply growth rate is far more than the sum of the inflation rate and the GDP growth rate. He proposed that it can be explained by the monetization process of China's economy[17]. The monetized part of the economy consumes the newly increased money supply. Shuai(2002) used 1993–2000 quarterly data to analyze China's excess money demand and drew a surprising conclusion that money supply and inflation have a negative relationship[2][12]. Wu(2002) analyzed the relationship between China's money supply growth rate and the retail price index (RPI) from 1985 to 1999, and found that M0 and RPI, M1 and RPI, M2 and RPI are not co-integrated. They don't have a long term stable relationship. Regression analysis gave the same conclusion as correlation analysis that money supply cannot explain inflation[14].[3]

Due to the contradictory nature of the literature, it was hard to draw a definite conclusion. However, we can see the literature has the following characteristics. The literatures which deny the existence of the Chinese Puzzle tend to use earlier data sets, and longer time intervals. The literatures which agree with the existence of the Chinese Puzzle tend to use later data sets (especially from the last 3 decades), and shorter time intervals.

3. Theoretical Intuition, Econometric Specification and Data

3.1 Theoretical Intuition and Hypothesis

We use graphs to show the possibility of the Chinese Puzzle.

Figure 1 shows the annual M2 growth rate and CPI growth rate. We could see M2 moves preceding CPI and has inverse relation in 80s and 00s. If we move the M2 curve right by 1 year, we can find the two variables have almost the same trend for most of these years. See Figure 2. In addition, Figure 3 shows the CPI and M2 growth rate per quarter. We could see the relationship between the two is almost negative. However, in figure 4 where we move the M2 curve right by 1 year, we can find that the two curves have almost the same trend most of the time.

The negative relationship in annual and quarterly graph reminds the possibility of the Chinese Puzzle. The lagged curve fitting hypotheses the possibility of carryover effect, i.e. time-lag. In quarterly data,we also tried to move the M2 curve right by 2 quarters and 3 quarter; the two curves do not fit better than in the graph below. Similarly, in the annual data, one=year curve fitting is the best. This demonstrates the time-lag probably is one-year.

The graph analysis cannot prove the existence of Chinese Puzzle, nor the carryover effect. However, we could built hypothesis based on them. The Chinese Puzzle does seem exist. If time-lag takes effect, the negative relationship between the money supply and price level might very well be caused by the two being out-sync.

[2] $\ln \Delta M2_t = 0.8026 \ln \Delta Y_t + (-0.0275) \ln \Delta \pi_t + 0.2566 \ln \Delta W_t$, where ΔW_t refers to capital market expansion or generalized capitalizing index, which consist of value added in a stock market, bond and real estate market.

[3] $M0 = -1.5478RPI + 4.0058$, $r = 0.210$, $t = -1.697021$; $M1 = -0.2958RPI + 2.51$, $r = -0.044$, $t = -0.783290$; $M2 = 1.0309RPI + 0.8834$, $r = 0.108$, $t = -0.697326$; All t test not significant at 5% level.

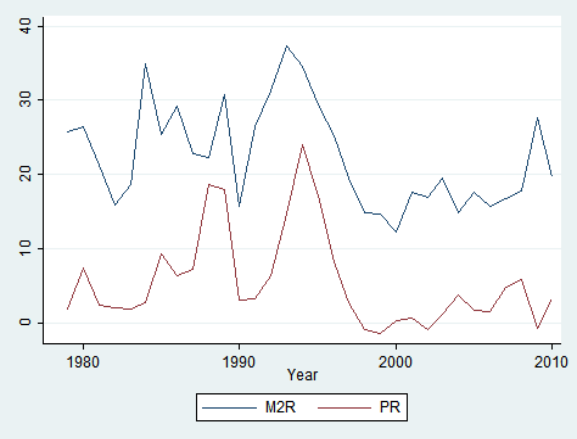

Figure 1: *the annual M2 and CPI growth rate*

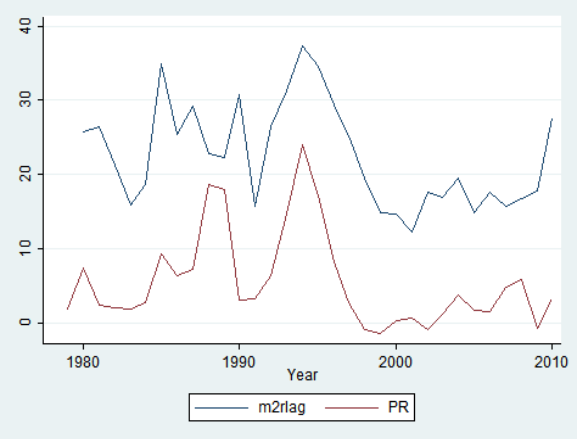

Figure 2: *the lagged annual M2 and CPI growth rate*

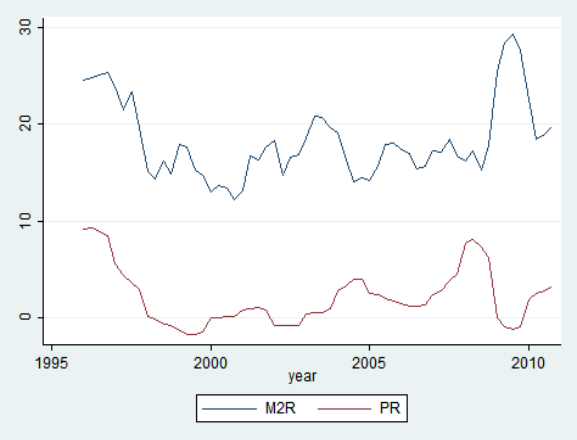

Figure 3: *the quarterly M2 and CPI growth rate*

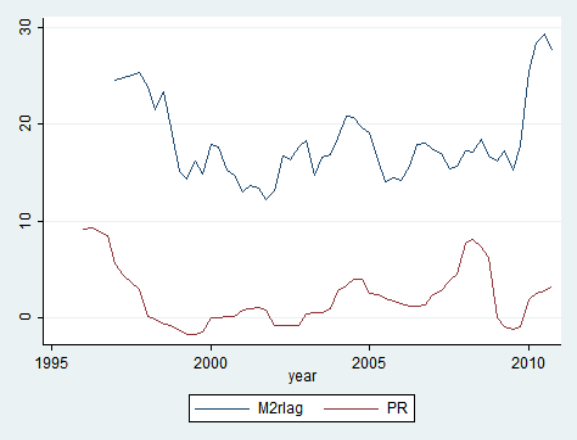

Figure 4: *the lagged quarterly M2 and CPI growth rate*

3.2 Econometric Models and Estimation Equations

3.2.1 The Basic Model with Three Money Supply Definitions

We analyze a basic Fisher equation model specification. In this first model, we want to allocate the relevance of money supply and inflation into different parts of the money supply. Therefore, we need to use the data of M0, M1-M0, and M2-M1[4] and the real GDP (Y). Because the original Fisher equation is $MV = PY$ where P stands for the price level and what we really interested in is the inflation, we need to adjust the price level to the inflation rate. Therefore, we adjust the M0, M1-M0, M2-M1 and Y into the growth rate [5]. We use $M0R$, $(M1 - M0)R$, $(M2 - M1)R$ and YR to denote the growth rates as our independent variables and use PR to denote the inflation rate as our dependent variable. Therefore, we will use the following equation as our first regression model.

$$PR_t = \alpha + \beta_1 M0R_t + \beta_2(M1 - M0)R_t + \beta_3(M2 - M1)R_t + \beta_4 YR_t + \epsilon_t \tag{1}$$

[4] A reason of doing this is try to rule out the effect of the possible multicollinearity as M1 contains M0 and M2 contains M1. In addition, because we want to allocate the effect of different part of money supply, it makes sense to separate them.

[5] According to page 283, *Macroeconomics*, Robert J. Gordon, the growth rate of any product of two numbers, such as P times Y in the equation $MV = PY$, is equal to the sum of the separate growth rates of the two numbers. Therefore, $m + v = p + y$, where small case letters stand for growth rates.

3.2.2 The Basic Model with M2

In this second model, we still analyze a basic Fisher equation model specification, using M2R [6] as the increase of money supply variable in order to test whether the Chinese Puzzle exists.We will use the following equation as our second regression model.

$$PR_t = \alpha + \beta_1 M2R_t + \beta_2 YR_t + \epsilon_t \tag{2}$$

3.2.3 The M2/GDP Model

In third model, we want to further demonstrate the existence of the Chinese Puzzle. We transform Fisher equation into $\ln M + \ln V = \ln P + \ln Y$. M2/GDP is commonly used as an indicator of financial deepening. Generally speaking, the greater the ratio, the higher the degree of monetization of the economy. Therefore, we choose $\ln(M2/Y)$ as our independent variables and $\ln P$ as our dependent variable in our third regression model.

$$\ln P_t = \alpha + \beta_1 \ln(M2_t/Y_t) + \epsilon_t \tag{3}$$

3.2.4 The Velocity of Money Model

As the data of velocity of money is impossible to obtain, our previous models made an assumption that velocity of money is stable. So we need to analyze whether this assumption is valid here. As noticed, we haven't included the velocity of money as our independent variable in the previous models because it is not available. However, it is possible to test whether the velocity of money changed significantly by analyzing residuals. We use the second model, Basic Model with M2, to analyze the residuals and regard residuals as the velocity of money. This model gives us a reasonable guess of the change of velocity of money and could demonstrate whether the change of velocity of money is a part of the reason for the Chinese Puzzle.

$$PR_t = \alpha + \beta_1 M2R_t + \beta_2 YR_t + \epsilon_t \tag{4}$$

3.2.5 The Time-lag Model

As hypothesis, we analyze whether time-lag causes the Chinese Puzzle. We will demonstrate that whether time-lag exists by using the lagged money supply variable. As previous explained, the lagged term would be one year. We test if the coefficient for the $\ln M2_{t-1}$ is large and significant. Equation is as follow.

$$\ln P_t = \alpha + \beta_1 \ln M2_{t-1} + \beta_2 \ln Y_t + \epsilon_t \tag{5}$$

3.3 Regression Techniques

3.3.1 Ordinary Least Square

OLS is used to estimate the parameters in a linear regression model. This method finds out the minimum of the sum of squared vertical distances between the observed responses in the dataset, and the responses predicted by the linear approximation. As a result, the estimator can be expressed by a simple linear formula. The OLS estimator is reliable if the regressors are exogenous and the class of linear unbiased estimators is optimal and not multicollinear. A reliable estimate requires errors to be homoskedastic and serially uncorrelated.

3.3.2 Newey-West Standard Errors

A Newey-West estimator is used to estimate the standard errors of the parameters of a linear model when the assumption of standard linear model does not apply. This estimator is used to adjust serial

[6]The result of the first model shows M2 is the most relevant money supply variable. Additionally, in the literature M2 was frequently used as money supply variable since it' s the broadest definition.

correlation and heteroskedasticity. As both our data sets are time-series, it is very possible that the serial correlation exists. Our further examination proves this point. We will use the Newey-West Standard Errors as a remedy if only serial correlation exists.

3.3.3 Huber-White errors

Huber-White errors approach was proposed by White (1980). It is used to fit a model whose residuals are heteroskedastic. This can be derived from generalized method of moments. We use this approach if the model only has problem of heteroskedasticity.

3.3.4 Cochran-Orcutt Regression

Cochran-Orcutt Regression is used to correct a linear model with serial correlation in the residuals. It is named after Donald Cochrane and Guy Orcutt. To estimate the coeffients, take the quasi difference of x's and y's, i.e. $y'_i = y_i - \rho y_{i-1}$, $x'_i = x_i - \rho x_{i-1}$. And then do regression on x' and y'. It may takes a few iterations to acquire the estimation of ρ.

3.3.5 Prais-Winsten Regression

Prais-Winsten is used to adjust serial correlation. It is a modification of Cochran-Orcutt Regression. The transformation of Prais-Winsten Regression is the same as that in Cochran-Orcutt Regression but it adds a transformation of the first observation. That is $\sqrt{1-\rho^2}y_1 = \alpha\sqrt{1-\rho^2} + \left(\sqrt{1-\rho^2}x_1\right)\beta + \sqrt{1-\rho^2}e_1$. It is better than Cochran-Orcutt Regression in term of not losing observations. In the data sets, we find heteroskedasticity also exist at some of our regression results. At that case, we will use Prais-Winsten estimators to correct for heteroskedasticity and serial correlation simultaneously.

3.4 Variable Construction and Data sources

We both use 1978 to 2010 annual data and 1996 to 2010 quarterly data to demonstrate the existence of the Chinese Puzzle. We would use annual data mainly for long run relationship and quarterly data for short run relationship. In macroeconomics, the long run is the period when the general price level, contractual wage rates, and expectations adjust fully to the state of the economy, in contrast to the short run when these variables may not fully adjust.[7]We set the arbitrary division of long run and short run to be one year from the graph analysis of Theoretical Intuition and Hypothesis section.

The 1978–2010 annual data set has M0, M1, M2, CPI, and Nominal GDP data that come from *Compilation of Statistics of New China in 60 years* and *2010 China Statistical Year Book*. Because these resources don't have M2 data before 1990, we get the 1978–1990 M2 data from the official website of the People's Bank of China. In addition, because the Quantity Theory of Money calls for the real GDP and we only have the nominal GDP data from above resources, we use the following method to get the real GDP data. We transform the nominal GDP data into real GDP data, setting the base year into 1978. For consistency, we also use 1978 as the base year for the price level. [8]

$$\text{Real GDP} = \frac{\text{Nominal GDP}}{\text{GDP deflator}/100} \tag{6}$$

The quarterly data set is from 1996 to 2010. M0, M1, M2, CPI, and Nominal GDP data come from the *China Economic Information Network*. As the original data for M0, M1 and M2 are monthly data, we take the

[7]Paul A. Samuelson and William D. Nordhaus (2004). Economics, 18th ed., [end] Glossary of Terms, "Long run" and "Short run."

[8]However, there are three potential weaknesses about the annual data. Firstly, there are changes in statistical scale in 1993 due to China's financial system reform. Secondly, the People's Bank of China has made some adjustment about the monetary statistics system since the beginning of 1997. Therefore, the statistics since 1997 are not fully comparable with historical data. Thirdly, since June in 2001, the margin account of security companies maintained with financial institutions, part of Other Deposits, are included in money supply M2. These changes were mentioned in *2010 China Statistical Yearbook*. These three changes in data nature would weaken our regression results as the data are not fully consistent from 1978 to 2010.

average of three months as the quarterly money supply data. For the quarterly real GDP, the original data is cumulative. Therefore, we use the second quarter data minus the first quarter data to get the second quarter's net nominal GDP and all future quarterly data has been calculated in the same way. Then we use the yearly GDP deflator to get the real GDP for each quarter, and follow the same method as the annual data set above. We can use the CPI compared to the previous month and to the same month of the previous year to calculate the fixed base price index. Then we use the average fixed base price index in 3 months as the quarterly price index. Here we let 1978 be the base year for consistency. [9]

3.5 Descriptive Statistics

Table 1 presents descriptive statistics for the annual data set and the quarterly data set. The average of M0 is 11314.08 in annual data and 2037.85 in quarterly data. The average of M1 is 50709.24 in annual data and 93395.42 in quarterly data. The average of M2 is 135223.3 in annual data and 260123.5 in quarterly data. The average of real GDP is 23114.93 in annual data and 10063.32 in quarterly data. All the money supply variables and real GDP have been measured in RMB. The average of price level is 209.9959 in annual data which based on year 1978, and 450.6591 in quarterly data which based on year 1996.

Table 1: *Descriptive Statistics*

Abbrev.	Variable	Annual Mean $N = 33$	Quarterly Mean $N = 60$
$M0$	M0	11314.08	20437.85
		(12416.85)	(9751.09)
$M1$	M1	50709.24	93395.42
		(67994.6)	(62610.93)
$M2$	M2	135223.3	260123.5
		(187692.1)	(179459.3)
Y	Real GDP	23114.93	10063.32
		(19666.17)	(4468.996)
P	Price Level	309.9959	450.6591
		(157.8198)	(32.8592)

Standard deviations are in parentheses.

4. Estimation Results

4.1 The Basic Model with Three Money Supply Definitions

4.1.1 Regression Results

We estimate the basic Fisher equation model as equation (1). Results from the regression are reported in Table 2.

[9] The potential weakness of the quarterly data set is China GDP's quarterly characteristics. The GDP quarterly growth rate is high in the second and the fourth quarters and slow in the first and the third quarters. In addition, using the GDP deflator in that year to deflate the quarterly nominal GDP is only an estimate and is not fully accurate. It is a matter of expediency when we don't have the quarterly GDP deflator. Taking the average of the three months' money supply to get the quarterly money supply is also an estimate.

Table 2: *Regression Results*

	The Basic Model		
Abbrev.	Variable	Annual $N = 32$	Quarterly $N = 60$
$M0R$	The growth rate of M0	0.0575	-0.0010
		[0.2143]	[0.1108]
$(M1 - M0)R$	The growth rate of (M1-M0)	0.0416	0.0444
		[0.1840]	[0.0546]
$(M2 - M1)R$	The growth rate of (M2-M1)	0.2771**	0.1421**
		[0.1192]	[0.0702]
YR	The growth rate of real GDP	0.0794	0.1902***
		[0.4471]	[0.1902]
Constant		-4.4417	-8.2335***
		[6.3894]	[2.5391]
F		2.79**	5.10***

*Newey-West Standard Errors are in square brackets. "***", "**", and "*" denote significance from the corresponding overall mean value at the 1%, 5% and 10% levels, respectively.*

4.1.2 Detect and Fix Violation of Classic Linear Regression Assumptions

In annual data, VIF for $M0R$, YR, $(M2 - M1)R$, $(M1 - M0)R$ are 1.58, 1.41, 1.32, 1.23, which means that there is no serious multicollinearity. We use Breusch-Pagan test for heteroskedasticity. The p-value of the test is 0.0006, so we reject H_0 that variances are constant. We use Durbin-Watson test for serial correlation. Test statistic is 0.9568, which is less than critical value in 5% significance. So we conclude that there is positive serial correlation. We use Prais-Winsten regression to correct serial correlation. The coefficients and the standard errors of the model are in the table.

In quarterly data, the mean VIF is 1.14, so there is no serious multicollinearity. We use Breusch-Pagan test for heteroskedasticity. The p-value of the test is 0.0178, so we conclude that variances are not constant. Durbin-Watson test statistic is 0.3208, which is less than critical value in 5% significance. So we conclude that there is positive serial correlation. We use Newey-West Standard Errors to correct serial correlation.

4.1.3 Analysis and Interpretation

In the annual data, we find positive and significant influences of the growth rate of M2-M1 on the inflation rate. The result is reasonable because M2-M1 stands for fixed deposits of enterprise, institution, organization, army, school, residents' savings deposits and securities client margin. Although M2 has weak liquidity, it reveals the change in total demand and inflationary pressure in the future. Notice that the coefficient for the growth rate of M0 and the growth rate of M1-M0 are nearly 0, which are much smaller than that for the growth rate of M2-M1. This informs us that the growth rate of M2-M1 is a very important portion of money supply. Therefore, we will use M2 as our money supply variable in the future analysis, which also confirms the majority of literature. However, although the coefficient of the growth rate of M0 has the positive sign which confirm our expectation; it is small and not statistically significant. The coefficient of the growth rate of M1-M0 is also small, positive, and insignificant. These insignificant results probably due to our small sample size. Moreover, the coefficient for the growth rate of Y is small, has an unexpected sign, but is not statistically significant. So it is meaningless. This confirms to the Quantity Theory of Money, which assumes that the growth rate of output is stable because the output (rGDP) equals the nature output under full employment.

In the quarterly data, the coefficient of growth rate of M0 is negative, insignificant and nearly 0. The negative coefficient contradicts our expectation that M0 has positive sign. However, due to the insignificance

of the result, the negative sign is meaningless. The coefficient of growth rate of M1-M0 is again nearly 0, positive and insignificant. In this model, the coefficient of the growth rate of M2-M1 is positive, significant at 5% level and much larger than other coefficients. This confirms to the annual data that M2-M1 is a very important portion of money supply and could not be excluded. Notice the coefficient of YR is also positive and is statistically significant which contradict quantity theory. The coefficient of 0.1902 informs us GDP does play a positive role in determine price level in quarterly data.

In summary, we could see all three parts of the money supply are relevant. However, the most relevant portions is M2-M1 in both annual and quarterly data. No matter which portion is the most relevant, it's clear that all three portions are determinants of the inflation rate. Therefore, we will use M2, which contains all three portions of money supply, in our further analysis. Another important lesson is that almost all the coefficients we got are small,i.e. not far above 0, compared to 1 as quantity theory predicted. No matter in annual data or in quarterly data, small coefficients mean price level is rigid and the increase in money supply and price level is not 1 to 1. The near-zero coefficient means the price level is essentially unresponsive to the money supply. The smaller coefficients in quarterly data compared to annual data probably show that price is more inelastic in short run than long run. This demonstrate the existence of the Chinese Puzzle.

4.2 The Basic Model with M2

4.2.1 Regression Results

The coefficients and the standard errors of the model are in the table 3.

Table 3: *Regression Results*

The Basic Model with M2			
Abbrev.	Variable	Annual $N = 32$	Quarterly $N = 59$
$M2R$	The growth rate of M2	0.5932***	−0.1748**
		(0.1642)	[0.0713]
YR	The growth rate of real GDP	0.0148	0.4080**
		(0.4128)	[0.1617]
Constant		−7.9047*	0.3460
		(4.3241)	[2.4809]
ρ			0.8712
F		6.96***	7.61***

*Huber-White errors are in parentheses. Cochrane-Orcutt Standard Errors are in square brackets. "***", "**", and "*" denote significance from the corresponding overall mean value at the 1%, 5% and 10% levels, respectively.*

4.2.2 Detect and Fix Violation of Classic Linear Regression Assumptions

In annual data, mean VIF for is 1.18 which means that there is no serious multicollinearity. We use Breusch-Pagan test for heteroskedasticity. The p-value of the test is 0.0009, so we reject H_0 that variances are constant. We use Durbin-Watson test for serial correlation. Test statistic is 1.3992, which is bigger than critical value in 5% significance. So we conclude that there is no positive serial correlation. We use Huber-White sandwich estimators to fix heteroskedasticity.

In quarterly data, mean VIF for is 1.00, which means that there is no serious multicollinearity. We use Breusch-Pagan test for heteroskedasticity. The p-value of the test is 0.0092, so we conclude that variances are not constant. Durbin-Watson test statistic is 0.2930, which is bigger than critical value in 5% significance. We conclude that there is positive serial correlation. So we use Cochrane-Orcutt regression to correct serial correlation.

4.2.3 Analysis and Interpretation

In annual data, the coefficient of M2 is nearly 0.6, positive and significant, so M2 and CPI have a clear positive relation. However, the coefficient 0.5932 shows that M2 does not grow proportionally with CPI as 1-1 of quantity theory predicts. There are still leakages of money supply. The coefficient of Y is not significant and nearly 0, so Y is not correlated with P which confirms to the quantity theory in the long run. This result tells us that M2 and CPI are correlated but the Fisher equation is only true qualitatively, not quantitatively. We may need a new theory to more accurately describe the change of money supply, GDP and CPI. However, in the long run, M2 and CPI is clear positively correlated. No Chinese Puzzle exists here.

In quarterly data, the coefficient of M2 is not significant, close to 0 and has an unexpected sign. So we suggest that money supply does not even affect the price level in a short period of time as P is rigid in short run. The coefficient of Y is nearly 0.4, positive and significant. All of these coefficients contradict to the quantity theory, which notify us the Chinese Puzzle exists in the short run.

We conclude that in long term, P is affected by M2, but not proportionally. The elasticity of M2 and P is 0.59, not 1. So Fisher is partly true and Chinese Puzzle does not exist. In short term, P is not affected by M2. Fisher equation does not hold true, which confirms the Chinese Puzzle.

4.3 The M2/GDP Model

According to the literature, the Chinese Puzzle happens after the mid 1980s. We will transform the basic Fisher equation into $\ln P = \ln M2 - \ln Y$. Results are reported in table 4.

4.3.1 Regression Results

Table 4: *Regression Results*

The M2/GDP Model			
		Annual	Quarterly
Abbrev.	Variable	$N = 33$	$N = 60$
$\ln(M2/Y)$	Log of M2 over real GDP	0.5182***	0.0190**
		(0.0391)	(0.0078)
Constant		5.1581***	5.9233***
		(0.0668)	(0.0687)
ρ		0.8872	1.0261
F		945.41***	5.92**

*Prais-Winsten standard errors are in parentheses. "***", "**", and "*" denote significance from the corresponding overall mean value at the 1%, 5% and 10% levels, respectively.*

4.3.2 Detect and Fix Violation of Classic Linear Regression Assumptions

In annual data, We use Breusch-Pagan test for heteroskedasticity. The p-value of the test is 0.4523, so we conclude that variances are constant. We use Durbin-Watson test for serial correlation. Test statistic is 0.2891, which is less than critical value in 5% significance. So we conclude that there is positive serial correlation. We use Prais-Winsten regression to correct serial correlation. The coefficients and the standard errors of the model are in the table.

In quarterly data, We use Breusch-Pagan test. The p-value of the test is 0.6720, so we conclude that variances are constant. We use Durbin-Watson test. Test statistic is 0.5009, which is less than critical value in 5% significance. So we conclude that there is positive serial correlation. We use Prais-Winsten regression to correct serial correlation. The coefficients and the standard errors of the model are in the table.

4.3.3 Analysis and Interpretation

M2-to-GDP ratio is a proportion that reflects a country's financial development. A higher M2-to-GDP ratio means a larger financial sector.

In annual data, we can see that $\ln(M2/Y)$ has significant, positive and nearly 0.5 coefficient 0.5182. It confirms the result of model 1 that P and $\ln(M2/Y)$ have about 0.5 elasticity. This shows $\ln(M2/Y)$ plays an important role determine price level in the long run, which partly proves Fisher equation. The Chinese Puzzle does not exist in annual data.

In quarterly data, $\ln(M2/Y)$ has significant but very small coefficient. This means that P and $\ln(M2/Y)$ have very weak relation compared to annual data model. So Fisher equation is not true for quarterly data. Again, this confirms to the Chinese Puzzle and shows that the price is rigid in the short run, money supply and price level therefore has a weaker relation than long run.

We conclude that Fisher equation is partly true in long term. In short term, Fisher equation does not hold true. Therefore Chinese Puzzle happens in the long run, not short run, which confirms to our previous models.

4.4 The Velocity of Money Model

4.4.1 Regression Results

We do the same regression as Model 2 and analyze the residuals. The regression results are in Table 3. The residual plot of annual data is in Figure 5. The residual plot of quarterly data is in Figure 6:

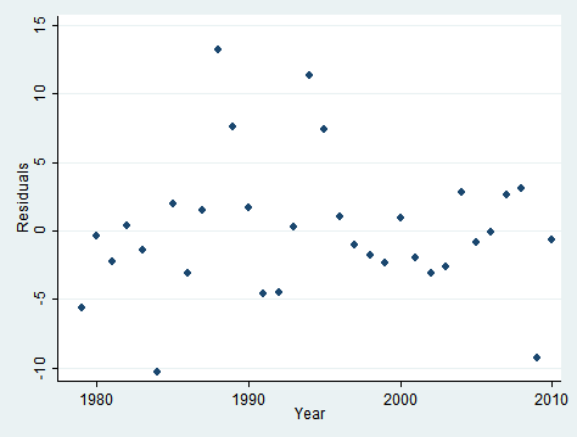

Figure 5: *The residual plot of annual data*

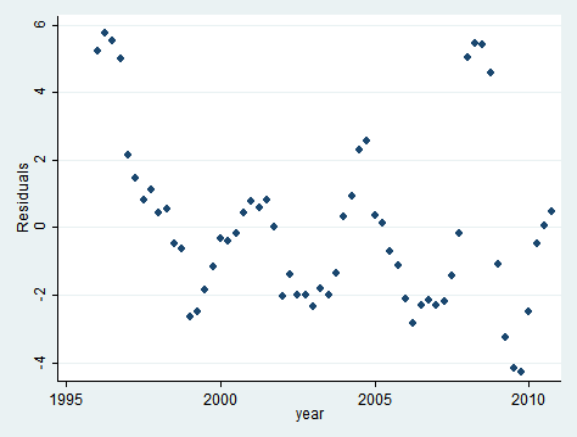

Figure 6: *The residual plot of quarterly data*

4.4.2 Analysis and Interpretation

After discovering the Chinese Puzzle exist in the short run, we want to find the reason of it. According to the literature, the advocates of this explanation are Zhao Liuyan, Wang Yiming(2005) et al. They used the variations of the Equation of Exchange to support their conclusion. They argued that the reason for the high growth rate of money supply and low inflation is due to the decrease in velocity of money. They further pointed out that it was the growth rate of money supply that was higher than the rate of income increase which caused the decrease of China's velocity of money. In $PR = M2R + VR - YR$, decrease in velocity of money will also let the Chinese Puzzle happen. We treat residuals in the models as velocity of money, assuming Fisher equation is correct in the data.

In annual data, we find that velocity of money does change from 1978 to 2010 but doesn't have significant trend. The velocity of money in annual data ranges from -10.26 to 13.22. This small amount of change can't explain the Chinese Puzzle. Therefore this doesn't support that the change in velocity of money is a reason

for the Chinese Puzzle. In the quarterly data, we found that velocity of money ranges from -2.54 to 2.19, and doesn't change much from 1996 to 2010. This amount of change, compared to the change of M2, also can't explain the Chinese Puzzle. Comparing these two results, we found the velocity of money fluctuated slightly in the long run. The change in velocity of money is not a reason for the Chinese Puzzle.

Besides residual analysis, we further our analysis by using GDP/M2. The ratio of GDP over M2 is commonly used by researchers to show the velocity of money, assuming the quantity theory hold true. Figure 7 and 8 show the velocity of money in annual data and quarterly data. We can see that the velocity of money in China is decreasing. Also we can see that the change rate of the velocity of money is decreasing. The fluctuation of GDP/M2 in quarterly data is due to the quaterly characteristics of China. However, this analysis has a weakness as GDP/M2 is not necessary representative of velocity of money. As our previous results, the quantity theory might not even true in the long run. Therefore, the decreasing GDP/M2 only mention us the money supply grows much quicker than GDP. We would rely on the residual analysis as a better proxy for velocity of money and conclude that change in velocity of money is not a reason for the Chinese Puzzle.

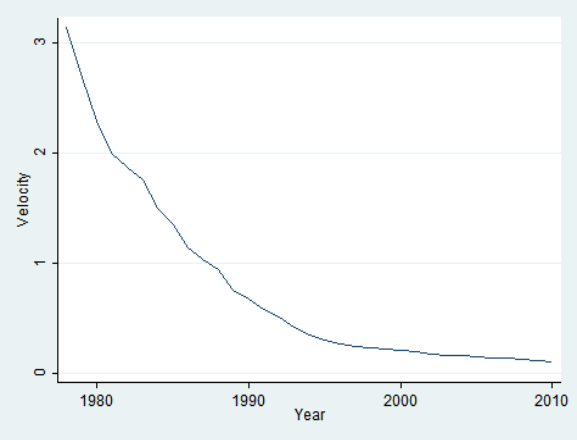

Figure 7: *The ratio of GDP over M2 in annual data*

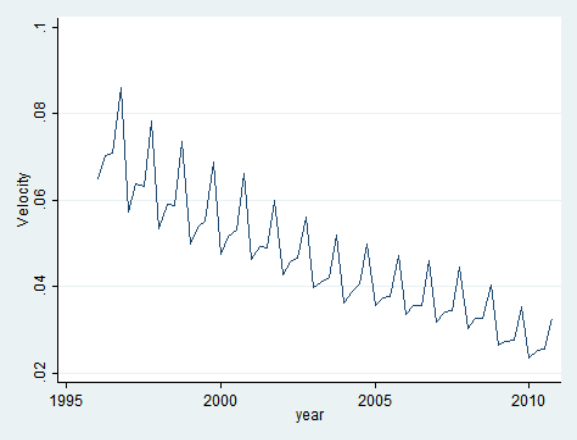

Figure 8: *The ratio of GDP over M2 in quarterly data*

4.5 The Time-lag Model

4.5.1 Regression Results

We use the annual data and the quarterly data to run a regression which includes a variable of M2's lag term. Results from the regression are reported in Table 5.

Table 5: *Regression Results*

		The Time-lag Model	
		Annual	Quarterly
Abbrev.	Variable	$N = 33$	$N = 59$
$\ln M2$	Log of M2, lagged	0.8977***	0.0149***
		[0.9606]	[0.0237]
$\ln Y$	Log of real GDP	-1.3140***	0.0176
		[0.2059]	[0.0336]
Constant		9.0650***	5.0325***
		[1.0188]	[0.1585]
F		782.61***	25.84***

*Newey-West Standard Errors are in square brackets. "***", "**", and "*" denote significance from the corresponding overall mean value at the 1%, 5% and 10% levels, respectively.*

4.5.2 Detect and Fix Violation of Classic Linear Regression Assumptions

In the annual data, The mean VIF is 131.88. So the data have multicollinearity. We choose to do nothing. The Durbin-Watson d-statistic 0.6362, which means it has serial correlation. The p-value of Breusch-Pagan test is 0.9143 and we conclude that the variances are equal. We use Newey-West Standard Errors to correct serial correlation.

In the quarerly data, The mean VIF is 10.53. So the data have multicollinearity. We choose to do nothing. The Durbin-Watson d-statistic 0.1407, which means it has serial correlation. The p-value of Breusch-Pagan test is 0.2065 and we conclude that the variances are equal. We use Newey-West Standard Errors to correct serial correlation.

4.5.3 Analysis and Interpretation

For the annual data, the coefficient for the lagged M2 term is nearly 0.9 and significant at 1% level, and has the positive sign which confirmed our expectation. The overall fit is also very good. This informs us the time-lag does exist in the long run. The coefficient of M2 for the quarterly data is nearly 0, positive and significant at the 1% level. Notice in annual data sets the coefficient of Y has the negative sign which confirm our expectation and is significant at the 1% level. Although two regression results can't be directly compared, we can see the result of the second model, which has M2 as a current term, has coefficients and F statistic lower than the fourth model. Therefore, this model has an overall fit better than the second model. Thus, we could conclude that the fourth model explains the situation much better. Because the time-lag exists, the money supply changes and the inflation rate haven't change yet, which makes the relationship seem negative in the same period. However, in the long run when price fully adjust, the Chinese Puzzle does not exist.

Many research papers agree that time-lag is the cause of the Chinese Puzzle. Yao(2007) found that The money supply has lag effect on inflation rate[16]. Friedman thought the average time-lag is about 6 to 9 months. Meiselman(1969) thought it is 3 to 6 months or even 3 to 5 years. Shuai(2002) suggested that it is the dramatic change in China's money supply and long time-lag that cause this unusual relationship between the two[12]. Liu Wei(2002) believed that the effect of change in M1 and M2 growth rate lags behind 9 to 13 quarters[10]. Liu Bin(2002) shows that money supply has a significant influence on the price level in the long term. When the money supply increases, the price level goes up after 2 quarters. After 12 quarters, the change in the money supply fully reflects the change of the price level[7]. In "The Analysis of Contradiction of China's Money Supply and Inflation", Bu Yan and Li Xiaoming stated that, first, China's money supply has an effect on inflation, creating lags for about 5 years. Second, the money supply within 2 years has an positive effect on the increase of CPI. But after a quarter, the money supply before 3 to 5 years

has a negative effect on the increase of CPI. The deposition of money in an economic system has formed a reservoir between the money supply and the inflation. It absorbs the current money supply and deposits money in the early phase so that it weakens the money supply's influence on the inflation. Finally, it forms China's contradiction of a large money supply and low inflation. Third, in the long term, money supply has a negative effect on inflation due to the reservoir factor.

5. Conclusion and Discussion

In conclusion, while mainstream economists agree that the quantity theory holds true in the long run, there is still disagreement about its applicability in the short run. Critics of the theory argue that velocity of money is not stable and, in the short-run, prices are sticky, so the direct relationship between money supply and price level may not exist. After estimating five Quantity Theory of Money specifications using annual and quarterly data, we found the Chinese Puzzle does exist, however, for a relatively short period. In the long run, the relationship of money supply and inflation rate in China is partly consistent with the Quantity Theory of Money and Chinese Puzzle does not exist. M2 and P are positively correlated, but are not proportional as 1-1. We found the M2 is the most relevant money supply variable determining price level among M0, M1, M2. We also found the change of velocity of money is small and can't explain the Chinese Puzzle. The small change agrees with the Quantity Theory of Money's assumption, which states that the velocity of money is stable in the long run. Therefore, change in velocity of money is not a cause of the Chinese Puzzle. We also found that time-lag, i.e. carryover effect, might be a cause of the Chinese Puzzle. As we can see in the graphs, if we move the CPI curve left by 1 year, we can see the two curves almost perfectly fit each other. This explains why Chinese Puzzle only exist in the short run, not in the long run.

Our research results shed lights on the efficiency of China's monetary policy. Our research shows that in short term, money supply and inflation rate does not have positive relationship. We can see that in 2007, the central bank has increased interest rate for 5 times, but the CPI increase rate remained high. From 1997 to 2002, there was deflation. The central bank decreased interest for 6 times, but it was not effective to tackle deflation. This shows that the central bank's monetary policy is not so effective. However, in long term, the money supply has effect on price level. Therefore, we should notice long term effect of money supply on economy.

Our research shows the time-lag effect of monetary policy. The monetary policy can take effect only when the credits are issued to customers and firms. There some problems that prevent the credits being issued. First, because the interest rates are decided by the central bank and there is big difference in deposit and loan rate. In Aug, 2006, the one year deposit rate is 2.25% and loan rate is 5.76%, which means that banks only need to lend half of the deposit to pay for the deposit interest. Banks also can receive interest of bank researves at the deposit reserve rate of 1.89%. This makes commercial banks less motivated to lend more money. Second, commercial banks overemphasize risk prevention and ignore small and medium-sized enterprises and the privately owned enterprises. These factors prevent monetary policy taking immediate effect. The dependence of the central bank is also a cause of time-lag effect. The central bank is under the leadership of the State Council. The central bank cannot make its own decision of monetary policy but carry on the State Council's policy. This results in longer time-lag than other developed countries. In addition, the effectiveness of monetary depends on the public's expectation. In 2006, the inflation was driven by the increase of the price of pork and chicken. To make matters worse, the government increased the salaries of officials, which aggravated the expectation of inflation, which made the central bank's policy ineffective.

Our research provides suggestions to monetary policy.

1. Reduce the time-lag effects of monetary policy. First, the central bank should have more independence and transparency when making decisions. The central bank law should be amended to allow central bank to have the right to independently decide money supply, interest rate, exchange rate and other important targets. This will reduce the time-lag in the decision process. It will also help better

stabilize price level in long term and the monetary policies will not be affected by the government's goal, i.e. to increase employment and boost economy. The central bank should increase transparency, i.e the transparency of making monetary policy to make the public to have clear expectation about the central bank's future policies. Second, the central bank should increase the predictability of monetary policy. The central bank should use all available economic information to make more prediction about economy. For example, the central bank should fully analyze the impact of subprime mortgage crisis in US in 2008 to China economy to do its best to limit this impact.

2. Promote interest rate liberalization reform. The regulation of interest rate violates the interest rate mechanism and cannot show the demand and supply of money. Then marketization of interest rate will promote the development of money market, which is one of the tools for monetary policy to take effect. The interest rate of money market will show the true situation of the market, which is helpful for the central bank to make effective monetary policy.

3. Avoid using monetary policy to control price level if fiscal policy is more effective. In the inflation from 2006 to 2008, the central bank increased interest rate and required deposit reserve ratio to control money supply, but it was not effective to tackle inflation. This inflation was mainly caused by the increase of the price of food, such as pork. The increase of interest rate cannot curb the demand of food, but can curb the investment in the food industry, which limited the production of food in the future. Therefore, the increase of interest rate cannot control the increase of food price. One effective way to control food price is to provide subsidy to farmers who raised pigs.

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