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The Fisher effect in the Chinese economy

Qian, Fang, Ph.D.

City University of New York, 1994

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The Fisher Effect in the Chinese Economy

by

Fang Qian

**A dissertation submitted to
the Graduate Faculty in Economics
in partial fulfillment of the requirements for
the degree of Doctor of Philosophy,
The City University of New York**

1994

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THE CITY UNIVERSITY OF NEW YORK

Abstract

The Fisher Effect in the Chinese Economy

by

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Adviser: Professor Thom Thurston

This dissertation studies the Fisher effect, i.e., the relationships between inflation rates and interest rates, in the Chinese economy.

The simplest model for the Fisher effect is a linear regressive model of the inflation rate regressed on the interest rate. As pointed out by Barsky, however, this linear model tells us the Fisher effect as well as the persistence of inflation. An ARIMA model can be found to describe the persistence of inflation, but a careful study reveals that it actually represents a mixture of the Fisher effect and the persistence of inflation. In other words, the above linear model and ARIMA model can not separate the Fisher effect and the persistence of inflation.

In this dissertation, I propose a new ARIMA model of the inflation rate cross-correlated with the interest rate. This new model has two parts: one is for the Fisher effect and the other is for the persistence of inflation. By applying this model to Chinese data and U.S. data, I discover that these two parts are independent. Therefore the new ARIMA model may be used to separates the Fisher effect and the persistence of inflation. The computation results on Chinese data indicate an apparent short-run Fisher effect. The computation results on U.S. data coincide with the standard theory of the Fisher effect in the U.S. economy and hence confirm the validity of the new model.

Preface

The purpose of this thesis is to study the Fisher effect in the Chinese economy. The Chinese financial system is an administered one and hence one may question what is the meaning of a Fisher effect in China. By a close examination of the economy, we discover that the underlying mechanism is rather market-oriented, especially during the periods before 1965 and after 1984. Therefore a study of the Fisher effect becomes a way to investigate the market-oriented behavior in the Chinese economy.

The data we use are monthly annual inflation rates computed from the National General Retail Price Index and the interest rates on one year time savings from July, 1948, to July, 1993. Since the Chinese economy is still not fully a market one, the data have certain deficiencies: (i) the inflation rates before 1951 are compiled from different sources and thus the final figures may not have the desired continuity; (ii) the only available inflation data from 1951 to 1985 are yearly averages of unpublished monthly inflation rates; (iii) the prices in the period between 1966 and 1984 were restricted and heavily subsidized and hence the inflation rates from 1966 to 1984 may be partly administered; (iv) the monthly inflation data after 1985 are not complete; and (v) the interest rates are bank rates administered by the central bank. Despite these deficiencies our inflation rates and interest rates are still among the best Chinese data available covering the entire history of the Chinese economy continuously from late 1948 to 1993.

To assess the deficiency in (v) we compare the bank rate with a market interest rate over the early years of the Chinese economy; the resulting correlations between

the two rates support the claim that they are essentially similar. We also quote official documents from 1948 to 1971 related to adjustments of interest rates by the central bank; these documents imply that although the rates are administered rates, they are adjusted according to the market situation and hence a good proxy of the market interest rates over different historical periods.

The preliminary test of the Fisher effect is a simple linear regressive model with various time lags of inflation on monthly data. This preliminary test suggests the existence of the (long-run) *ex post* Fisher effect over the entire history of the Chinese economy when the time lag is set so that the interest rate appears about five months after the realization of the inflation rate. Since our interest rates were administered by the central bank according to market conditions, an interpretation of this phenomenon is that it usually took about five months for the central bank to follow the market situation and adjust interest rates accordingly.

In order to eliminate the effect of the deficiency in (iii), we recalculate this simple linear regressive model with missing data from 1966 to 1984. The results are surprisingly similar to the preliminary test and therefore we can conclude that the inflation rates from 1966 to 1984 are acceptable representatives of the real inflation and that the effect of the deficiency in (iii) is not important.

Next we want to alleviate the deficiencies in (ii) and (iv) by considering the same simple linear regressive model on yearly data. The yearly interest rates are yearly averages of monthly interest rates. In order to still have monthly time lags of inflation, we compute these yearly averages over the calendar year and various fiscal years. The results confirm our monthly findings.

The only way to overcome the deficiency in our data suggested by (i) is to ignore the first couple of years and consider the Fisher effect from 1950 to 1992 on

yearly data. Using a SAS PROC ARIMA procedure we discover a short-run *ex post* Fisher effect over this period with the same time lags as in the preliminary test. The ARIMA procedure, however, shows that the residuals of this model are highly autocorrelated and hence a new model is needed to correctly describe the relation between inflation rates and interest rates. In fact, it is pointed out by Barsky [2] and others that the linear regressive models on the Fisher effect sometimes actually test the persistence of inflation. Our highly autocorrelated residuals may have confirmed this observation. As suggested by Barsky [2] we then use another SAS PROC ARIMA procedure to compute a model on the persistence of inflation.

Since the model of the short-run Fisher effect contains information on the persistence of inflation and the model of the persistence of inflation contains information of the Fisher effect, each model represents only a part of the story and hence is not the desired one. We propose a new ARIMA model of inflation crosscorrelated with the interest rates using again a SAS PROC ARIMA procedure. This new model has two parts, one for the short-run Fisher effect and the other for the persistence of inflation. Since the computation shows that the two parts are essentially uncorrelated, the former part represents the short-run Fisher effect only and the latter represents the persistence of inflation only. Since we can separate the Fisher effect and the persistence of inflation, we can then claim the existence of the *ex ante* short-run Fisher effect in the Chinese economy, when the time lag of inflation is set so that the interest rate adjustments appear about five months after the realization of the inflation rates.

We conduct an empirical test on this new model in Chapter 3. Indeed we apply the new model to yearly data of the U.S.A. from 1945 to 1992. The results support our model when we compare them with the standard theory on the Fisher effect

for the U.S. economy.

I would like to extend my sincere appreciation to all the people and loyal friends who have helped me during the preparation of this dissertation. In particular, I want to express my deep gratitude to my adviser Professor Thom Thurston whose constant encouragement and advice throughout the duration of this work is a debt which could never be repaid in full. I also wish to extend my heartfelt thanks to Professor Michael Grossman for his generous support and help in all areas of my graduate study and to Professor Salih Neftci for his kind help and instruction on econometrics and time series analysis. Special thanks are due to Ms. Ann Holzman for her valuable assistance when I was in and out of New York City. Finally I would like to thank my parents and husband for their kind understanding and support in all these years.

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Chapter 1

The Fisher theory

§1. Introduction.

In 1930 Irving Fisher [13] discovered a relation between inflation rates and interest rates. Since then the Fisher effect or Fisher hypothesis has become one of the most active topics in the field of monetary economics. In order to verify Fisher's hypothesis in various economic regimes, several versions of the Fisher effect have been proposed. Some of these versions are essentially equivalent, but some of them are quite different.

The study of the Fisher effect in American economy is well-developed, as it is in European countries. For the U.S. economy the Fisher effect is widely accepted over the period from 1951 to 1979 (cf. Gibson [16], Mishkin [22], Roll [39] and Summers [45]) and over the period after 1979 (cf. Clarida and Friedman [9]). However, the Fisher effect in most other countries is not found so readily. The search for the Fisher effect in Asian countries, in particular, has not been fruitful. A possible reason for this situation is that the economies in Asia have just been developed in recent decades so that systematic monetary data in most Asian countries are usually unavailable.

In this paper we will first summarize some influential studies of the Fisher effect. Then we will concentrate on the relations between inflation rates and interest rates in the economy of the mainland China. Moreover, we will develop new math-

emathical models for the Fisher hypothesis. Indeed, the improvements in statistics computer softwares in the past several years made it possible to consider and compute more sophisticated models which can best describe relations between inflation rates and interest rates.

In order to verify the validity of our new models, we will finally apply the new models to the data for the U.S. economy. The comparison of our computations with the standard theory confirms our new models.

§2. Fisher's original arguments.

In his book *The theory of interest* [13] Fisher investigated the inflation rates and interest rates in the markets in London, New York, Berlin, Paris, Calcutta and Tokyo. The inflation rates he used are annual rates derived from the wholesale price indexes in these countries, and the interest rates are central banks' discount rates and prevailing rates on prime bankers' or merchants' bills with maturities from two to six months. For the London market his data are dated from 1825 through 1927 while in New York the data are from 1866 to 1927, in Berlin from 1861 to 1912, in Paris from 1872 to 1914, in Calcutta from 1861 to 1926, and in Tokyo the time periods over 1887 through 1926.

Fisher then divided the entire time period for each country into several subperiods so that the interest rates and inflation rates are roughly constant during each subperiod. He then observed from the data in London and Berlin market: "When the rate of price change falls from one (sub)period to the next, the money rate of interest usually falls, and when the rate of price change rises, the interest rates usually rises also." With great economic foresight Fisher then proposed his famous hypothesis, saying: "There is a very apparent, though feeble, tendency for

the interest rate to be high when prices are rising, and the reverse. The adjustment is imperfect and rather irregular, but in the great majority of cases the tendency is evident.”

Fisher had to admit that he could not observe the tendency for markets in countries other than England and Germany. In particular, the data from the New York market shown nothing supporting the claimed tendency, as confirmed by recent studies on the Fisher effect in the United States. In other words, there is essentially no evidence of the Fisher effect based on data in the United States before World War II. (cf. Friedman and Schwartz [14], [15], Mishkin [22], Roll [39] and Summers [45].)

§3. The *ex ante* Fisher effect.

Today simple linear regressions are the most common method used to test the Fisher effect. Let i_t^m be the annualized interest rates at time t , measured in months, on loans or deposits which will mature at time $t + m$ in months, and let π_t^m be the annualized future inflation rate from time t to time $t + m$ in months. Note that at time t the interest rate i_t^m is known, but π_t^m is still a random variable. We first consider the following simple linear regression (cf. Mishkin [23], p. 5.)

$$E_t(\pi_t^m) = \alpha_m + \beta_m i_t^m + a_t \quad (1)$$

over a certain period of time. Where E_t is the expectation at time t , α_m and β_m are regression coefficients and a_t is a random error term. The Fisher effect over that time period is equivalent to a significantly positive coefficient β_m . (Some people believe that β_m should be close to 1 in order to support the Fisher effect. Please refer to section 6 below.) Here by a significant positive β_m we mean that the t -

statistic for the null hypothesis of $\beta_m = 0$ is larger than 2. Since we use monthly data, the sample sizes of our linear regressions are usually very large. A t -statistic larger than 2 will give us a positive β_m with a confidence level higher than 97.5%. In order to measure the goodness of our model we calculate the R -square estimation.

It is easy to see that the Fisher effect implied by the linear regression in (1) is that the nominal interest rates can predict inflation, or more accurately, that the nominal interest rate i_t^m which is known at time t and to be matured at time $t + m$ can be used to determine the expectation of the inflation rate π_t^m from time t to $t + m$ which is unknown at time t .

An obvious disadvantage of this model is that there are usually no data on expectations of inflation available. A paper on the Fisher effect for the U.S. economy by Gibson [16] seems to be the only known study of that kind of linear regression analysis. Actually Gibson used a proxy for $E_t(\pi_t)$ which was derived from direct data on inflationary expectations collected by surveys to a group of business, government, labor and academic economists from 1947 to 1970. The data obtained this way is rather distinguished and rare, if not unique. Gibson's results strongly support the argument that the Fisher effect appears quite strong since 1950's in the United States.

Unfortunately data of inflation expectations of this kind are not available for the Chinese economy which we are going to study. Therefore we have to consider other models.

§4. The *ex post* Fisher effect.

Since data on expectations of inflation are hardly available, we consider the linear regression (cf. Mishkin [23])

$$\pi_t^m = \alpha_m + \beta_m i_t^m + a_t \quad (2)$$

where π_t^m is the *ex post* inflation rate, i.e. a realized inflation rate based on a price index over a period from time t to $t + m$. Barsky [2] defined an *ex post* Fisher effect as a strong correlation between nominal interest rates and realized inflation in (2); hence the linear regression in (2) can be called a test for the *ex post* Fisher effect.

To study the difference between the two models in (1) and (2), let us write

$$\pi_t^m = E_t(\pi_t^m) + \epsilon_t^m$$

where π_t^m is the inflation rate unknown at time t and ϵ_t^m is the forecast error of inflation. If we assume the hypothesis of rational expectations of inflation, the error term ϵ_t^m is irrelevant to the inflation data known at time t . Thus under the hypothesis of rational expectations of inflation, testing the Fisher effect by the linear regression in (2) is equivalent to testing the Fisher effect by the model in (1).

Some economists believe that the hypothesis of rational expectations of inflation is automatically true and assume it through out their research (c.f. Mishkin [23], Friedman and Schwartz [14], [15], and Summers [45]). Others, however, point out that this hypothesis is not automatically valid and should be tested (cf. Barsky [2]). Nevertheless this hypothesis of inflation can not be easily tested, because the expectations $E_t(\pi_t^m)$ are usually not known.

Noting that the underlying rationale for the model in (2) is that people can forecast inflation without bias, Barsky [2] proposes to study the persistence and forecastability of inflation instead of the rational expectations of inflation. Persistence and forecastability analysis is usually performed on quarterly or yearly data; hence we want to investigate the linear models

$$\pi_T = \alpha + \beta i_T + a_T \quad (3)$$

and

$$\pi_{T+1} = \alpha + \beta i_T + a_T \quad (4)$$

where π_T is the *ex post* annual inflation rate realized in year T , and i_T is an annual average of interest rates in year T . Here as in the rest of this article, T denotes a time measured in years and t in months. The first model above is a linear regression on inflation rates against the interest rates prevailing at the time of the realization of the inflation rates, while the second model compares annual interest rates and inflation rates realized at the maturity of the savings. According to [2], the model in (3) tells us something about the persistence of inflation, and the model in (4) provides information on the forecastability of inflation, as well as the Fisher effect.

§5. The Forecastability and persistence of inflation.

As in Barsky [2], the forecastability of inflation is measured by the corrected square correlation coefficient

$$\bar{R}^2 = 1 - \frac{\frac{1}{L-K} \sum_{T=1}^L b_T^2}{\frac{1}{L-1} \sum_{T=1}^L (\pi_T - \bar{\pi})^2}$$

of the autoregression of inflation

$$\pi_T = \beta_1 \pi_{T-1} + \dots + \beta_K \pi_{T-K} + b_T$$

on inflation data of sample size L , where b_T is the random error. We will use SAS PROC AUTOREG procedure to do the computation (cf. [40]).

For the persistence of inflation, a common method using advanced statistics techniques is the autoregressive integrated moving-average (ARIMA) procedure by Box and Jenkins [4]. Briefly speaking, we want to study time series data of inflation rates π_T . If the time series of inflation is not stationary, i.e., if the stochastic process of π_T exhibits time-changing level and/or variance, we may have to consider its first difference defined as a new time series

$$Z_T = \pi_T - \pi_{T-1}.$$

If Z_T is still not stationary, we will look at the second difference of inflation defined by

$$Y_T = Z_T - Z_{T-1}.$$

Let us say that we finally obtain the d th difference W_T of inflation which is stationary. Then the autoregressive integrated moving-average model of π_T is

$$W_T = \mu + \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q} \quad (5)$$

where a_T is again the random error. This model is denoted by ARIMA(p, d, q), where d is the degree of differencing, p is the order of the autoregressive part

$$\varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p},$$

and q is the order of the moving-average part

$$a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}.$$

If d is zero, we may denote the model by ARMA(p, q); if d is positive, the constant term μ is usually assumed to be zero.

The computation of the ARIMA model in (5) is usually very complicated and left to computers using SAS PROC ARIMA procedure (cf. [40]). One thing what we have to do, however, is to determine the orders p and q using autocorrelations, inverse autocorrelations and partial autocorrelations of W_T . These autocorrelation functions are given in the printed output of the SAS PROC ARIMA procedure, and their behavior suggests possible ARIMA models. For example, when the autocorrelation coefficients essentially equal zero after the p th one and the inverse and partial autocorrelation coefficients are dominated by an exponential decay function, we may use the model $ARIMA(p, d, 0)$. When the inverse and partial autocorrelation coefficients are equal to zero after the q th one and the autocorrelation coefficients are dominated by an exponential decay function, we may try $ARIMA(0, d, q)$.

§6. Lagged inflation rates.

In the linear regression model in (2) the inflation rate π_t^m and the interest rate i_t^m are all taken over the time period from t to $t + m$: π_t^m is the inflation rate at time t realized at $t + m$, and i_t^m is the interest rate at time t on savings matured at $t + m$. To investigate the relationships between these rates we also want to study linear models of interest rates and lagged inflation rates:

$$\pi_{t-k}^m = \alpha_m + \beta_m i_t^m + a_t$$

where k is the time lag of inflation. This model can be written in a different way

$$\pi_t^m = \alpha_m + \beta_m i_{t+k}^m + b_t$$

where i_{t+k}^m is the future interest rate k months after time t . In the following we will mainly consider the case of $m = 12$, i.e., linear models with annual rates

$$\pi_t^{12} = \alpha + \beta i_{t+k}^{12} + b_t. \quad (6)$$

When $k = 12$ the model in (6) is a linear regression between monthly annualized inflation rates and interest rates which prevail at the time of the realization the inflation rates. When k is larger than 12, the model in (6) is between inflation rates and interest rates which prevail $k - 12$ months after the realization of the inflation rates. The economic interpretation of these cases of the model in (6) is that they represent possibilities of predicting current (when $k = 12$) and future (when $k > 12$) interest rates using inflation rates just realized at time t .

If we use yearly data of inflation and interest rates, we see that the model in (3) is indeed the linear regression on yearly data with a time lag of inflation equal to one year, i.e., 12 months, which just corresponds to the linear model in (6) on monthly data with the time lag of $k = 12$. In order to construct a linear model on yearly data with a time lag of inflation larger than 12 months, we propose to use a yearly average of monthly interest rates over a fiscal year. More precisely, if we want a time lag of k months, $12 < k < 24$, in a linear model on yearly data, we define $i_T^{(k-12)}$ the yearly average of monthly interest rates on the T th fiscal year starting from the $k - 11$ th month of the calendar year. For example, when $k = 13$, the fiscal year T is from February, calendar year T , to January, calendar year $T + 1$; the average of the twelve monthly interest rates from February, calendar year T , to January, calendar year $T + 1$, is the yearly rate $i_T^{(1)}$. When $k = 12$, the fiscal year becomes the calendar year, and hence we get the usual yearly rate i_T . The linear model on yearly data with a monthly time lag k with $12 < k < 24$ then can be written as

$$\pi_T = \alpha + \beta i_T^{(k-12)} + a_T. \quad (7)$$

Similar to the model on monthly data in (6), the linear regression in (7) tests the possibility of prediction of future interest rates using realized inflation rates.

§7. The short-run Fisher effect.

The Fisher effect we have studied in the previous sections was called by Mishkin [23] the long-run Fisher effect, which is characterized by the fact that when the inflation rate is higher for a long period of time the interest rate will also tend to be high, and vice versa. The short-run Fisher effect, on the other hand, is a relation between the first difference of inflation and the first difference of interest rates, which indicates that a change in the inflation rate is associated with a change in the interest rate in the same direction. For instance, the short-run *ex ante* Fisher effect can be tested by a significant positive coefficient β_m in the linear model

$$E_t(\pi_t^m) - E_{t-1}(\pi_{t-1}^m) = \beta_m(i_t^m - i_{t-1}^m) + a_t, \quad (8)$$

where $E_t(\pi_t^m) - E_{t-1}(\pi_{t-1}^m)$ is the expectation of the first difference of inflation, and $i_t^m - i_{t-1}^m$ is the first difference of the interest rates. Likewise, the short-run *ex post* Fisher effect is given by

$$\pi_t^m - \pi_{t-1}^m = \beta_m(i_t^m - i_{t-1}^m) + a_t, \quad (9)$$

where $\pi_t^m - \pi_{t-1}^m$ is the first difference of the realized inflation rates; the short-run *ex post* Fisher effect with lagged inflation is in

$$\pi_t^m - \pi_{t-1}^m = \beta_m(i_{t+k}^m - i_{t+k-1}^m) + a_t, \quad (10)$$

where k is the time lag of inflation in months. Using yearly data, the short-run Fisher effect has similar forms:

$$\pi_{T+1} - \pi_T = \beta(i_T - i_{T-1}) + a_T, \quad (11)$$

$$\pi_T - \pi_{T-1} = \beta(i_T - i_{T-1}) + a_T, \quad (12)$$

and

$$\pi_T - \pi_{T-1} = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + a_T \quad (13)$$

for $12 < k < 24$.

One of the advantages to study short-run Fisher effect and its various models is that the first difference of inflation usually looks stationary, while inflation itself does not (see Chapters 2 and 3 for examples). Since this is the same consideration we had for the ARIMA models, we could then compare the linear regression results in (11), (12) and (13) with the results from the ARIMA model in (5). Also we may use the SAS PROC ARIMA procedure to compute the models above, instead of using the usual linear regression methods like SAS PROC GLM. The reason we prefer SAS PROC ARIMA is that its computation has consideration on autocorrelations between various variables and residuals, and hence it can give us more information on the goodness of the models.

Technically, if we want to use a SAS PROC ARIMA procedure to compute (11), (12) and (13), we should set $p = q = 0$ and $d = 1$ and use the model ARIMA(0, 1, 0) crosscorrelated with a term of the first difference of the interest rates.

§8. New models of the short-run Fisher effect.

The models in (11), (12) and (13) raise new questions about the short-run Fisher effect: What are the relationships between the short-run Fisher effect tested by (11), (12) and (13) and the *ex ante* short-run Fisher effect described by the model

$$E_T(\pi_{T+1}) - E_{T-1}(\pi_T) = \beta(i_T - i_{T-1}) + a_T \quad (14)$$

What is the role played by the time lags of inflation in models in (12) and (13)? Since we use realized inflation here, the linear model in (11) is also associated with the forecastability of inflation, and the models in (12) and (13) are related to the persistence of inflation, together with their connection to the short-run Fisher effect. What is the connection between the short-run Fisher effect and the forecastability or persistence of inflation?

Let us concentrate on the last two models and the persistence of inflation. As in (5) the persistence of inflation is described by an ARIMA model ARIMA(p, d, q) with no crosscorrelation:

$$W_T = \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}$$

where $W_T = \pi_T - \pi_{T-1}$ is the first difference of inflation. On the other hand, the short-run Fisher effect can be tested using an ARIMA model ARIMA(0, 1, 0) crosscorrelated with a term of the first difference of the interest rates.

$$W_T = \beta(i_T - i_{T-1}) + a_T,$$

and

$$W_T = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + a_T$$

for $12 < k < 24$. Consequently the first difference of inflation W_T is related to its past values as well as the first difference of interest rates $i_T - i_{T-1}$ or $i_T^{(k-12)} - i_{T-1}^{(k-12)}$ for $12 < k < 24$. Therefore to answer the above questions we may consider new ARIMA models on inflation crosscorrelated with the first difference of interest rates

$$W_T = \beta(i_T - i_{T-1}) + \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}, \quad (15)$$

and

$$W_T = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}, \quad (16)$$

for $12 < k < 24$.

These models are ARIMA($p, 1, q$) models which contain all the information related to the inflation rates. The first term $\beta(i_T - i_{T-1})$ or $\beta(i_T^{(k-12)} - i_{T-1}^{(k-12)})$ is the part of the corresponding model which represents the short-run Fisher effect, and the part consisting of $\varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}$ representing the persistence of inflation. Since these new models have two parts, they are evidently better than any of the models in (5), (12) and (13). These new models also can be used to study the relation between the short-run Fisher effect and the persistence of inflation. Indeed, a significantly positive coefficient β in (15) or (16) indicate an apparent short-run Fisher effect. Since the SAS PROC ARIMA procedure also calculates the correlations of the estimates of the coefficients $\beta, \varphi_1, \dots, \varphi_p, \theta_1, \dots, \theta_q$, we can determine the correlations between β in the part of the short-run Fisher effect and the coefficients in the part of the persistence of inflation. When such correlations are small, we can then say that the relation

between the short-run Fisher effect and the persistence of inflation is negligible, and hence a significantly positive coefficient β in (15) or (16) indicates the validity of the short-run Fisher effect.

The computation of these new models are certainly quite complicated. Thanks to recent developments in statistics software, we can now study models of this kind cheaply. To confirm the validity of these models, we will apply them to the original data used by Fisher in his book [13]. We will see what conclusions we can get from Fisher's data using sophisticated statistics and computer techniques.

Chapter 2

The Fisher effect in China

§1. Inflation data.

It is known that financial data are relatively scarce in developing countries, and they become even rarer during the periods of transitions of governments and their economies. When available, of course, these data can provide insight in a special perspective into the underlying economies and their financial mechanisms. This is especially true for the situation in Mainland China.

The People's Republic of China was established on October 1, 1949. Its economy indeed dates back to the second half of 1948, when the communists conquered about half of the mainland. Therefore there were actually two different economies in China in 1948 and 1949: one was the economy in the region still controlled by Nationalists, and the other was the economy in the newly liberated area. The former became the economy of Taiwan, while the latter developed gradually into the economy of the whole mainland of China in 1949. In this chapter, we will study the economy of the People's Republic of China from the second half of 1948 to 1993.

A reason we want to investigate the financial data from the very beginning of the economy to the present date is that this give us a complete portrait of the relation between inflation and interest rates in China. The most important reason, however, is that during the periods from 1948 to 1950s and from 1980s to 1993 the Chinese economy acted in a rather market-orientational way despite being

nominally a socialist one.

In order to obtain monthly inflation figures during the period from late 1948 to the present time, we have to look to related documents and articles to find the inflation information piece by piece. We admit that our data may not be accurate as compared with similar data in some other countries, but there are various reasons to believe that the monthly figures we obtained are good approximations and are best possible. Indeed, the information we abstract from official documents below is certainly first-hand data.

Now let us look at the economy before the liberation so that we can have a understanding about the political and economical situation in 1948 and 1949. In late 1940s, the inflation under the Nationalist government ran at a skyrocketing pace. For example in Shanghai the wholesale prices rose dramatically from August, 1948, to April, 1949, according to Kia-ngau Chang [5]:

Table 1
Wholesale Prices in Shanghai Before Liberation

January - June, 1937 = 100								
1947				Jul	1.0408	Aug	1.1464	
	Sep	1.2789	Oct	1.9771	Nov	2.5665	Dec	3.4467
1948	Jan	4.6914	Feb	6.7184	Mar	10.859	Apr	12.588
	May	18.094	Jun	65.897	Jul	95.9	Aug	186.3
	Sep	197.0	Oct	220.4	Nov	2543.1	Dec	3583.7
1949	Jan	12876	Feb	89788	Mar	405320	Apr	20967009

The above figures will be used in the computation below, because they do reflect the inflation experience and expectation of people at that time.

Shanghai was controlled by the People's Liberation Army in May 1949, and

henceforth became a part of the liberation area. Its new economy certainly was influenced heavily by the outgoing economy of the Nationalists; in particular, the inflation rate was still high. Unfortunately, there are no quantitative data available for the inflation rates in Shanghai or other parts of the liberation region in most part of 1948, except that the inflation was "high" according to all the related documents at that time. We find, however, the wholesale prices in big cities in the liberation area from December, 1948, to December, 1949, in Ma Hung and Kao Shang-ch'uan [18], pp. 18 and 20:

Table 2
Wholesale Prices in 13 Big Cities After Liberation

December, 1948 = 100	
1948	December 100
1949	January 153
	April 287
	July 1059
	September 1636
	November 5376
	December 3494

where the September figure is computed according to [8] p. 52. Note that the above prices are not given consecutively from December, 1948, to December, 1949. Since the prices in between are not available, we use the method of linear interpolation to get the following numbers:

Table 3
Monthly Wholesale Prices in 13 Big Cities After Liberation

December, 1948 = 100

1948	December	100
1949	January	153
	February	197.667
	March	242.333
	April	287
	May	644.333
	June	801.667
	July	1059
	August	1297.6
	September	1536
	October	3456
	November	6376
	December	3494

It is noted in People's Bank of China [25], p.15, that the prices dropped in an average 2.96% in several big cities in March, 1950. Together with the figures in Ma Hung and Kao Shang-ch'uan [18], p. 23, we get

Table 4
Retail Prices in 8 Big Cities

March, 1950 = 100

1950	February	103.0503
	March	100
	December	85.4
1951		94.6
1952		93.7

where the last two figures are the average price levels in the corresponding years.

We observe that the figures above in 1948 and 1949 are wholesale prices, and the data from 1950 to 1952 are retail prices. Moreover, the prices for the first period

are from 13 big cities, while the prices for the second time period are from 8 big cities. Certainly these figures should not be mixed up in normal situations. In our case, however, these figures are the only data we can get in the early years of the People's Republic of China, and hence we have to use them and assume that they are good representatives for the true values of the retail price index for the whole country (or the liberation region in 1948 and 1949).

Even with this assumption, we can not connect the price indexes above without first filling the gap between December, 1949, and February, 1950. This can be done using the retail price index given in [44], p. 359:

Table 5

National Retail Prices

December, 1949 = 100

December, 1949	100.0
1950	179.7
1952	200.8

Here the price for December, 1949, is the average price level in this month, while the figures for 1950 and 1952 are the average price levels for the entire years 1950 and 1952, respectively. Under the above assumption, we may identify the price level in December, 1948, in Tables 1 and 3, identify the price level in December, 1949, in Tables 3 and 5, and identify the price level in 1952 in Tables 4 and 5. Consequently we get the following price index.

Table 6
The National General Retail Price Index

1950 = 100																	
1947	Jul	4.625564×10^{-4}	Aug	5.094876×10^{-4}	Sep	6.683886×10^{-4}	1948	Jan	2.08497×10^{-3}	Feb	2.985818×10^{-3}	Mar	4.825984×10^{-3}				
	Oct	6.786706×10^{-4}	Nov	1.14017×10^{-3}	Dec	1.531781×10^{-3}		Apr	5.594438×10^{-3}	May	8.041303×10^{-3}	Jun	2.928605×10^{-2}				
	Jul	4.262026×10^{-2}	Aug	8.279617×10^{-2}	Sep	8.755151×10^{-2}		Oct	9.795102×10^{-2}	Nov	1.130215	Dec	1.592682				
1949	Jan	2.436803	Feb	3.148202	Mar	3.875526	1949	Apr	4.570997	May	8.669499	Jun	12.768				
	Jul	16.8665	Aug	20.66505	Sep	24.4636		Oct	56.04309	Nov	85.62258	Dec	65.64831				
1950	Jan	89.11889	Feb	122.5895	Mar	118.9608	1950	Jan	100.0	1951	112.2	1952	111.8	1953	115.6	1954	118.3
	Apr	117.031	May	115.1012	Jun	113.1714		Apr	117.031	1956	119.5	1957	121.3	1958	121.6	1959	122.7
	Jul	111.2416	Aug	109.3018	Sep	107.382		Jul	131.5	1961	147.0	1962	152.6	1963	143.6	1964	138.3
	Oct	105.4522	Nov	103.5223	Dec	101.5925		Oct	131.5	1966	134.2	1967	133.2	1968	133.3	1969	131.8
								1970	131.5	1971	130.5	1972	130.2	1973	131.0	1974	131.7
								1975	131.9	1976	132.3	1977	135.0	1978	135.9	1979	138.6
								1980	146.9	1981	150.4	1982	153.3	1983	155.6	1984	160.0
								1985	174.1	1986	184.5	1987	198.0	1988	234.6	1989	276.4
								1990	282.2	1991	290.4						

Here the figures before December, 1948, are from the region under the control of the Nationalist government, the monthly numbers for 1950 are gotten by linear interpolation, and the yearly data after 1950 are from [6] and [7].

An obvious problem with the above data is that the first part consists of monthly price levels, while the second half contains yearly data. To obtain a set of inflation data uniformly over the entire time period from 1948 to 1993, let us look at the meaning of the yearly price data above.

The State Statistical Bureau of the People's Republic of China compute monthly inflation data by comparing the national general retail price level in a given month with the price level in the same month in the previous year. These monthly inflation

rates, however, were not published in general. What were published regularly are the average of the above monthly inflation rates in a given year. In other words, they calculate the ratio of the retail price level in January, 1951, over the price level in January, 1950, the ratio of the price level in February, 1951, over that in February, 1950, and ratios corresponding to March through December. The average of these 12 ratios then is the quotient of the yearly price indices in 1951 and 1950: $112.2/100=1.122$. In other words, the national general retail price level rose 12.2% in 1951 compared with the price level in 1950.

Sometimes the State Statistical Bureau released inflation information saying, for example, that the retail price index grew 22% in the first nine months in 1989 over the same period in 1988, of which the first-time price hikes were only 7.6%. The interpretation of this announcement is that 1.22 is the average of (i) the ratio of the retail price levels in January, 1989, over January, 1988; (ii) the ratio of the retail price levels in February, 1989, over February, 1988;; and (ix) the ratio of the retail price levels in September, 1989, over September, 1988, while the price level in September, 1989, is 7.6% higher than the price level in December, 1988.

This kind of terminology is rather confusing so that even inflation specialists in China have sometimes been confused. For the data in Table 6, we point out that there is no direct relation between the monthly figures in 1950 and the yearly number 100 of that year. In particular, the number 100 is not the average of the monthly figures.

In order to form a uniform data set of the inflation over the entire period of Mainland China, we now deduce from Table 6 monthly inflation rates over the same months in previous years. That is, we calculate the ratio of the price index in a given month over the price index in the same month one year ago, and get the

inflation rate by subtracting the ratio by 1. This can be done from July, 1948, to December, 1950, according to the data in Table 6. After 1950, we can only obtain the yearly average of the monthly inflation rates, in view of the above explanation of our data. Given that situation, the best we can do is then to assume the monthly inflation rates remain constant, and hence equal to the yearly average, after 1950. This is acceptable before 1985 because the price index is rather flat from 1951 to 1984, with one exception for 1961, where the ratio of the price index in 1961 over that in 1960 is equal to 1.162, equivalent to an inflation rate of 16.2%. Since no further data for this period are available, we can do nothing to refine our figures. But we certainly can somewhat improve the data in Table 6 from 1985 to 1993.

According to [3], vol. 29, no. 2 (January 1986), p. 2, the retail price index rose 8.5% during the first 11 months of 1985 compared with the same period in 1984. Consequently the monthly inflation rates from January to November, 1985, over the same months in 1984 are equal to 8.5% (the average), and the inflation rate in December, 1985, is 12.1%, because then the twelve-month average of the inflation rates is $(11 \times 8.5\% + 12.1\%)/12$ equal to the yearly average 8.8%.

The monthly inflation rates are published in [3], vol. 30, no. 5-6 (February 1987), p. 24:

Monthly inflation rates in percentage in 1986

Over the same month, 1985

Jan	8.5	Feb	7.6	Mar	6.4	Apr	4.4	May	3.3	Jun	2.8
Jul	3.2	Aug	3.7	Sep	6.0	Oct	4.6	Nov	5.8	Dec	6.2

By [3], vol. 30, no. 36 (September 1987), p. 5, the average inflation rate in January, February and March, 1987, is 5.3%; the inflation rates in April, May

and June are 6.5%, 7.6% and 7.8%, respectively. According to Statistics for 1987 Social-Economic Development by the State Statistical Bureau in [3], vol.. 31, no. 10 (March 1988), the retail price index rose an average 7.3% in 1987 and the December's rise was 9.1% more than for December, 1986. Consequently the average inflation rate for July through November, 1987, is 8.14%, so that the yearly average of the inflation rates becomes

$$\frac{3 \times 5.3\% + 6.5\% + 7.6\% + 7.8\% + 5 \times 8.14\% + 9.1\%}{12}$$

which is equal to the published figure 7.3%.

Based on [3], vol.31, no. 41 (October 1988), p. 19, the retail prices jumped 13.14% in the first half of 1988, compared with the same period in 1987. By [3], vol. 31, no. 44 (October-November 1988), p. 12, the social retail price index in the first 3 quarter rose by 16% compared with the same period last year. According to [3]. vol. 32, no. 10 (March 1989), the general price level in 1988 increased by 18.5% above 1987, and the increase in December is 26.7% compared with December, 1987. With this information, we can find the monthly inflation rates in 1988 compared with the same months in 1987 given in the following table:

Monthly inflation rates in percentage in 1988

Over the same month, 1987

Jan	13.5	Feb	13.5	Mar	13.5	Apr	13.5	May	13.5	Jun	13.5
Jul	21.0	Aug	21.0	Sep	21.0	Oct	25.65	Nov	25.65	Dec	26.7

because

$$\frac{6 \times 13.5\% + 3 \times 21\%}{9} = 16\%$$

and

$$\frac{6 \times 13.5\% + 3 \times 21\% + 2 \times 25.65\% + 26.7\%}{12} = 18.5\%.$$

For 1989 we can find complete monthly inflation rates in (i) [3], vol. 33, no. 8 (February 1990), p. 31, (ii) [44], p. 357, and (iii) Statistics for China National Socio-Economic Development in 1989, in [3], vol. 33, no. 9 (February - March 1990):

Monthly inflation rates in percentage in 1989

Over the same month, 1988

Jan	27.0	Feb	27.9	Mar	26.0	Apr	25.8	May	24.3	Jun	21.5
Jul	19.0	Aug	15.2	Sep	13.0	Oct	8.7	Nov	7.1	Dec	6.4

The monthly inflation rates in 1990 are again not published completely, but rather intensively. Let us first list inflation information in 1990 from different sources below.

(i) By [3], vol. 33, no. 25 (June 1990), p. 11, the inflation in the first two months in 1990 was held at 4.1%, dropping to 3.3% in March and 3.1% in April.

(ii) By [3], vol. 33, no. 48 (November - December 1990), p. 7, the total retail sales price level rose 2.3% between January and September from the same period in 1989.

(iii) According to [3], vol. 34, no. 2 (January 1991), in the first ten months, China's total retail prices rose 2.1% on the same period of 1989.

(iv) By [3], vol. 34, no. 5 (February 1991), p.19, in the first 11 months the nation saw a 2% increase in its general level of retail prices from the same period of 1989; in the first three months, the overall price level increased; between April and June, it dipped slightly; and, after July, it picked up again.

(v) In the Statistical Communique of the State Statistical Bureau on National Economic and Social Development in 1990, the yearly increase on the general retail price level in 1990 is 2.1%.

According to these announcement, we will use the following figures for 1990.

Monthly inflation rates in percentage in 1990

Over the same month, 1989

Jan	4.1	Feb	4.1	Mar	3.3	Apr	3.1	May	-1.6	Jun	-1.6
Jul	3.1	Aug	3.1	Sep	3.1	Oct	0.3	Nov	1.0	Dec	3.2

Here the figures for January through April are given in (i). By (iv) the average of the inflation rates between April and June is slightly negative; hence we may just assume the average is -0.03 and use -1.6 as an approximate value for the the inflation rates in May and June. Based on (ii) the average of inflation rates from January to September is 2.3%, and hence the inflation rates in July, August and September must be 3.1% in average. By (iii) the inflation rate in October must be 0.3% in order to have a ten-month average equal to 2.1%. By the same reason we can get the inflation rates in November and December from (iv) and (v), respectively.

For 1991, the average inflation rate in the first six months is 1.8%, as given in [3], vol. 34, no. 30 (July 1991). By [7], p. 297, the average of the general retail price increase in the first 11 months in 1991 is 2.9%. By People's Daily, January 20, 1992, the yearly increase of the retail price level in 1991 is also 2.9%. Therefore

Monthly inflation rates in percentage in 1991

Over the same month, 1990

Jan	1.8	Feb	1.8	Mar	1.8	Apr	1.8	May	1.8	Jun	1.8
Jul	4.22	Aug	4.22	Sep	4.22	Oct	4.22	Nov	4.22	Dec	2.9

In 1992, the average increase in the retail prices was 5.2% for the first 11 months ([3], vol. 36, no. 1 (January 1993), p. 17), and was 5.4% for the whole year ([3], vol. 36, no. 18 (May 1993), p. 4). this information gives us the following figures.

Monthly inflation rates in percentage in 1992

Over the same month, 1991

Jan	5.2	Feb	5.2	Mar	5.2	Apr	5.2	May	5.2	Jun	5.2
Jul	5.2	Aug	5.2	Sep	5.2	Oct	5.2	Nov	5.2	Dec	7.6

1993 is the current year. By [3], vol. 36, no. 20 (May 1993), p. 4, the retail prices rose 8.6% in the first 3 months. According to an announcement by the State Statistical Bureau on August 20, 1993, the national retail price index in the first seven months rose 10.8%. These releases give us the inflation data in 1993 below.

Monthly inflation rates in percentage in 1993

Over the same month, 1992

Jan	8.6	Feb	8.6	Mar	8.6	Apr	12.45	May	12.45	Jun	12.45
Jul	12.45										

In conclusion we summarize the monthly inflation rates in Table 7.

Table 7
Monthly Rates of Increase in the National General Retail Price Level

Compared with the Same Month Previous Year

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1948							9114	16151	15303	11048	99027	103876
1949	116775	105339	80205	81606	107712	43498	39474	24859	27842	56096	7476	3394
1950	3557	3794	2970	2460	1228	766.4	559.5	429.0	338.9	91.6	20.9	82.6
1951	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
1952	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
1953	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
1954	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
1955	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1957	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1958	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1959	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1960	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
1961	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
1962	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
1963	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9
1964	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7
1965	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
1966	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
1967	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
1968	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1969	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
1970	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
1971	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
1972	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
1973	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1974	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1975	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1976	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1977	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
1978	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
1979	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
1980	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1981	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
1982	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
1983	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1984	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
1985	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	12.1
1986	8.5	7.5	6.4	4.4	3.3	2.8	3.2	3.7	5.0	4.6	5.8	6.2
1987	5.3	5.3	5.3	6.5	7.6	7.8	8.14	8.14	8.14	8.14	8.14	9.1
1988	13.5	13.5	13.5	13.5	13.5	13.5	21.0	21.0	21.0	25.65	25.65	26.7
1989	27.0	27.9	26.0	26.8	24.3	21.5	19.0	15.2	13.0	8.7	7.1	6.4
1990	4.1	4.1	3.3	3.1	-1.6	-1.6	3.1	3.1	3.1	0.3	1.0	3.2
1991	1.8	1.8	1.8	1.8	1.8	1.8	4.22	4.22	4.22	4.22	4.22	2.9
1992	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	7.6
1993	8.6	8.6	8.6	12.45	12.45	12.45	12.45					

§2. Interest rates.

The central bank of China, People's Bank of China, was established on December 1, 1948, from the merger of three regional banks in the liberation region: Bank of Northern China, Bank of North Sea, and Northwest Agriculture Bank. To reflect the interest rates in the liberation region in 1948, we use rates quoted from a directive of the Bank of Northern China dated July 28, 1948. For later period all our interest rates are mainly from directives of the People's Bank of China.

There are many different kinds of interest rates on deposits and loans in the history of new China. The most interesting ones are the interest rates charged by the central bank on loans to industrial and commerce businesses of private and joint state-private ownerships, because these businesses form the private sector and represent the market-oriental portion of the Chinese economy. However, these interest rates only existed before June, 1960, and were offered again after 1980. In view of their importance, we still want to incorporate these rates into our financial data by filling the gap with the loan rates to state owned businesses. This is reasonable, because there were indeed no private or joint state-private enterprises in China in 1960s and 70s, and because private and joint state-private businesses in late 1950s and early 1980s actually faced the same interest rates on loans as state-owned companies did. The related documents on the interest rates on commerce loans to private businesses are quoted below.

(i) According to [1], the interest rates on commerce loans to all state and private businesses were set between 84% and 180% annually in July, 1948.

(ii) By [24], the interest rates on commerce loans to private businesses were between 108% and 252% in May, 1949.

(iii) The interest rates on commerce loans to private businesses were 288% in

July, 1949, and 1200% in November, 1949, according to [8], p. 55.

(iv) According to [25], the interest rate on commerce loan to private enterprises was officially set at 288% at the end of March, but actually reached 480% ([8], p. 65). It decreased gradually to 72% at the end of April, 1950.

(v) Based on [26], the interest rates on commerce loan to private enterprises were set at 36% in May, 1950.

(vi) The interest rates on commerce loan to private and joint state-private businesses from 1950 to 1991 (to state businesses in 1960s and 70s) are published in [6] and [7].

(vii) The adjustments of lending rates in 1993 are announced by the People's Bank of China, according to [20] where the actual lending rates to private enterprises are customarily 20% higher than the published figures (cf. [7], p. 509).

These loan rates have other shortcomings: there is usually no reference to the terms of the loans. When rates on loans with different maturity are finally indicated explicitly, as in a rare case between February and June, 1952, the figures become inconsistent with other rates. We will overcome this difficulty by using average rates whenever necessary, and as in the official statistics, mentioned nothing about the terms of the underlying loans.

The interest rates on loans to private and joint state-private commerce businesses are given below. A date listed below indicates the time of adjustments, and hence a rate remains the same until the next adjustment.

Besides the commerce loan rates, we also have interest rates for bank savings. In China the money of a business put into a bank is called a "deposit", and the money of an individual put into a bank is called savings. Interest rates on deposits in China, especially by state enterprises, have less sense, because the money of

a state business is always owned by the government, regardless of it being in or outside a bank. Consequently, deposits rates of state enterprises are not representative. On the other hand, savings rates are meaningful, because savings are an important funding source for the government and financial institutions. In order to a continuous spectrum of rates from 1948 to 1993, we adopt interest rates on day-to-day savings, six-month CD savings, and one-year CD savings. The sources for savings rates are the same as for commerce lending rates above.

These interest rates are determined by the Chinese central bank, and hence they are bank rates and not purely market rates. Since the Fisher effect is a phenomenon in market economies, the interest rates to be used should be market rates, or at least close proxies of market rates. The Chinese economy is nominally a socialist economy, but a vast underlying portion of the economy is market oriented, especially during the periods from 1948 to 1950s and from 1980 to 1993. In fact, from 1980s the Chinese economy should be called "a socialist market economic system" ([10]). The goal of the present paper is to study the underlying market-oriented behavior, and in particular the Fisher effect, of the Chinese economy. Therefore we need to show that our interest rates faithfully reflect the market demand and are a good proxy of market interest rates.

What is lacking in China is a market interest rate over the whole history of the People's Republic from 1948 to 1993. There is, however, a truly market interest rate over the period from June, 1949 to December, 1952. Since this rate ceased to exist after 1952, we can not use it to test the Fisher effect. Nevertheless we may use this rate to compare with the interest rates of the central bank and show that over the time period from June, 1949 to December, 1952, the central bank rates are closely parallel to the market rate and hence are essentially market-oriented.

The market rate is the interest rate on daily interbank loans among Shanghai old-style banks. These old-style banks are called *ch'ien chuang* in Chinese (cf. [38] and McElderry [19]) and have a history from 1736 to 1952. From the end of the last century these old-style banks developed close business relations with modern western-style banks, but these *ch'ien chuang* maintained their own banking system. They had the Shanghai Old-Style Bankers Association, a daily clearing house and a money market. The money market opened twice a day, one in the morning and the other in the afternoon. In the market an interest rate on overnight interbank loan was determined according to market conditions for that day and member banks could only use the determined rate in that day on interbank transactions.

Shanghai was occupied by the Chinese Army in May, 1949; from that time the interbank rate became a market rate of new China. In December 18, 1952, all the member banks of the Shanghai Old-Style Bankers Association merged and formed the *United Board of Directors of the Joint Private-State Bank*. The directors of this new bank were acting under the guidance of the People's Bank of China and thus the old *ch'ien chuang* became a bank of modern-style. The market interest rate on interbank loans therefore ceased to exist after 1952.

Table 10 lists the monthly averages of this market interest rate on interbank loans among Shanghai old-style banks from June, 1949 to December, 1952, quoted from [38], pp. 630-642. (In [38] complete monthly average rates are listed over the time period from May, 1872, to December, 1952.) Using these monthly average rates we can compute their correlation estimates with the interest rates on one-year CD savings charged by the People's Bank of China. Using a SAS PROC ARIMA procedure we get a correlation analysis which is printed verbatim in Table 11.

From Table 11 we observe that the highest correlation between the two rates is

when there is no time lag between them. Since this highest correlation coefficient equals .85249, it is large enough considering a standard error of approximately .15. In other words, there is no evidence to reject the hypothesis that the two rates are essentially the same. Note that the rate of old-style banks is a market interest rate and the rate of the central bank is an administered rate. Therefore we conclude that the central bank's rate is close to a market one over the period from June, 1949, to December, 1952.

There is no market interest rate existing in China after 1952, and hence we can not use the above method to verify the market-oriented aspect of the interest rates administered by the central bank. What we can do, however, is to look at the policies and procedures of the central bank when they adjusted interest rates. From these policies and procedures we can see that the central bank followed market conditions closely when determined the interest rates, at least in period before 1966 and after 1980.

It is known that there are no ready formulas for the central bank to calculate interest rate adjustments. In 1991 the People's Bank of China established a computer model of macro econometrics named PBCM1 (cf. [7], p. 56) which consists of about 90 equations and can be used to predict macro economic effects of monetary policies. But it is not clear whether the People's Bank of China ever used this computer model to determine interest rate adjustments. (In fact the savings rates were only adjusted twice after April 21, 1991; the first adjustment was on May 15, 1993, and the second was on July 11, 1993.)

Now let us examine the policies of the central bank regarding interest rate adjustment. In the appendix at the end of this chapter there are excerpts of documents related to interest rate adjustment issued by the central bank and other

government authorities over the period from 1948 to 1971. From these excerpts we can see that the central bank was indeed monitoring the market situation closely, in particular in the early years of the People's Republic. More precisely, the central bank determined an interest rate adjustment based on three considerations: (i) the current inflation rate computed from the National General Retail Price Index, (ii) national economic policies including policies on bank savings and production, and (iii) lending spreads of commercial banks. It is believed that the inflation rate in (i) is the most important factor in interest rate administration. On the other hand the lending spreads in (iii) played a less important role and even became negative sometimes (cf. [46]). Also from these documents we can see the central bank usually adjusted interest rates once by a small amount; the next adjustment would be made only after the effect of the first adjustment was assessed. In 1960s and 1970s the language used in these documents are rather ideological but the government actually paid more attention on interest rate adjustment by retaining the right of final approval of interest rate adjustment. Although newer documents are not available, we can clearly see the mechanism of interest rate adjustment in China.

Table 8
Interest Rates on
Commerce Loans to Private and Joint Private-State Enterprises
(to State Enterprises in 1960s and 70s)

7/48	132.0	5/49	180.0
7/49	288.0	11/49	1200.0
12/49	480.0	4/50	72.0
5/50	36.0	6/50	46.8
2/51	42.12	7/51	36.0
6/52	19.8	10/55	16.2
1/58	8.64	1/59	7.2
11/71	5.04	1/82	7.2
4/85	7.92	9/88	9.0
8/90	11.23	4/91	10.37
5/93	11.23	7/93	13.2

Table 9

Interest Rates on Savings

	Day-to-Day Savings	Six-Month CD Savings	One-Year CD Savings
7/48	37.8	72.0	144.0
4/49	66.0	168.0	252.0
5/49	54.0	180.0	252.0
8/49	60.0	168.0	252.0
4/50	43.2	86.4	156.0
5/50	21.6	64.8	86.4
6/50	12.0	28.8	86.4
10/50	12.6	31.2	34.8
3/51	12.6	33.0	45.6
7/51	10.8	28.2	36.0
12/51	9.0	22.8	31.2
5/52	5.4	12.6	14.4
1/53	5.4	10.8	14.4
10/55	2.88	6.12	7.92
1/59	2.16	3.6	4.8
7/59	2.16	4.68	6.12
6/65	2.16	3.24	3.96
10/71	2.16	3.24	3.24
4/79	2.16	3.6	3.96
4/80	2.16	4.32	5.4
7/80	2.88	4.32	5.4
4/82	2.88	4.32	5.76
4/85	2.88	5.4	6.84
8/85	2.88	6.12	7.2
9/88	2.88	6.48	8.64
8/90	2.16	6.48	8.64
4/91	2.16	5.4	7.56
7/91	1.8	5.4	7.56
5/93	2.16	7.2	9.18
7/93	3.15	9.0	10.98

Table 10
Monthly Averages of Annualized Percentage Rate
on Overnight Interbank Loans
Among Member Banks of the Shanghai Old-Style Bankers Association
from June, 1949, to December, 1952

	1949	1950	1951	1952
January		324.72	36.00	32.40
February		365.04	36.00	32.40
March		219.96	36.00	30.60
April		87.12	36.00	28.80
May		30.96	36.00	28.80
June	619.92	24.48	36.00	26.64
July	633.24	28.80	34.92	18.00
August	501.48	28.80	34.20	18.00
September	297.72	28.80	34.20	18.00
October	330.48	32.76	34.20	18.00
November	969.12	36.00	34.20	18.00
December	594.00	36.00	34.20	18.00

Table 11
 Correlation of
 Monthly Averages of Annualized Percentage Rates
 on Overnight Interbank Loans
 Among Member Banks of the Shanghai Old-Style Bankers Association
 and Interest Rates on One-Year CD Savings
 of the People's Bank of China
 from June, 1949, to December, 1952

The SAS System

ARIMA Procedure

Correlation of
 The Rate of Old-Style Banks and the Rate of the People's Bank of China
 Variance of input = 47487.98
 Number of observations = 43

Crosscorrelations

Lag	Covariance	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	
-10	-1490.135	-0.07396											*											
-9	-656.292	-0.03258											*											
-8	718.855	0.03568											*											
-7	1989.257	0.09874											**											
-6	4273.783	0.21214											****											
-5	7975.744	0.39589											*****											
-4	9294.006	0.46132											*****											
-3	10489.725	0.52067											*****											
-2	12457.516	0.61835											*****											
-1	14907.606	0.73996											*****											
0	17174.656	0.85249											*****											
1	17039.488	0.84578											*****											
2	16364.703	0.81228											*****											
3	15544.404	0.77157											*****											
4	14193.367	0.70451											*****											
5	11559.623	0.57378											*****											
6	9676.001	0.48028											*****											
7	8755.218	0.43458											*****											
8	7262.310	0.36047											*****											
9	5193.456	0.26778											*****											
10	2623.375	0.13021											***											

". " marks two standard errors

§3. Relations between inflation and interest rates.

As we pointed out in Chapter I, the Fisher effect can be tested by the linear regression

$$\pi_{t-k}^m = \alpha_m + \beta_m i_t^m + \eta_t^m \quad (1)$$

where k is the time lag, π_{t-k}^m is the *ex post* inflation rate realized in the time period from $t-k$ to $t-k+m$, and i_t^m is the interest rate at time t matured at time $t+m$. More precisely, when the time lag k equals zero the regression in (1) tests the *ex post* Fisher effect, and when $k = m$ the regression tests the Fisher hypothesis with inflation rates just realized at time t . For time lags k other than 0 and m , we will get tests for lagged Fisher effect from (1).

Note that in (1) the lag k is the time lag of the inflation. It is equivalent to write (1) as

$$\pi_t^m = \alpha_m + \beta_m i_{t+k}^m + \varepsilon_t^m$$

where i_{t+k}^m becomes future interest rates. Here ε_t^m is another random error term.

According to section 1, our inflation data are at annual rates, i.e., m is always equal to 12. By section 2, there are four different interest rates available from 1948 to 1993, of which the rates on one-year CD savings are most suitable to our purpose. In order to have a better understanding of the Chinese economy, we will perform the regression in (1) to all the four interest rates and compare the computation results.

We use SAS software PROC GLM (General Linear Model) to do the computation. Tables 12 through 15 summarize the estimations of the coefficients α and β , their standard errors, tests for hypotheses of these coefficients being equal to zero,

and the R -square estimates for the regression of the lagged inflation against the four available interest rates.

From these tables, we observe that there is no evidence that the economy of China exhibits the *ex post* Fisher effect, because the R -square estimations for the linear regression are all less than or close to .11 for $k = 0$. Such small R -squares suggest that the linear regression in (1) does not fit well when the lag is zero.

Similarly, the regression with inflation time lag $k = 12$ against the four interest rates can not confirm the Fisher hypothesis with inflation rates just realized. Note that when $k = 12$, the highest R -square for the four regressions is .4078, corresponding to the interest rates on day-to-day savings.

It is interesting to note that when the lags are equal to 17 in Table 12, between 17 and 19 in Table 13, between 17 and 20 in Table 14, and equal to 22 in Table 15, the corresponding R -square estimates are larger than .70, and the t values for testing the null hypothesis that the coefficient β equals zero are all larger than 36. Consequently, the linear regressions fit well and the future interest rates i_{t+k}^m does contribute significantly to the model in these cases.

From this observation, we also know that the three savings rates are quite similar in the aspect of their relations to the inflation rates. Indeed, they all respond to the inflation positively after a time lag of 5 months. This demonstrates that the mechanism of inflation and interest rates in the Chinese economy in the past 45 years follows a pattern that the central bank usually wait five months before rise or lower interest rates on savings after they detect significant changes in inflation rates. A typical example the most recent rises of interest rates in 1993. According to Table 7, the annualized inflation rate in December, 1992, was 7.6% which is rather high comparing with the average rate of 5.2% in the first 11 months of

1992; then in early 1993, the prices continue the hike to an inflation rate of 8.6%. Coincidentally or predictably, five months after the first inflation rise of December, 1992, the central bank rose the interest rates in May, 1993; since the inflation continued to rise in early 1993, the central bank rose the interest rates again in July, 1993.

The lending rates seem to be slightly different. This can be seen from the positive intercept α for lags less than 16 in Table 15, as opposite to the situation in Tables 12 through 14. The lending rates, however, do support the Fisher hypothesis with lagged inflation, as indicated by the results for $k = 22$, where the R -square is equal to .7161 and the t value for testing the null hypothesis that the coefficient β equals zero is 36.87. These results show that the lending rates are strongly associated with the inflation rates realized 10 months earlier. Comparing with the savings rates, we conclude that the Chinese central bank tend to adjust the lending rates 10 months after they notice significant change in inflation rates, or 5 months after they adjust the saving rates.

According to [18], pp. 24-41, the retail prices from 1966 to 1984 were strictly controlled by the government through various price subsidies. Consequently the National General Retail Price Index in this period appears exceptionally flat and the resulting low inflation rates calculated from the price index along may not be enough to represent the actual inflation in the economy. Ma and Kao in [18] suggested that an index of the shortage of national product should be used as a supplement to the measurement of the actual inflation. Here the shortage of national product is the difference of the national aggregate purchasing power at the year end minus the aggregate reserve of national product at the year end. Due to lack of available data, we can not possibly use this approach over the entire

period from 1948 to 1993. What we will do below is to rerun to the General Linear Models without the inflation rates from 1966 to 1984. From these linear regressions on inflation with missing values, we can find out the effect of these administered inflation rates to our linear models and conclusions. The computations of the SAS PROC GLM procedure on inflation rates with missing values against the interest rates on one-year CD savings are summarized in Table 16. Comparing the results in Tables 16 to those in Table 14, we realize that the General Linear Models yield essentially the same estimations regardless of the status of the inflation data between 1966 and 1984. In other words, the inflation rates in the 19 year period from 1966 to 1984 are acceptable when we study their relationships with the interest rates, although these rates may not be as good in other aspects. Because of this discovery we will use the entire inflation data in the following models.

We have to admit that the monthly inflation figures in Table 7 have certain deficiencies, because we assumed that the monthly inflation rates from 1951 to 1984 are all equal to the yearly average rates of their corresponding years. Inflation rates after 1985 are not perfect, as indicated by the figure generated by SAS PROC PLOT below.

Here in the figure, the horizontal bars consisting of letters 'A' represent the hypothetical values of inflation rates derived from the average rates on the corresponding time periods. Note that these bars of A's preserve the shape of the graph of the monthly inflation rates, but the resulting curve becomes not smooth around the bars. Since it is impossible to derive the actual figures of the monthly inflation rates from their averages over a year or a shorter time period, we have to make the above assumption in order to construct a set of consecutive monthly inflation data. Nevertheless, this assumption has to be verified and tested. In the rest of this

section, we will use yearly inflation and interest rates to show that our assumption on the monthly data are reasonable and the conclusions above remain valid.

Now let us go back to the yearly data. After calculating the yearly averages of monthly inflation rates from 1949 to 1992, we get from Table 7 a set of yearly inflation rates from 1949 to 1992, and we will denote these yearly inflation rates by π_T , where T is a year between 1949 and 1992. (Recall that t always denotes a time in month.) Using the monthly interest rates on one-year CD savings, we can also construct yearly averages of interest rates from Table 9, but we want to calculate these yearly averages first according to calendar years and then according to various fiscal years. For example, when $k = 0$, the yearly interest rate i_T is the average of the 12 monthly interest rates in year T ; when k is an integer ≥ 1 and ≤ 11 , the yearly interest rate $i_T^{(k)}$ is the average of monthly interest rates from the $k + 1$ st month of year T to the k th month of year $T + 1$.

We want to perform linear regressions on these yearly data of π_T , i_T and $i_T^{(k)}$, according to different time lag of inflation. More precisely, if the lag l is equal to 0, the yearly inflation rate π_{T+1} should be regressed against i_T :

$$\pi_{T+1} = \mu + \psi i_T + a_T,$$

because π_{T+1} represents the price increase from year T to year $T + 1$ and i_T is the interest rate in year T on savings to be matured in year $T + 1$. If the lag l is equal to 12, then the yearly inflation rates π_T should be associated with the yearly interest rates i_T :

$$\pi_T = \mu + \psi i_T + a_T,$$

because in this case π_T is just realized at the time T . If the lag l is between 13 and 23, we run regressions on π_T and $i_T^{(l-12)}$:

$$\pi_T = \mu + \psi i_T^{(l-12)} + a_T,$$

because the lag between i_T and $i_T^{(l-12)}$ is just $l - 12$. In order to use SAS PROC GLM, we list the data sets and a summary of the computation below.

The computation results in Table 19 confirms our finding on the linear relationship between inflation rates and interest rates. Indeed, the regressions on the yearly data showed that the best linear models are between inflation rates and those interest rates which are three to ten months after the realization of the inflation rates. Comparing with the estimates in Table 14, we see a similar pattern for the regressions on monthly inflation rates and those monthly interest rates which are three to ten months after the realization of the inflation rates; hence our reconstruction of the monthly inflation rates in Table 7 is reliable.

Moreover the SAS computations on yearly data indicate that the linear relations between interest rates and inflation with no time lag, and between interest rates and inflation with 12 month lag are also acceptable. When there is no time lag of inflation, the linear regression has an R -square equal to .7684 and a t value for testing the null hypothesis of β being zero equal to 11.66. When the time lag of inflation equals 12, the corresponding R -square and t value are .7819 and 12.27, respectively. These figures imply that the *ex post* Fisher effect and the Fisher effect on inflation just realized are observable from the yearly data, though they are not strong enough to appear in the regression on monthly data. From this point of view, we see the deficiency of our monthly data again.

Figure 1

Monthly Inflation Rates Since 1985

The SAS System

Plot of Inflation*Year. Legend: A = 1 obs, B = 2 obs, etc.

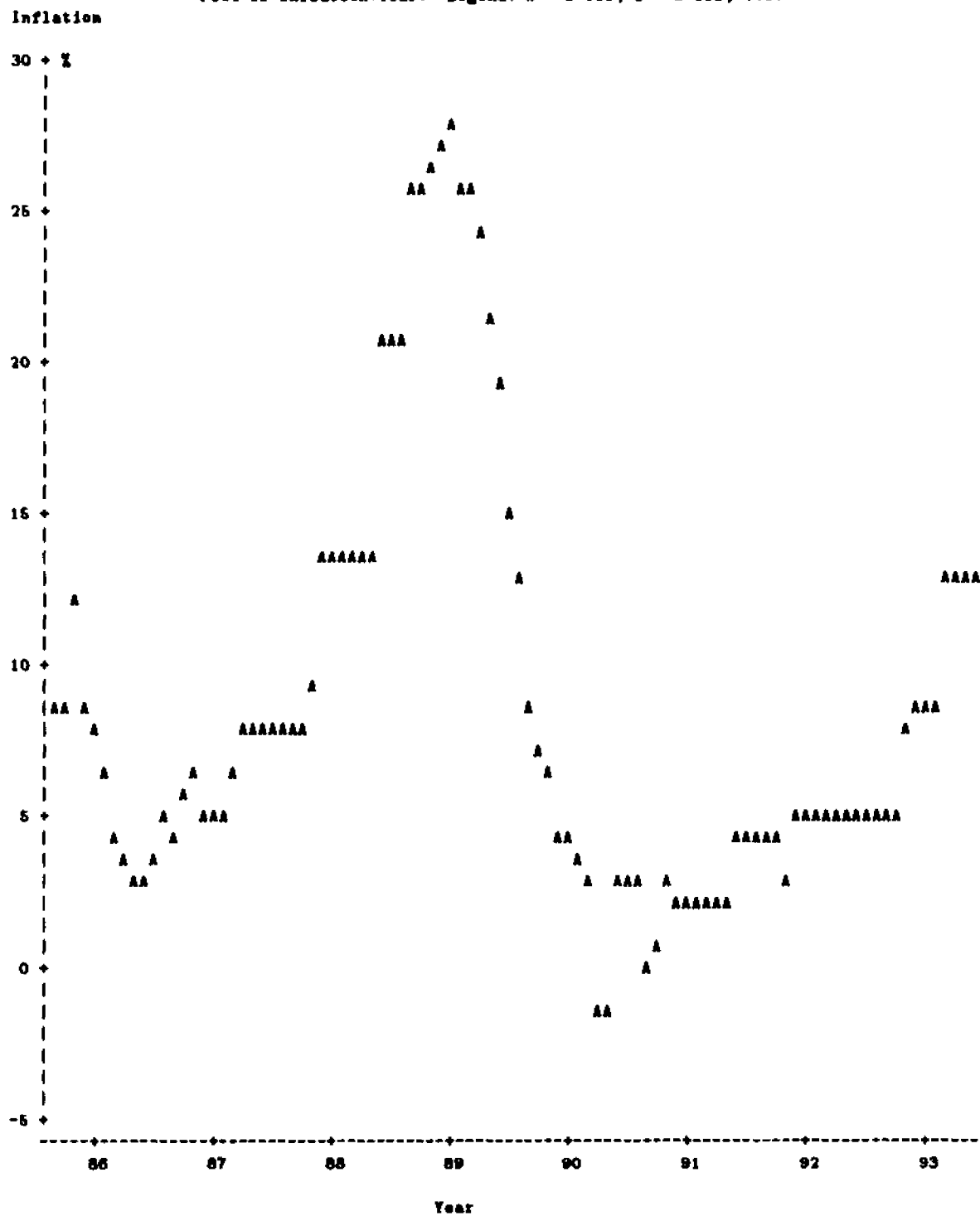


Table 12
 General Linear Models Estimation
 of the Regression of Monthly Annual Inflation Rates
 Against Interest Rates on Day-to-day Savings

Lag	Intercept α (Standard Error)	T for H0: $\alpha = 0$	Coefficient β (Standard Error)	T for H0: $\beta = 0$	R-Square
0	-250.87 (157.47)	-1.59	116.41 (14.33)	8.13	.1113
3	-588.62 (316.39)	-1.86	271.22 (28.86)	9.40	.1428
6	-1175.57 (440.68)	-2.67	502.10 (40.31)	12.45	.2254
9	-1597.38 (486.86)	-3.28	667.14 (44.66)	14.94	.2940
11	-2002.36 (455.57)	-4.40	760.58 (41.86)	18.17	.3802
12	-2121.66 (444.69)	-4.77	787.87 (40.90)	19.26	.4078
13	-2299.94 (429.19)	-5.36	834.59 (39.92)	20.91	.4478
14	-2553.72 (405.23)	-6.30	898.17 (38.12)	23.56	.5073
15	-2852.62 (373.13)	-7.65	972.91 (35.52)	27.39	.5819
16	-3092.12 (343.22)	-9.01	1037.06 (33.07)	31.36	.6460
17	-3332.82 (308.50)	-10.80	1103.25 (30.09)	36.66	.7138
18	-3251.29 (319.18)	-10.19	1100.87 (31.53)	34.92	.6934
19	-3236.10 (320.24)	-10.11	1113.13 (32.05)	34.74	.6912
20	-3232.27 (319.81)	-10.11	1128.30 (32.43)	34.79	.6919
21	-3214.76 (321.49)	-10.00	1140.79 (33.05)	34.52	.6885
22	-3380.66 (315.26)	-10.72	1210.71 (33.88)	35.74	.7032
23	-3273.74 (339.35)	-9.65	1212.36 (37.66)	32.20	.6679
24	-3047.60 (376.80)	-8.11	1184.86 (43.15)	27.46	.5831

Table 13
 General Linear Models Estimation
 of the Regression of Monthly Annual Inflation Rates
 Against Interest Rates on Six-Month CD Savings

Lag	Intercept α (Standard Error)	T for H0: $\alpha = 0$	Coefficient β (Standard Error)	T for H0: $\beta = 0$	R-Square
0	-1.33 (156.65)	-.01	29.93 (5.41)	5.53	.0549
3	-16.79 (317.69)	-.06	70.36 (11.01)	6.39	.0716
6	-189.97 (452.28)	-.42	136.37 (15.71)	8.68	.1238
9	-470.30 (503.03)	-.93	197.06 (17.52)	11.25	.1909
11	-892.92 (473.40)	-1.89	240.04 (16.52)	14.53	.2819
12	-1147.39 (452.71)	-2.53	264.26 (15.81)	16.72	.3414
13	-1380.38 (430.93)	-3.20	288.27 (15.14)	19.04	.4022
14	-1678.63 (398.87)	-4.21	318.80 (14.09)	22.62	.4870
15	-1994.62 (357.80)	-5.57	351.63 (12.72)	27.65	.5865
16	-2286.87 (310.28)	-7.37	382.96 (11.09)	34.52	.6885
17	-2551.80 (254.52)	-10.03	412.38 (9.16)	45.04	.7901
18	-2439.30 (272.82)	-8.94	406.18 (9.87)	41.13	.7684
19	-2336.56 (287.91)	-8.12	400.79 (10.49)	38.22	.7305
20	-2216.26 (306.18)	-7.26	393.55 (11.18)	35.19	.6967
21	-2075.12 (324.64)	-6.39	384.07 (11.97)	32.08	.6562
22	-2102.56 (325.68)	-6.46	398.45 (12.46)	31.97	.6548
23	-1994.95 (350.96)	-5.68	400.39 (14.06)	28.48	.6008
24	-1916.37 (371.80)	-5.15	405.64 (15.66)	25.90	.5545

Table 14
 General Linear Models Estimation
 of the Regression of Monthly Annual Inflation Rates
 Against Interest Rates on One-Year CD Savings

Lag	Intercept α (Standard Error)	T for H0: $\alpha = 0$	Coefficient β (Standard Error)	T for H0: $\beta = 0$	R-Square
0	-74.62 (161.81)	-.49	25.09 (3.39)	7.40	.0941
3	-183.08 (305.90)	-.60	58.66 (6.85)	8.56	.1214
6	-427.50 (430.07)	-.99	108.54 (9.66)	11.23	.1914
9	-684.30 (474.23)	-1.44	148.92 (10.68)	13.94	.2660
11	-980.58 (446.46)	-2.20	170.74 (10.08)	16.94	.3480
12	-1134.65 (430.56)	-2.64	181.25 (9.73)	18.63	.3918
13	-1290.26 (412.70)	-3.13	193.86 (9.41)	20.59	.4403
14	-1492.91 (387.13)	-3.86	209.87 (8.92)	23.53	.5087
15	-1718.35 (354.24)	-4.85	227.89 (8.25)	27.63	.5862
16	-1921.40 (318.61)	-6.03	245.01 (7.49)	32.69	.6647
17	-2109.95 (278.33)	-7.58	261.72 (6.62)	39.55	.7437
18	-2041.47 (286.85)	-7.12	261.43 (6.89)	37.92	.7273
19	-1969.01 (295.90)	-6.65	260.87 (7.19)	36.27	.7094
20	-1938.23 (296.80)	-6.53	263.22 (7.30)	36.08	.7072
21	-1872.97 (304.24)	-6.16	263.18 (7.57)	34.78	.6918
22	-1912.13 (301.07)	-6.35	274.80 (7.77)	35.35	.6986
23	-1836.58 (320.21)	-5.74	278.41 (8.61)	32.33	.6597
24	-1673.96 (352.39)	-4.75	275.34 (9.91)	27.79	.5890

Table 15
 General Linear Models Estimation
 of the Regression of Monthly Annual Inflation Rates Against
 Interest Rates on Commerce Loans to Private and Joint State-Private Enterprises
 (to State Enterprises in 1960s and 70s)

Lag	Intercept α (Standard Error)	T for H0: $\alpha = 0$	Coefficient β (Standard Error)	T for H0: $\beta = 0$	R-Square
0	184.37 (152.91)	1.21	7.11 (2.02)	3.52	.0229
3	415.14 (311.67)	1.33	16.87 (4.13)	4.08	.0305
6	703.15 (453.54)	1.55	29.92 (6.03)	4.96	.0441
9	800.25 (517.66)	1.55	44.01 (6.90)	6.37	.0705
11	763.46 (512.65)	1.47	48.81 (6.85)	7.13	.0862
12	664.48 (506.74)	1.31	53.75 (6.78)	7.93	.1045
13	274.70 (480.76)	.57	73.19 (6.45)	11.35	.1929
14	290.96 (480.72)	.61	73.18 (6.47)	11.32	.1920
15	189.03 (471.16)	.40	79.02 (6.36)	12.43	.2229
16	-27.93 (449.26)	-.06	90.73 (6.08)	14.93	.2925
17	-195.32 (428.65)	-.46	100.20 (5.82)	17.23	.3551
18	-624.65 (363.76)	-1.72	123.28 (4.95)	24.90	.5350
19	-576.74 (368.08)	-1.57	122.20 (5.02)	24.32	.5233
20	-671.06 (346.82)	-1.93	128.54 (4.75)	27.07	.5762
21	-822.46 (309.81)	-2.66	138.04 (4.25)	32.45	.6614
22	-903.02 (283.52)	-3.19	143.97 (3.90)	36.87	.7161
23	-659.02 (333.69)	-1.97	133.11 (4.62)	28.80	.6061
24	-504.25 (358.50)	-1.41	126.81 (4.99)	25.39	.5447

Table 16
 General Linear Models Estimation
 of the Regression of Monthly Annual Inflation Rates
 with Missing Values from 1966 to 1984
 Against Interest Rates on One-Year CD Savings

Lag	Intercept α (Standard Error)	T for H_0 : $\alpha = 0$	Coefficient β (Standard Error)	T for H_0 : $\beta = 0$	R-Square
0	-61.22 (275.90)	-.19	24.95 (4.66)	5.36	.0875
3	-136.24 (553.35)	-.25	58.38 (9.39)	6.22	.1135
6	-419.13 (774.35)	-.54	108.50 (13.20)	8.22	.1813
9	-755.10 (849.81)	-.89	149.40 (14.56)	10.26	.2547
11	-1228.90 (797.33)	-1.54	172.35 (13.70)	12.58	.3378
12	-1477.17 (767.48)	-1.92	183.46 (13.21)	13.89	.3827
13	-1720.07 (734.65)	-2.34	196.62 (12.77)	15.39	.4325
14	-2037.64 (687.84)	-2.96	213.37 (12.08)	17.66	.5008
15	-2389.50 (627.68)	-3.81	232.18 (11.14)	20.85	.5829
16	-2700.86 (562.47)	-4.80	249.98 (10.09)	24.79	.6639
17	-2985.68 (488.64)	-6.11	267.29 (8.86)	30.18	.7455
18	-2854.35 (504.26)	-5.66	266.61 (9.24)	28.86	.7281
19	-2717.11 (520.69)	-5.22	265.63 (9.65)	27.53	.7091
20	-2646.47 (522.20)	-5.07	267.73 (9.79)	27.35	.7064
21	-2521.08 (535.55)	-4.71	267.31 (10.16)	26.32	.6902
22	-2548.31 (529.60)	-4.81	278.98 (10.43)	26.75	.6970
23	-2393.18 (563.83)	-4.24	282.20 (11.57)	24.39	.6568
24	-2102.10 (621.23)	-3.38	276.40 (13.33)	20.89	.5839

Table 17
 Yearly Inflation Rates and Lagged Interest Rates
 from 1949 to 1991
 for Lag Equal to Zero

Year	Inflation rates	Interest rates
1950	1359.8	225.00
1951	12.2	120.70
1952	-.4	37.70
1953	3.4	20.00
1954	2.3	14.40
1955	1.0	14.40
1956	.0	12.78
1957	1.5	7.92
1958	.2	7.92
1959	.9	7.92
1960	3.1	6.46
1961	16.2	6.12
1962	3.8	6.12
1963	-5.9	6.12
1964	-3.7	6.12
1965	-2.7	6.12
1966	-.3	4.86
1967	-.7	3.96
1968	.1	3.96
1969	-1.1	3.96
1970	-.2	3.96
1971	-.7	3.96
1972	-.2	3.78
1973	.6	3.24
1974	.5	3.24
1975	.2	3.24
1976	.3	3.24
1977	2.0	3.24
1978	.7	3.24
1979	2.0	3.24
1980	6.0	3.78
1981	2.4	5.04
1982	1.9	6.40
1983	1.5	6.67
1984	2.8	6.76
1985	8.8	6.76
1986	6.0	6.72
1987	7.3	7.20
1988	16.5	7.20
1989	17.6	7.68
1990	2.1	8.64
1991	2.9	8.64
1992	5.4	7.83

Table 18
 Yearly Inflation Rates and Lagged Interest Rates
 from 1949 to 1992
 for Lags from 12 to 23

Year Inflation Rates	Lagged Yearly Averages of Interest Rates on One-Year CD Savings												
	Lag=12	Lag=13	Lag=14	Lag=15	Lag=16	Lag=17	Lag=18	Lag=19	Lag=20	Lag=21	Lag=22	Lag=23	
1949	57856.3	225.00	234.00	243.00	252.00	244.00	230.20	216.40	202.60	188.80	175.00	156.90	138.80
1950	1359.8	120.70	102.60	84.50	66.40	57.20	53.80	50.40	46.20	42.00	37.80	37.90	38.00
1951	12.2	37.70	37.40	37.10	36.80	35.60	33.00	30.40	28.60	26.80	25.00	23.20	21.40
1952	-4	20.00	18.60	17.20	15.80	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
1953	3.4	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
1954	2.3	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	13.86	13.32
1955	1.0	12.78	12.24	11.70	11.16	10.62	10.08	9.54	9.00	8.46	7.92	7.92	7.92
1956	.0	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
1957	1.5	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
1958	.2	7.92	7.66	7.40	7.14	6.88	6.62	6.36	6.21	6.06	5.91	5.76	5.61
1959	.9	5.46	5.57	5.68	5.79	5.90	6.01	6.12	6.12	6.12	6.12	6.12	6.12
1960	3.1	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
1961	16.2	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
1962	3.8	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
1963	-5.9	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
1964	-3.7	6.12	6.12	6.12	6.12	6.12	6.12	5.94	5.76	5.58	5.40	5.22	5.04
1965	-2.7	4.86	4.68	4.50	4.32	4.14	3.96	3.96	3.96	3.96	3.96	3.96	3.96
1966	-.3	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
1967	-.7	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
1968	.1	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
1969	-1.1	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
1970	-.2	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.90	3.84
1971	-.7	3.78	3.72	3.66	3.60	3.54	3.48	3.42	3.36	3.30	3.24	3.24	3.24
1972	-.2	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1973	.6	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1974	.5	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1975	.2	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1976	.3	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1977	2.0	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24
1978	.7	3.24	3.24	3.24	3.24	3.30	3.36	3.42	3.48	3.54	3.60	3.66	3.72
1979	2.0	3.78	3.84	3.90	3.96	4.08	4.20	4.32	4.44	4.56	4.68	4.80	4.92
1980	6.0	5.04	5.16	5.28	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40
1981	2.4	5.40	5.40	5.40	5.40	5.43	5.46	5.49	5.52	5.55	5.58	5.61	5.64
1982	1.9	5.67	5.70	5.73	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76
1983	1.5	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76
1984	2.8	5.76	5.76	5.76	5.76	5.85	5.94	6.03	6.12	6.24	6.36	6.48	6.60
1985	8.8	6.72	6.84	6.96	7.08	7.11	7.14	7.17	7.20	7.20	7.20	7.20	7.20
1986	6.0	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20
1987	7.3	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.32	7.44	7.56
1988	18.5	7.68	7.80	7.92	8.04	8.16	8.28	8.40	8.52	8.64	8.64	8.64	8.64
1989	17.8	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64
1990	2.1	8.64	8.64	8.64	8.64	8.55	8.46	8.37	8.28	8.19	8.10	8.01	7.92
1991	2.9	7.83	7.74	7.65	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56
1992	5.4	7.56	7.56	7.56	7.56	7.56	7.69	7.83	8.12	8.40	8.68	8.97	9.25

Table 19
 General Linear Models Estimation
 of the Regression of Yearly Inflation Rates
 Against Yearly Averages of Interest Rates on One-Year CD Savings
 from 1949 to 1992 (from 1950 for Lag Zero)

Lag	Intercept α (Standard Error)	T for H0: $\alpha = 0$	Coefficient β (Standard Error)	T for H0: $\beta = 0$	R-Square
0	-37.69 (18.57)	-2.27	4.83 (.41)	11.66	.7684
12	-1713.87 (669.40)	-2.56	207.68 (16.92)	12.27	.7819
13	-1767.83 (565.42)	-3.13	215.11 (14.30)	15.05	.8435
14	-1774.25 (461.62)	-3.84	219.47 (11.60)	18.92	.8949
15	-1735.47 (362.35)	-4.79	220.75 (9.00)	24.52	.9347
16	-1769.89 (330.03)	-5.36	230.87 (8.52)	27.10	.9459
17	-1851.76 (328.48)	-5.64	245.28 (8.98)	27.33	.9468
18	-1944.23 (326.97)	-5.95	261.59 (9.49)	27.57	.9476
19	-2052.60 (324.04)	-6.33	280.37 (10.03)	27.96	.9490
20	-2176.98 (321.23)	-6.78	301.98 (10.64)	28.37	.9504
21	-2321.11 (318.75)	-7.28	327.12 (11.36)	28.78	.9518
22	-2553.18 (354.21)	-7.21	362.56 (13.91)	26.06	.9418
23	-2833.74 (400.84)	-7.07	405.84 (17.50)	23.19	.9276

§4. The short-run Fisher effect.

According to Mishkin [23] the short-run *ex ante* Fisher effect can be characterized by the following model on the first differences of yearly inflation rates and interest rates:

$$E_T(\pi_{T+1}) - E_{T-1}(\pi_T) = \beta(i_T - i_{T-1}) + a_T,$$

and the short-run *ex post* Fisher effect is given by

$$\pi_{T+1} - \pi_T = \beta(i_T - i_{T-1}) + a_T,$$

$$\pi_T - \pi_{T-1} = \beta(i_T - i_{T-1}) + a_T,$$

and

$$\pi_T - \pi_{T-1} = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + a_T$$

for $12 < k < 24$. Applying the last three models to the yearly data of inflation rates and interest rates, we get the estimates of the models using the SAS PROC ARIMA procedure which are summarized in Table 20.

From Table 20, we observe that the coefficient β of the interest rates is always significantly positive for various time lags of inflation. Therefore we can conclude that the short-run *ex post* Fisher effect exists in the Chinese economy. On the other hand, however, we can not deduce from the results in Table 20 the existence of the short-run *ex ante* Fisher effect, because there may be contribution of the persistence of inflation in the coefficient β of interest rates. In fact, the residuals of our ARIMA models are highly autocorrelated, as evident from the high values of autocorrelations of residuals for lag equal to 2 and of inverse autocorrelations of

residuals for lags less than 5. These autocorrelated residuals indicate that there is a role played by the underlying persistence of inflation in our models. Therefore our models can not be used to test separately either the short-run *ex ante* Fisher effect or the persistence of inflation, because their effect on the models can not be separated.

Nevertheless, the results in Table 20 do confirm our findings on *ex post* Fisher effect that the strongest Fisher effect can be found in models with time lags of inflation between 17 and 20 months. Indeed, the *t* statistics of the null hypothesis of the test of β being zero is larger than 2.90 when the time lags are between 17 and 20. In other words, a short term change of inflation will predict a similar change in interest rates five to eight months after the realization of the inflation rate; or, from the view point and practice of the central bank, the interest rates should be changed accordingly five to eight months after an apparent change of inflation.

For later reference let us write down the estimated model for the time lag of inflation equal to 17 months:

$$\pi_T = \pi_{T-1} + \begin{array}{c} .70257 \\ (.24199) \end{array} (i_T^{(5)} - i_{T-1}^{(5)}) + a_T.$$

We note that this model has highly autocorrelated residuals.

Table 20
 ARIMA(0,1,0) Models Estimation
 of the Short-Run *ex post* Fisher Effect on Yearly Inflation Rates
 Against Yearly Averages of Interest Rates on One-Year CD Savings
 from 1949 to 1992 (from 1950 for Lag Zero)

Lag	β (Std Error)	T for H0: $\beta = 0$	Autocorrelations of Residuals Lags 1-10	Inverse Autocorrelations of Residuals Lags 1-10
0	.13157 (.05738)	2.29	-.064 -.468 .002 .111 -.079 -.059 .041 .147 -.019 -.152	.434 .597 .364 .300 .254 .127 .113 .026 .034 .042
12	.56307 (.24983)	2.25	-.062 -.435 -.011 .092 -.024 -.062 -.009 .158 -.039 -.137	.443 .580 .352 .301 .239 .139 .136 .026 .062 .040
13	.58972 (.24043)	2.45	-.072 -.442 -.014 .097 -.024 -.059 -.011 .149 -.016 -.145	.408 .566 .326 .277 .220 .120 .122 .020 .048 .044
14	.60201 (.22979)	2.62	-.065 -.450 -.015 .102 -.027 -.055 -.012 .137 .005 -.150	.390 .562 .314 .268 .215 .114 .113 .025 .036 .049
15	.60207 (.21855)	2.75	-.060 -.457 -.015 .105 -.031 -.050 -.014 .124 .025 -.150	.388 .567 .318 .270 .221 .118 .112 .036 .028 .054
16	.61616 (.21575)	2.86	-.058 -.463 -.014 .106 -.034 -.043 -.017 .109 .043 -.148	.393 .577 .328 .279 .234 .127 .117 .061 .024 .059
17	.70257 (.24199)	2.90	-.057 -.461 -.012 .108 -.036 -.030 -.026 .101 .042 -.145	.362 .559 .307 .250 .227 .103 .120 .043 .026 .060
18	.80958 (.27485)	2.95	-.060 -.456 -.006 .103 -.036 -.012 -.037 .089 .040 -.139	.330 .540 .282 .221 .216 .079 .123 .035 .030 .061
19	.89592 (.30117)	2.97	-.066 -.443 .000 .096 -.042 .008 -.047 .076 .038 -.133	.312 .523 .268 .199 .216 .061 .132 .033 .036 .064
20	.98367 (.33101)	2.97	-.077 -.427 .007 .085 -.049 .033 -.058 .060 .031 -.121	.308 .512 .264 .186 .222 .053 .148 .038 .048 .066
21	1.05164 (.36545)	2.88	-.090 -.411 .014 .074 -.058 .057 -.068 .044 .017 -.104	.333 .519 .282 .200 .245 .086 .176 .053 .069 .067
22	1.20513 (.41945)	2.87	-.093 -.405 .034 .060 -.061 .068 -.067 .029 .004 -.092	.292 .496 .237 .175 .222 .048 .174 .050 .079 .065
23	1.37137 (.48659)	2.82	-.096 -.398 .056 .045 -.065 .078 -.063 .011 -.017 -.074	.262 .479 .199 .163 .205 .041 .178 .052 .096 .060

§5. The persistence of inflation.

If we only look at the annual data for inflation in Table 18, the inflation rates in 1949 and 1950 appear unusually high compared with later periods. These data may cause one to wonder whether we should remove these two extraordinary years from our regression analysis. When we examine the monthly figures in Table 7, however, we see that the high rates in the early years of the People's Republic do not appear so artificial and form an integrated part of the financial data of new China. The results of our analysis on data from 1948 to 1993 thus represent the true financial situation and history of China. If the first two or three years were excluded from the analysis, the conclusions would not be a complete description of the economy of China, but a study of later tendencies of the Chinese economy.

Nevertheless, later tendencies are also interesting to us, especially when we want to look at the forecastability of the financial situation. Indeed, according to Chapter I, we have to consider the forecastability of the inflation rates when we test the Fisher hypothesis, and the forecastability is closer related to the recent behavior of the inflation than to the inflation long time ago. Consequently in this section we will study the inflation rates and their relations with interest rates after 1951.

Recall that the monthly inflation rates were reconstructed from yearly inflation rates and certain averages rates over time intervals. Since we assumed that all the monthly rates are equal to the yearly average in the corresponding year, from 1951 to 1984, the resulting monthly rates certainly have a kind of built-in autocorrelations: a rate tends to equal its neighbors. Therefore it makes no sense to consider the forecastability of these monthly rates, and we will use the yearly data only.

As in Barsky [2] we will use an ARIMA (AutoRegressive Integrated Moving-

Average) model to study the forecastability of the yearly inflation rates; for a complete description of the method we refer the reader back to Chapter I. The model suggested by Barsky is

$$W_T = \mu + \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q} \quad (2)$$

where:

- T indexes time
- W_T is the original data or a difference of the original data of inflation
- μ is the constant term
- φ_i, θ_j are coefficients to be determined
- a_T is the independent disturbance (the random error)
- p, q are nonnegative integers.

We remark that the first difference of the inflation rates π_T is defined as $U_T = \pi_T - \pi_{T-1}$, and the second difference of π_T is $V_T = U_T - U_{T-1}$, etc. This differencing technique is used to get a stationary process out of the time series of inflation rates, if the inflation rates are themselves not stationary. If the difference W_T is the d th difference of the inflation rates, we will denote the model in (2) by ARIMA(p, d, q), where p is the degree of the autoregressive part and q is the degree of the moving-average part.

Figure 2 here is a chart of the yearly inflation rates from 1951 to 1992. Note that the rates of 1949 and 1950 are 57856.3 and 1359.8 which are too large to be included in the graph. With or without these two large values, the graph looks

nonstationary in the sense that the level of the time series exhibits an apparent trend.

A nonstationary process suggests that we study its first difference, which is shown in Figure 3. Note that the difference data is from 1950 to 1992, because one year is lost when we calculate the difference; the graph in Figure 3 covers from 1952 to 1992, because the values for 1950 and 1951 are exceptional: -56496.5 and -1347.6 . Also because of these two exceptional values, the first difference of inflation from 1949 to 1992 is not stationary and we may argue by the same reason all the consecutive differences of inflation from 1949 to 1992 are nonstationary. By Figure 3, however, we can see that the first difference of inflation from 1951 to 1992 appears stationary, or at least has a constant level over time. These truncated data represent the later tendencies of the inflation in China and our forecastability study will be based on the first difference of inflation given in Figure 3.

The next step in an ARIMA procedure is to study autocorrelations, inverse autocorrelations and partial autocorrelations of the time series process. For the inflation rates from 1951 to 1992, these autocorrelations are given in Table 21 using SAS PROC ARIMA. We first observe from Table 21 that the first difference of inflation is not white noise, because the correlation between the difference and its second time lag is nonzero significantly. We then note that the autocorrelations, inverse autocorrelations and partial autocorrelations are all essentially equal to zero after the second time lag, according to the standard errors marked in the table. Consequently possible models for the first difference of inflation after 1951 are $ARIMA(2,1,0)$, $ARIMA(0,1,2)$ and $ARIMA(2,1,2)$, i.e., the second order autoregressive procedure of the first difference

$$W_T = \mu + \varphi_1 W_{T-1} + \varphi_2 W_{T-2};$$

the second order moving average procedure of the first difference

$$W_T = \mu + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2};$$

and an autoregressive moving average procedure of the first difference

$$W_T = \mu + \varphi_1 W_{T-1} + \varphi_2 W_{T-2} + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

where W_T is the first difference of inflation. Tables 22, 23 and 24 list the estimations of these three models using the SAS PROC ARIMA procedure. Note that in these tables, the constant term μ is denoted by **MU**, and the coefficients φ_1 , φ_2 , θ_1 and θ_2 are denoted by **AR1,1**, **AR1,2**, **MA1,1** and **MA1,2**, respectively.

From Tables 22, 23 and 24, we conclude that the models ARIMA(2,1,0) and ARIMA (0,1,2) seem to be good, while the model ARIMA(2,1,2) does not fit well, because all the estimates of the parameters in the last model are not different from zero significantly. For ARIMA(2,1,0) the parameters **MU** and **AR1,1** are negligible, and for ARIMA(0,1,2) the constant term **MU** is also negligible. Therefore we reestimate the models ARIMA(2,1,0) and ARIMA(0,1,2) by setting **MU** and **AR1,1** equal to zero. The results are in Tables 25 and 26. From the values of **Variance Estimate** and **Std Error Estimate** in Tables 25 and 26 and the fact that all the autocorrelations, inverse autocorrelations and partial autocorrelations of residuals in these last two estimations are essentially zero, we conclude that the two models can both be used as forecasting models of the inflation. If we look at Tables 25 and 26 and compare the autocorrelation plots of residuals of these two models, we

see that the autocorrelations, inverse autocorrelations and partial autocorrelations of residuals of ARIMA(0,1,2) appear smaller. Therefore the model ARIMA(0,1,2) is better. In conclusion we write these two models as

$$W_T = - \begin{matrix} .44056 \\ (.14015) \end{matrix} W_{T-2} + a_T$$

and

$$W_T = a_T - \begin{matrix} .27615 \\ (.15196) \end{matrix} a_{T-1} - \begin{matrix} .48217 \\ (.15149) \end{matrix} a_{T-2}.$$

Using the inflation rates π_T , the models can be rewrite

$$\pi_T = \pi_{T-1} - \begin{matrix} .44056 \\ (.14015) \end{matrix} \pi_{T-2} + \begin{matrix} .44056 \\ (.14015) \end{matrix} \pi_{T-3} + a_T \quad (3)$$

and

$$\pi_T = \pi_{T-1} + a_T - \begin{matrix} .27615 \\ (.15196) \end{matrix} a_{T-1} - \begin{matrix} .48217 \\ (.15149) \end{matrix} a_{T-2}. \quad (4)$$

Figure 2
Yearly Inflation Rates

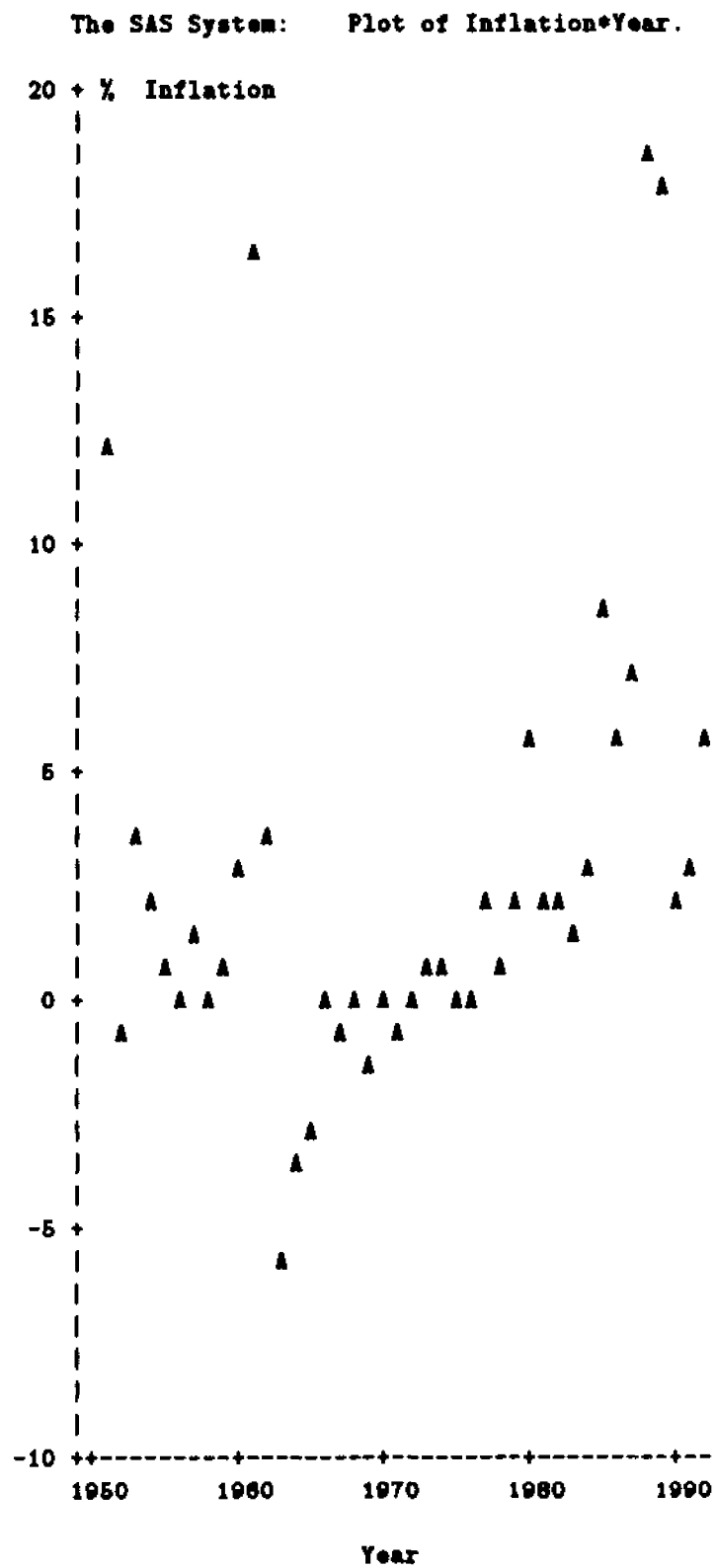


Figure 3
The First Difference of Yearly Inflation Rates

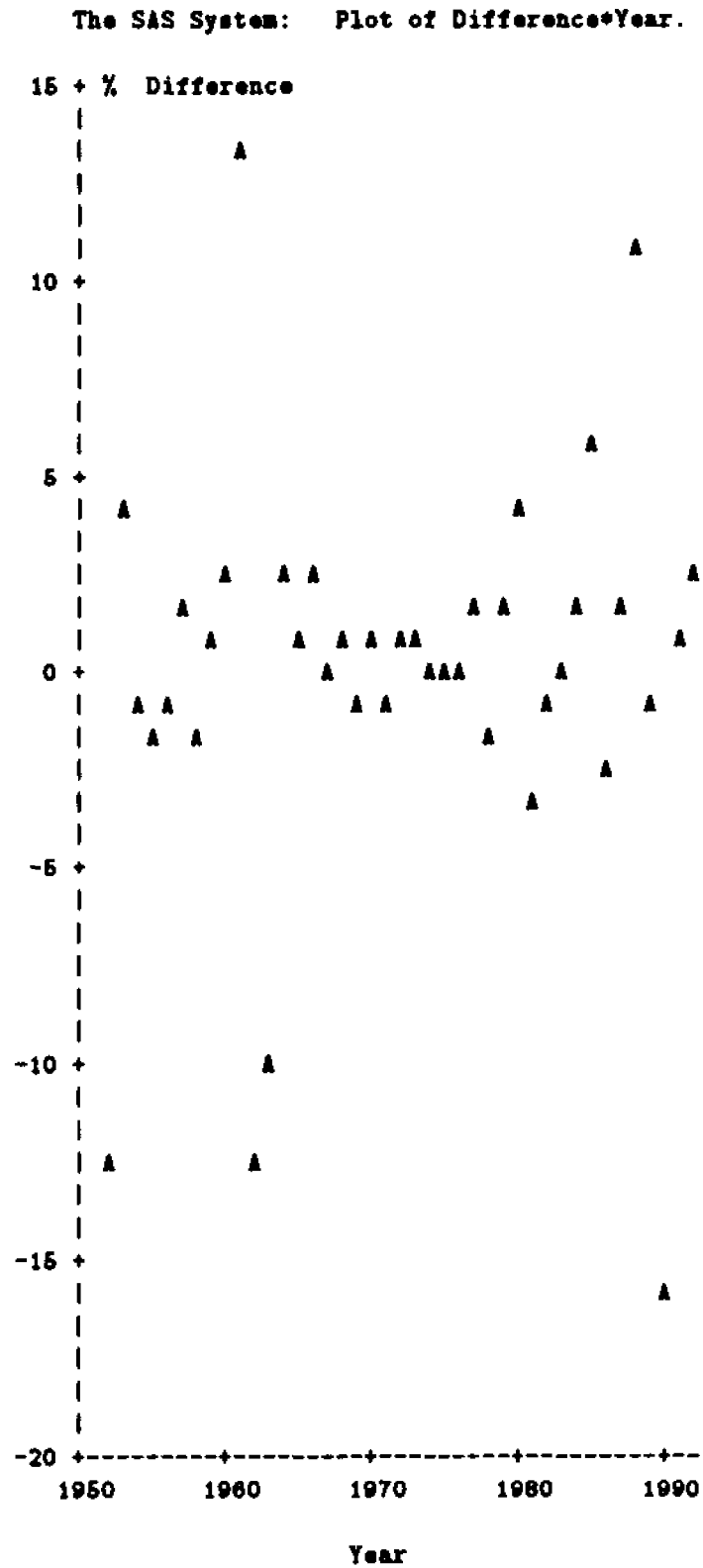


Table 21
Autocorrelation Study of the First Difference of Inflation
from 1951 to 1992

The SAS System

ARIMA Procedure

Name of variable = Inflation.

Period(s) of Differencing = 1.

Mean of working series = -0.16585

Standard deviation = 5.139976

Number of observations = 41

NOTE: The first observation was eliminated by differencing.

Autocorrelations

Lag	Covariance	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	Std
0	26.409076	1.00000													*****									0
1	-2.496346	-0.09453									**													0.156174
2	-10.297676	-0.38993								*****														0.157563
3	0.508493	0.01925																						0.179563
4	2.592010	0.09815										**												0.179613
5	-1.987239	-0.07625									**													0.180917
6	-0.923383	-0.03496										*												0.181678
7	0.425214	0.01610																						0.181842
8	2.319148	0.08782										**												0.181877
9	-3.152023	-0.11936									**													0.182908
10	0.206664	0.00783																						0.184798

"," marks two standard errors

Inverse Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	
1	0.29743													*****									
2	0.48142													*****									
3	0.22670													*****									
4	0.19137													****									
5	0.18993													****									
6	0.07468													*									
7	0.13860													***									
8	-0.01302																						
9	0.09906													**									
10	-0.01592																						

Partial Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	
1	-0.09453									**													
2	-0.40246									*****													
3	-0.08486									**													
4	-0.08244									**													
5	-0.11700									**													
6	-0.06425										*												
7	-0.07907									**													
8	0.05060										*												
9	-0.14631									***													
10	0.02221																						

Autocorrelation Check for White Noise

To	Chi	Autocorrelations									
Lag	Square	DF	Prob								
6	8.08	6	0.232	-0.095	-0.390	0.019	0.098	-0.075	-0.035		

Table 22
 Estimation of the ARIMA(2,1,0) Model of the Inflation
 from 1951 to 1992

The SAS System

ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag
NU	-0.11001	0.47541	-0.23	0
AR1,1	-0.13766	0.15249	-0.90	1
AR1,2	-0.44947	0.14306	-3.14	2

Constant Estimate = -0.174595

Variance Estimate = 22.8428852

Std Error Estimate = 4.77942311

AIC = 247.972179

SBC = 253.112896

Number of Residuals = 41

Correlations of the Estimates

Parameter	NU	AR1,1	AR1,2
NU	1.000	-0.015	0.012
AR1,1	-0.015	1.000	0.092
AR1,2	0.012	0.092	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations						
6	1.67	4	0.796	-0.034	-0.000	-0.129	-0.094	-0.091	0.016	
12	3.49	10	0.968	-0.074	0.096	-0.078	0.058	0.088	0.033	
18	3.91	16	0.999	0.030	-0.062	-0.027	-0.026	-0.029	-0.018	
24	7.20	22	0.999	0.119	-0.061	0.025	-0.080	-0.106	-0.028	

Model for variable Inflation

Estimated Mean = -0.1100067

Period(s) of Differencing = 1.

Autoregressive Factors

Factor 1: $1 + 0.13766 B + 0.44947 B^2$

Table 23
Estimation of the ARIMA(0,1,2) Model of the Inflation
from 1951 to 1992

The SAS System

ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag
MU	0.07097	0.18348	0.39	0
MA1,1	0.29223	0.15428	1.89	1
MA1,2	0.49210	0.15420	3.19	2

Constant Estimate = 0.07097102

Variance Estimate = 21.2198229

Std Error Estimate = 4.6004979

AIC = 245.446504

SBC = 250.58722

Number of Residuals = 41

Correlations of the Estimates

Parameter	MU	MA1,1	MA1,2
MU	1.000	0.004	-0.122
MA1,1	0.004	1.000	-0.506
MA1,2	-0.122	-0.506	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations						
6	0.81	4	0.937	0.021	0.011	0.011	0.102	-0.062	0.054	
12	3.03	10	0.981	0.003	0.135	-0.056	0.061	0.104	0.061	
18	3.36	16	1.000	0.030	-0.018	0.016	-0.012	-0.035	-0.041	
24	6.20	22	1.000	0.079	-0.075	-0.026	-0.114	-0.078	-0.010	

Model for variable Inflation

Estimated Mean = 0.07097102

Period(s) of Differencing = 1.

Moving Average Factors

Factor 1: 1 - 0.29223 B**1) - 0.4921 B**2)

Table 24
 Estimation of the ARIMA(2,1,2) Model of the Inflation
 from 1951 to 1992

The SAS System

ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag
MU	0.06679	0.21055	0.32	0
MA1,1	0.37355	0.45444	0.82	1
MA1,2	0.34587	0.44794	0.77	2
AR1,1	0.07870	0.45372	0.17	1
AR1,2	-0.17176	0.34173	-0.50	2

Constant Estimate = 0.07300616

Variance Estimate = 22.2241054

Std Error Estimate = 4.71424496

AIC = 249.10343

SBC = 257.67129

Number of Residuals = 41

Correlations of the Estimates

Parameter	MU	MA1,1	MA1,2	AR1,1	AR1,2
MU	1.000	0.087	-0.118	0.062	-0.121
MA1,1	0.087	1.000	-0.888	0.923	-0.690
MA1,2	-0.118	-0.888	1.000	-0.835	0.859
AR1,1	0.062	0.923	-0.835	1.000	-0.665
AR1,2	-0.121	-0.690	0.859	-0.665	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	0.53	2	0.768	0.026	0.058	0.009	0.040	-0.059	0.043
12	2.69	8	0.952	-0.014	0.137	-0.047	0.064	0.103	0.053
18	3.06	14	0.999	0.043	-0.017	0.007	-0.013	-0.035	-0.042
24	6.67	20	0.998	0.076	-0.088	-0.023	-0.121	-0.105	-0.020

Model for variable inflation

Estimated Mean = 0.06679053

Period(s) of Differencing = 1.

Autoregressive Factors

Factor 1: $1 - 0.078697 B^{(1)} + 0.17176 B^{(2)}$

Moving Average Factors

Factor 1: $1 - 0.37355 B^{(1)} - 0.34587 B^{(2)}$

§6. ARIMA models on inflation and interest rates.

In Section 3 we considered linear regressions on inflation and interest rates, and then in Section 4 we used ARIMA models to study the relations between inflation and its time lags. The conclusion is that the inflation rates are related to some future interest rates and they are also related to past inflation. This suggests that we should consider the relationships of inflation to future interest rates and past inflation simultaneously, because future interest rates and past inflation are apparently not independent. Thanks to a feature in SAS PROC ARIMA procedure, we can use ARIMA models to study such complicated relationships. We will find a best model describing the true relation between inflation and interest rates.

The general model is of the form

$$W_T = \mu + \psi X_T + \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q} \quad (5)$$

where as before

- T indexes time
- W_T is the original data or a difference of the original data of inflation
- μ is the constant term
- X_T is the original data or a difference of the original data of interest rates
- $\psi, \varphi_i, \theta_j$ are coefficients to be determined
- a_T is the independent disturbance (the random error)
- p, q are nonnegative integers.

Note that the only difference between the models in (2) and (5) is the term ψX_T

on the right side, which represents the relation between inflation and interest rates. We will call the model in (5) an ARIMA(p,d,q) model crosscorrelated with X_T .

The first step to study the model in (5) is again to determine a suitable differencing procedure. Our supposition from Figures 2 and 3 is that the yearly inflation rates are not stationary, but their first difference is. Therefore we assume that W_T is the first difference of the inflation rate π_T , i.e., $W_T = \pi_T - \pi_{T-1}$.

On the other hand, the inflation rates and their first and second differences are plotted in Figures 4, 5 and 6. Note that the first two graphs here clearly represent nonstationary time series, while the last graph is Figure 6 has stationary level but nonconstant variance. These observations suggest that we may have to try the model in (5) on the original interest rates, their first difference, as well as the second difference.

Another thing we have to decide is the choice of p and q , the order of the autoregressive part and the order of the moving average part in the ARIMA model (5). Note that when $p = q = 0$, the ARIMA model becomes the standard simple linear regression between inflation and interest rates, and hence we can analyze the results of the linear regressions from a different view point. Tables 27, 28 and 29 summarize such a computation using yearly data from 1951 to 1992; the three yearly interest rates used here are those with lags equal to 0, 12 and 18 in Tables 17 and 18. Note that the relation between inflation and interest rates becomes negligible for these truncated data with lag equal to 0, and becomes apparent but not strong for interest rates with time lags equal to 12 and 18. Also all the residuals have nonzero autocorrelations, inverse autocorrelations and partial autocorrelations for the first several time lags. These facts then indicate that the simple linear regression on yearly inflation rates and interest rates

$$\pi_{T+1} = \mu + \psi i_T + a_T,$$

$$\pi_T = \mu + \psi i_T + a_T,$$

or

$$\pi_T = \mu + \psi i_T^{(k)} + a_T$$

with $13 \leq k \leq 23$, is not a good model to describe the relationships between the inflation and interest rates in China, especially the relationships over the time period from 1951 to 1992.

Comparing the results in Tables 27 to 29 with the simple linear regressions performed on data over the entire time period from 1949 to 1992 in Table 19, we see that the same linear regression over different time period can yield dramatically different conclusions. Since only the financial data in 1949 and 1950 are eliminated from the computation in Tables 27 through 29, we see that the huge inflation rates 57856.3 and 1359.8 of 1949 and 1950, together with the corresponding interest rates, have a dramatic impact on the Chinese economy in the later period. On the other hand, it becomes necessary to study the relation between inflation rates and interest rates in China over the period from 1951, without using the two huge yearly rates in 1949 and 1950, in order to fully understand the mechanism and trend of the Chinese economy.

In order to search for a suitable model between yearly inflation rates and interest rates from 1951 to 1992, we first estimate the following three ARIMA models in Tables 30, 31 and 32:

$$W_{T+1} = \mu + \psi i_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

$$W_T = \mu + \psi i_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

or

$$W_T = \mu + \psi i_T^{(6)} + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

where W_T is the first difference of the inflation rate π_T , and the inflation rate π_T in the last equation is lagged 18 months to the interest rate $i_T^{(6)}$. Here we use the ARIMA(0,1,2) model because this is the best model for the first difference of the inflation without crosscorrelating the interest rates, according to the results in Table 26. According to the computation in Tables 30, 31 and 32, the linear relation between the first difference of inflation and the original data of the interest rates is negligible.

Next let us consider the same ARIMA(0,1,2) models of inflation but crosscorrelated with the second difference of the inflation rates:

$$W_{T+1} = \psi Y_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

$$W_T = \psi Y_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

or

$$W_T = \psi Y_T^{(6)} + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

where W_T is again the first difference of the inflation rate π_T , Y_T is the second difference of the interest rate i_T , and $Y_T^{(6)}$ is the second difference of the interest

rate $i_T^{(6)}$. From the computation summarized in Tables 33, 34 and 35, we see that the coefficient ψ of the second difference Y_T or $Y_T^{(6)}$ of the interest rate is again not significantly nonzero, suggesting that a new model is needed.

Now we look at ARIMA(0,1,2) models of the first difference of inflation cross-correlated with the first difference of the interest rate:

$$W_{T+1} = \psi X_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

$$W_T = \psi X_T + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

or

$$W_T = \psi X_T^{(k)} + a_T - \theta_1 a_{T-1} - \theta_2 a_{T-2},$$

where W_T is the first difference of the inflation rate π_T , X_T is the first difference of the interest rate i_T , and $X_T^{(k)}$ is the first difference of the interest rate $i_T^{(k)}$ for $k = l-12$ and $13 \leq l \leq 23$. Table 36 contains the estimation results of these models. Since the autocorrelations, inverse autocorrelations and partial autocorrelations of the residuals are all essentially equal to zero, we only list the estimates of the coefficients, their standard errors, and the t statistics for the null hypothesis of the coefficients being zero. According to these estimates, the best models are those with time lags of inflation equal to 16, 17 and 18, where the t values for testing the null hypothesis that the coefficient ψ equals zero attain a maximal 3.36 or 3.35. Since our data have 41 observations, a t value of 3.35 means that probability of the coefficient ψ being positive is larger than 99.9%. We list these three models below:

$$\pi_T = \pi_{T-1} + \begin{array}{c} .51631 \\ (.15368) \end{array} (i_T^{(4)} - i_{T-1}^{(4)}) + a_T - \begin{array}{c} .25373 \\ (.14227) \end{array} a_{T-1} - \begin{array}{c} .54080 \\ (.14768) \end{array} a_{T-2},$$

$$\pi_T = \pi_{T-1} + \begin{matrix} .56781 \\ (.16879) \end{matrix} (i_T^{(5)} - i_{T-1}^{(5)}) + a_T - \begin{matrix} .25853 \\ (.14263) \end{matrix} a_{T-1} - \begin{matrix} .53669 \\ (.14795) \end{matrix} a_{T-2},$$

and

$$\pi_T = \pi_{T-1} + \begin{matrix} .62598 \\ (.18683) \end{matrix} (i_T^{(6)} - i_{T-1}^{(6)}) + a_T - \begin{matrix} .26403 \\ (.14307) \end{matrix} a_{T-1} - \begin{matrix} .53242 \\ (.14827) \end{matrix} a_{T-2},$$

where as before π_T is the annual inflation rate just realized at the year T , $i_T^{(k)}$ is the average of the monthly interest rates on one-year CD savings in the fiscal year T starting in the k th month, and a_T is the random error.

The SAS PROC ARIMA procedure also calculated the correlations of estimates of various coefficients of the ARIMA models. From the second half of Table 36 we observe that the correlations between the coefficient ψ (NUM1) of the interest rates and the coefficients θ_1 (MA1,1) and θ_2 (MA1,2) in the moving-average part are all very close to zero for any time lag of inflation. This fact indicates two things. First, there are no significant correlations between the Fisher effect part and the moving average part of the model, and hence for our yearly data, the short-run Fisher effect and the persistence of inflation are essentially two independent properties of the Chinese economy. Secondly, since the correlations between ψ and the coefficients θ_1 and θ_2 are negligible, the coefficient ψ of the interest rates in the ARIMA model can be fully attributed to the short-run Fisher hypothesis. Since ψ is significantly positive for all the models with time lag of inflation between 12 and 23, we conclude that the short-run Fisher effect is valid for the Chinese economy in these cases.

Furthermore, the computations in Table 36 coincide with the pattern discovered in previous sections that the most satisfactory linear relations between inflation and interest rates are those between inflation and interest rates which prevail four to

eight or nine months after the realization the the inflation rates. Consequently these models confirmed that the Fisher hypothesis is valid in the Chinese economy over the time period from 1951 to 1992.

Figure 4
Yearly Interest Rates from 1953 to 1992

The SAS System: Plot of Interest Rate*Year.

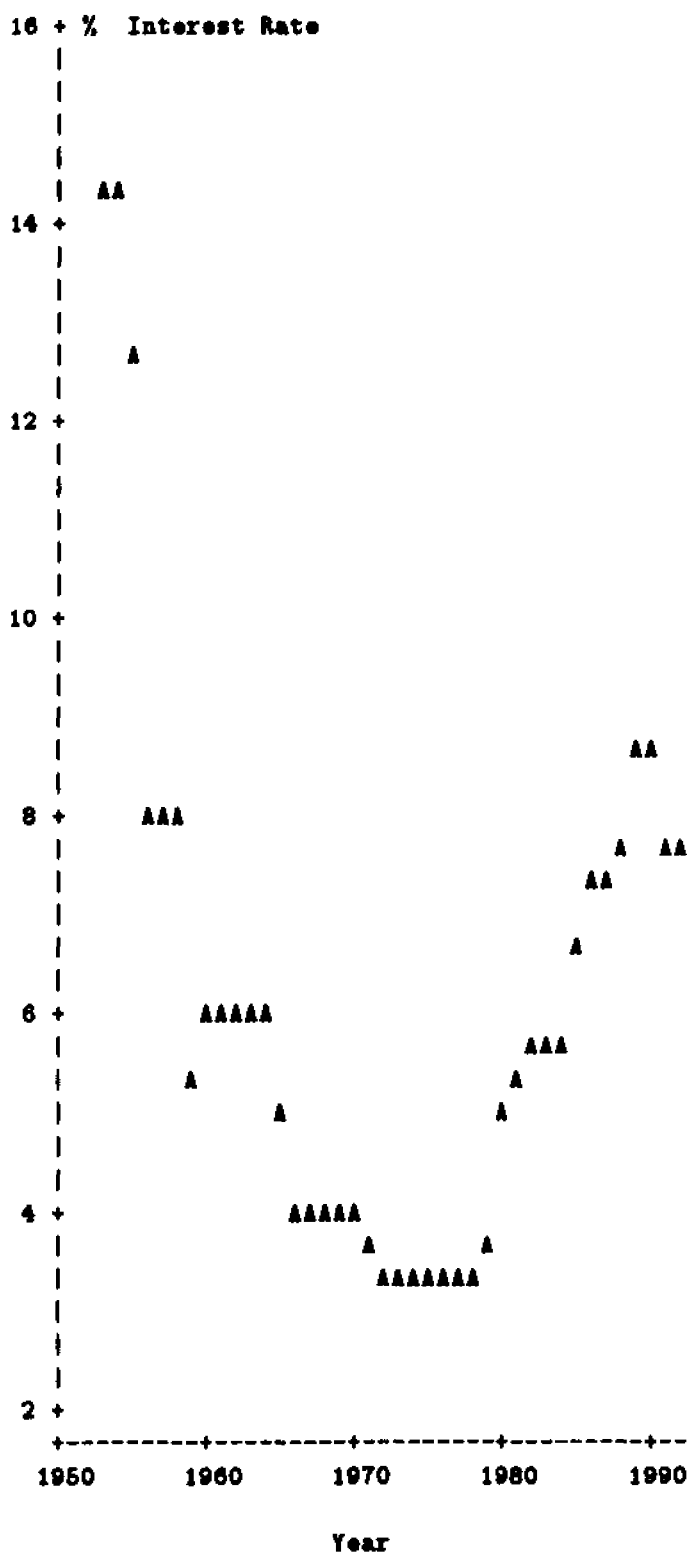


Figure 5
The First Difference of Interest Rates from 1953 to 1992

The SAS System
Plot of First Difference*Year

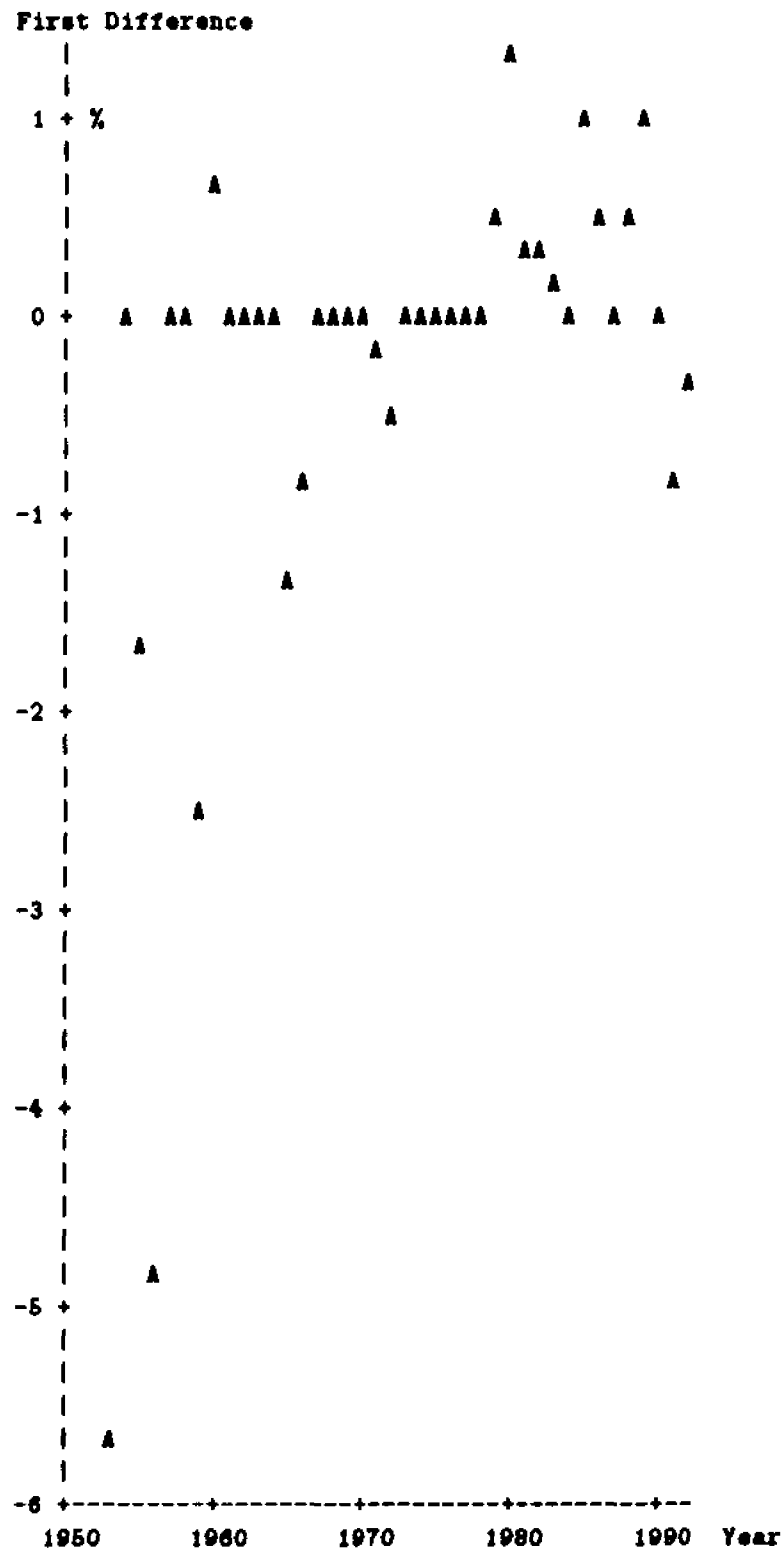


Figure 6
The Second Difference of Interest Rates
from 1954 to 1992

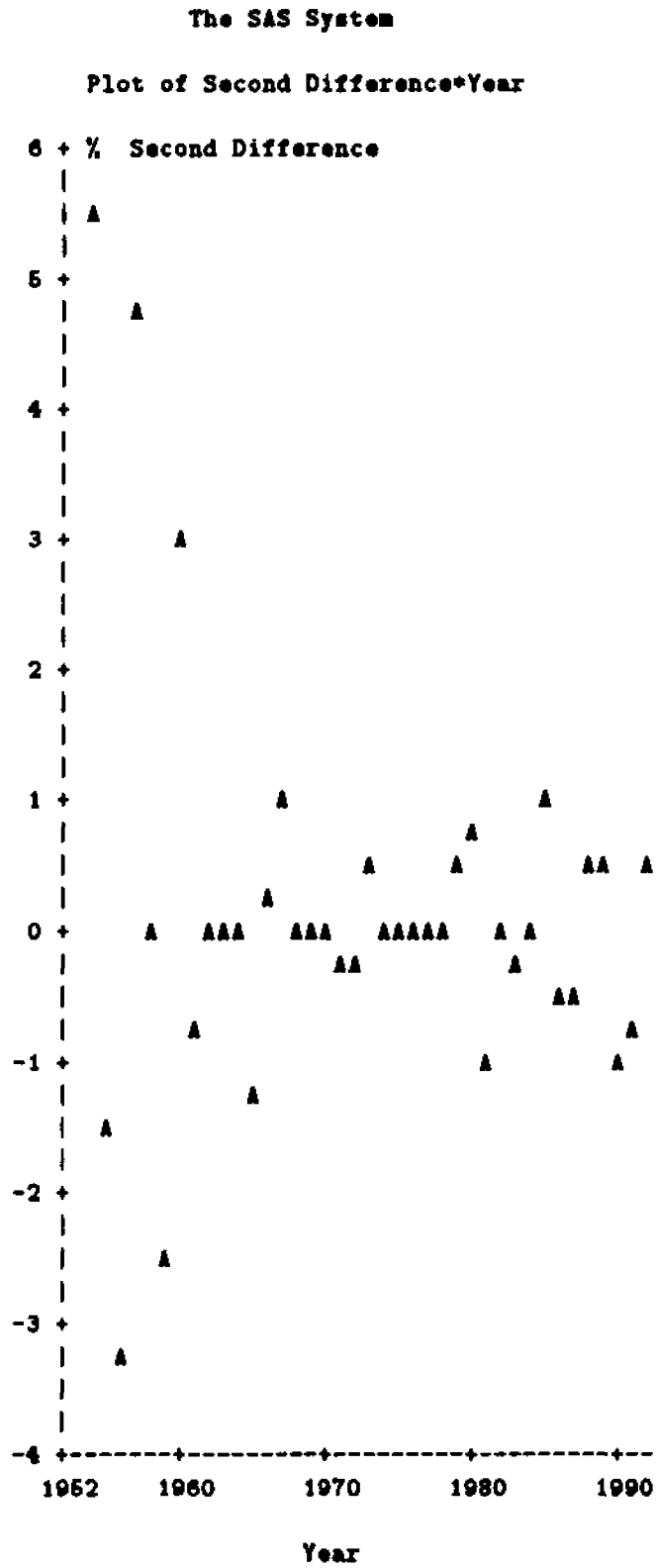


Table 36

The ARIMA(0,1,2) Model on Yearly Inflation Rates Crosscorrelated with
the First Difference of Interest Rates with Time Lags
from 1951 to 1992

Lag	NUM1 ψ (Std Error)	T for HO: $\psi = 0$	MA1,1 θ_1 (Std Error)	T for HO: $\theta_1 = 0$	MA1,2 θ_2 (Std Error)	T for HO: $\theta_2 = 0$
0	-.06769 (.16945)	-0.40	.20382 (.14409)	1.41	.54845 (.14860)	3.68
12	.44116 (.15987)	2.76	.27714 (.14388)	1.93	.52338 (.14903)	3.51
13	.46302 (.15817)	2.93	.26960 (.14342)	1.88	.52804 (.14859)	3.55
14	.48048 (.15564)	3.09	.26300 (.14296)	1.84	.53257 (.14822)	3.59
15	.49323 (.15248)	3.23	.25760 (.14262)	1.81	.53707 (.14800)	3.63
16	.51631 (.15368)	3.36	.25373 (.14227)	1.78	.54080 (.14769)	3.66
17	.56781 (.16879)	3.36	.25853 (.14263)	1.81	.53669 (.14795)	3.63
18	.62598 (.18683)	3.35	.26403 (.14307)	1.85	.53242 (.14827)	3.59
19	.66243 (.20050)	3.30	.27631 (.14376)	1.92	.52359 (.14890)	3.52
20	.69579 (.21510)	3.23	.29161 (.14458)	2.02	.51323 (.14968)	3.43
21	.72161 (.23025)	3.13	.30793 (.14516)	2.12	.50428 (.15027)	3.36
22	.77716 (.24972)	3.11	.30659 (.14509)	2.11	.51097 (.15020)	3.40
23	.83020 (.27111)	3.06	.30350 (.14514)	2.09	.51938 (.15032)	3.46

Table 36 (Continued)

The ARIMA(0,1,2) Model on Yearly Inflation Rates Crosscorrelated with
the First Difference of Interest Rates with Time Lags from 1951 to 1992

Correlations of the Estimates

Lag	Correlations	Correlations	Correlations
	Between Estimates: NUM1 ψ and MA1,1 θ_1	Between Estimates: NUM1 ψ and MA1,2 θ_2	Between Estimates: MA1,1 θ_1 and MA1,2 θ_2
	For Variables: INT and INF	For Variables: INT and INF	For Variables: INF and INF
0	.114	.111	-.367
12	-.051	.061	-.472
13	-.055	.042	-.463
14	-.055	.034	-.456
15	-.051	.026	-.450
16	-.047	.023	-.447
17	-.051	.019	-.463
18	-.060	.019	-.461
19	-.057	.019	-.476
20	-.049	.018	-.493
21	-.036	.022	-.513
22	-.049	.038	-.518
23	-.061	.060	-.522

§7. Summary and conclusions.

In this Chapter we first computed monthly figures of annual inflation rates in China from a national general retail price index over the period from July, 1947, to July, 1993. Since the actual retail price index contains only yearly averages in some years and monthly data are not always available, we made several assumptions during the computation. Consequently a set of yearly inflation data is also calculated for the later comparison. We note that the inflation rates in China were mainly endogenous before 1965 and after 1985 inclusive, but were administered from 1966 to 1984, because the government controlled the price system by heavy subsidies (cf. [18], pp. 24-41).

Secondly we collected monthly data of four kinds of interest rates over the period from July, 1948, to July, 1993, partly based on early directives from the Chinese central bank. In order to study the relation between the yearly data of inflation and interest rates, we used the interest rates on one-year CD savings and calculated yearly averages of these interest rates using the calendar year and various fiscal years. We point out that these interest rates are not market-determined and are all administered rates set by the central bank. Since market-determined interest rates never existed in China in the national basis, these rates are the best we can get for our study.

Having these data ready, we next performed simple linear regressions on the monthly inflation rates and interest rates with various time lags of the inflation. The experiments show that the three interest rates on savings perform similarly. Focusing on the interest rates on one-year CD savings, we discovered that the linear model fits best for inflation against interest rates about five months after the realization of the inflation rates; in this case the coefficient of the interest rate

in the linear regressive model is definitely positive. The lending rate on commerce loans are slightly different, which suggests a best linear model of inflation rates against interest rates ten months after the realization the the inflation rate.

These results represent the first evidence of the Fisher effect in the Chinese economy. Since our interest rates are not determined by market, the Fisher effect here must have a new interpretation. Indeed, the time lags of inflation in the above linear models indicate that the interest rates, although administered by the central bank, do reflect market information, but only when five to ten months after the realization of the inflation rates. Therefore we may claim that the Fisher hypothesis is valid in the Chinese economy; since these are not market interest rates, this can be interpreted as an administered version of the Fisher effect, based on the government behavior reflecting market information. This administered Fisher effect suggests that the Fisher effect in the usual market sense might also exist, but it can only be observed after the establishment of a system of market interest rates in the future. The time lags in the above linear models also suggest that the Chinese central bank tends to wait about five months before adjusting savings rates based on the financial information it receives, and it tends to wait longer, about ten months, before do the same thing to lending rates.

Recall that the inflation rates in the time period from 1966 to 1984 are partly administered. In order to support our linear models and assertions we also performed simple linear regressions on monthly data of inflation rates and interest rates by treating the figures between 1966 and 1984 as missing data. The results coincide with our early findings.

Since our monthly data of inflation contain some assumptions that might undermine the validity of the above conclusions, we then conducted simple linear

regressions on yearly data of inflation rates and savings rates on one-year CD's. By using various yearly averages of interest rates on calendar years and fiscal years, we constructed linear models with monthly time lags similar to those in the linear models on monthly data. The results again support the previous models on monthly data.

As in Mishkin [23] we then study the short-run Fisher effect. Since the first difference of inflation happens to be stationary, we can use a SAS PROC ARIMA procedure to do the calculation and analyze the residuals. We found apparent support for the short-run *ex post* Fisher hypothesis, but the highly autocorrelated residuals of the model indicate that we can not separate the effect of the *ex ante* Fisher hypothesis and the persistence of inflation using this model. Nevertheless, the *ex post* short-run Fisher effect exhibits the same pattern of the effect on the model by the time lags of inflation.

By carefully examining the inflation data, we noticed that the figures for 1949 and 1950 are exceptionally large and wonder what can happen if we omit these two special values from our linear models. In fact, the Fisher effect is often closely related to the persistence of the inflation rates, as claimed in Barsky [2], and the persistence may be mainly associated with the behavior of inflation over a recent period of time. Therefore it is necessary to study the persistence of inflation using the yearly data without the two huge values. We thus formulated an ARIMA model of inflation using the SAS PROC ARIMA procedure

$$\pi_T = \pi_{T-1} + a_T - \begin{matrix} .27615 \\ (.15196) \end{matrix} a_{T-1} - \begin{matrix} .48217 \\ (.15149) \end{matrix} a_{T-2}.$$

which demonstrated the forecastability over the period from 1951 to 1992.

It is known that the persistence of inflation and the Fisher effect are often

closely related to each other, but all available models deal with these two hypotheses separately (cf. Barsky [2]). Using SAS PROC ARIMA again we then considered a general ARIMA model crosscorrelated with interest rates or their differences. In order to search for a best model expressing the relation between inflation rates and interest rates together with their time lags, we studied several special cases of the general ARIMA model.

The first special case is indeed the simple linear regressions between inflation rates and interest rates, using data from 1951 to 1992. Different from the results of the linear regressions over the period from 1949 to 1992, the computation indicates no apparent linear relation between the rates, and hence further suggests that the two huge values of inflation rates are too special.

We considered special cases of the model of the first difference of inflation rates against the original data of the interest rates, and then against the second difference of the interest rates. The computation shows nothing affirmative. Here the differencing technique is used because we want to have a stationary process of inflation.

Finally ARIMA models of the first difference of inflation rates crosscorrelated with the first difference of interest rates are studied. Since ARIMA(0,1,2) is the best model for the first difference of the inflation without crosscorrelating the interest rates, we use it again with a term of the first difference of interest rates. Having estimated this model for various time lags of the inflation, we discovered that the coefficient of the interest rates are significantly positive for all the time lags of inflation between 12 and 23. Since the correlations between this coefficient and the coefficients in the moving-average part of the model are essentially equal to zero, there are no apparent relations between the short-run Fisher effect and the

persistence of inflation. Also because these correlations are negligible, the positive coefficient of the interest rates is contributed almost entirely to the Fisher effect, not to the persistence of inflation. Consequently we can safely conclude that the short-run Fisher hypothesis holds in the Chinese economy.

Since the best cases of the above ARIMA model are the models crosscorrelated with interest rates of one-year CD savings about five months after the realization of the inflation rates. Therefore our previous conclusions on the Fisher effect in the Chinese economy are once more confirmed by different models on yearly data of inflation rates and interest rates.

To conclude this Chapter, let us list the best models describing the relation between inflation rates and interest rates.

(i) The General Linear Model on monthly annual inflation rates and interest rates on one-year CD savings from July, 1948, to July, 1993:

$$\pi_t^{12} = - \frac{2109.95}{(278.33)} + \frac{261.72}{(6.62)} i_{t+17}^{12} + a_t$$

where π_t^{12} is the inflation rate based on the National Retail Price Index from time t in month to time $t + 12$, i_{t+17}^{12} is the interest rate on one-year CD savings at time $t + 17$ to be matured at time $t + 29$, and a_t is the random error. The R -square estimate of this model is .7437, the highest among similar models with different time lags.

(ii) The General Linear Model on monthly annual inflation rates and interest rates on one-year CD savings from July, 1948, to July, 1993, with missing inflation data from 1966 to 1984:

$$\pi_t^{12} = - \frac{2985.68}{(488.64)} + \frac{267.29}{(8.86)} i_{t+17}^{12} + a_t$$

where π_t^{12} , i_{t+17}^{12} , and a_t are the same as in (i). The R -square estimate is .7455, also the best among similar models with different time lags.

(iii) The General Linear Model on monthly annual inflation rates and lending rates on commerce loans to private and joint state-private enterprises (to state enterprises in 1960s and 70s) from July, 1948, to July, 1993:

$$\pi_t^{12} = - \frac{903.02}{(283.52)} + \frac{143.97}{(3.90)} i_{t+22}^{12} + a_t$$

where π_t^{12} and a_t are the same as in (i), i_{t+22}^{12} is the lending rate at time $t + 22$ with undisclosed maturing date. The R -square estimate of this model is .7161, again the highest among similar models with different time lags.

(iv) The General Linear Model on yearly annual inflation rates and yearly averages of interest rates on one-year CD savings from 1949 to 1992:

$$\pi_T = - \frac{1851.76}{(328.48)} + \frac{245.28}{(8.98)} i_T^{(5)} + a_T$$

where π_T is the yearly inflation rate in year T , $i_T^{(5)}$ is the average of the interest rates in the fiscal year T starting in June, and a_T is the random error. The R -square of this model is .9468, one of the highest among similar models with different time lags. The highest R -square is .9518 for a model with $i_T^{(9)}$.

(v) The ARIMA model on the short-run *ex post* Fisher effect on inflation rates and one-year CD savings from 1951 to 1992:

$$\pi_T = \pi_{T-1} + \frac{.70257}{(.24199)} (i_T^{(5)} - i_{T-1}^{(5)}) + a_T.$$

Note that this model best describe the short-run *ex post* Fisher effect but can not be used to determine the existence of the short-run *ex ante* Fisher effect nor the persistence of inflation, because the coefficient of the model contains the effects

from both the Fisher effect and the persistence. Indeed, the residuals of this model is highly autocorrelated.

(vi) The ARIMA Model on the persistence of yearly inflation rates on one-year CD savings from 1951 to 1992:

$$\pi_T = \pi_{T-1} + a_T - \begin{matrix} .27615 \\ (.15196) \end{matrix} a_{T-1} - \begin{matrix} .48217 \\ (.15149) \end{matrix} a_{T-2}$$

where π_T and a_T are the same as in (iv).

(vii) The ARIMA Model on yearly inflation rates crosscorrelated with the first difference of interest rates on one-year CD savings from 1951 to 1992:

$$\pi_T = \pi_{T-1} + \begin{matrix} .56781 \\ (.16879) \end{matrix} (i_T^{(5)} - i_{T-1}^{(5)}) + a_T - \begin{matrix} .25853 \\ (.14263) \end{matrix} a_{T-1} - \begin{matrix} .53669 \\ (.14795) \end{matrix} a_{T-2}$$

where π_T , $i_T^{(5)}$ and a_T are the same as in (iv). The t value of the test for the null hypothesis of the coefficient of $(i_T^{(5)} - i_{T-1}^{(5)})$ being zero is 3.36, implying that the probability of the coefficient being nonzero is larger than 99.9%, the highest among similar models with different time lags.

The correlations between the coefficient of interest rates and the coefficients in the moving-average part of this model in (vii) are $-.051$ and $.019$. Therefore the term of the interest rates is basically independent of the moving-average part of the model. The interest rate part confirms the short-run *ex ante* Fisher effect, while the moving-average part of the model describes the persistence of inflation. Comparing this last model with the one in (v) we see that a portion of the coefficient $.70257$ ($.24199$) in (v) is actually attributed to the persistence of inflation, and only the rest portion of $.56781$ ($.16879$) is resulted from the Fisher effect.

These seven models confirmed the existence of an administered version of the Fisher effect in the Chinese economy. Over the entire time period of the history of

new China the long-run Fisher effect is apparent, and over the time period from 1951 to 1992, the Fisher effect mainly takes a short-run form, both *ex post* and *ex ante*. Over the latter period, there is no apparent relation between the short-run *ex ante* Fisher effect and the persistence of inflation. These models furthermore suggest the validity of the usual market Fisher hypothesis, which, unfortunately, can only be tested directly after the establishment of a system of market-determined interest rates in the future.

Appendix

Excerpts of Documents Related to the Interest Rate Administration

In China From 1948 to 1971

Recently because of the war, the commodity prices became unstable and the monetary purchasing power decreased. Since we did not adapt ourselves to this situation and categorically restricted adjustment of the particularly low interest rates on savings and loans of the state bank, private lending practice has been severely affected so that credit market has become stagnant in the countryside. In recent years banks continued to sustain losses in rural business while in urban areas monetary speculations were stimulated; banks can no longer funnel funds into manufacturing sectors and can hardly perform their basic functions on savings and loans. Therefore for a long period of time we have lost the ability to control the market and economy. In order to change this situation, it is necessary to check and ratify our policies on interest rates again. Enclosed are the adjusted interest rates and policies. ([1], July 28, 1948)

* * *

Each Regional Bank and Each Branch in North Region:

National commodity prices have generally leveled down and dropped since March. From March 1st to 24th, prices dropped 5.27% in Shanghai, dropped 1.88% in Tientsin, dropped 2.27% in Hankow, dropped 2.42% in Peking, dropped 22.8% in Xi'an, and dropped 0.9% in Canton. Now state-owned trading companies have plentiful supplies of various commodities and the market demand has

sharply decreased. The commodities hoarded for speculation by privately owned industrial and commercial enterprises have appeared in markets gradually and we are increasingly confident that the market prices will be stable from now on. In the banking sector, money deposits have grown gradually in state owned and private owned banks and old-style banks.

Market interest rates, including rates of the state bank, dropped somewhat in various regions, but are still much too high compared with normal interest rates in a situation of stable prices. If the rates remain at such a high level, not only the state bank will continue to suffer heavy losses, but also a group of industrial and commercial enterprises will face bankruptcy immediately. Based on this new economic situation the interest rates of our bank should immediately be lowered and the interest rates of other banks and old-style banks should be strictly ordered to be lowered simultaneously. A table of national interest rate ranges was determined and enclosed.

The prices will be stable in the future and the decisions on interest rates should mainly be based on our economic policies and profitability of all the industrial and trade sectors. The levels and adjustments of interest rates will be the main factor in controlling the financial market and hence the whole economy. ([25], March 28, 1950)

* * *

Recently the state prices and market prices of basic commodities became stable all over the country and the overall prices will be stabilized on the current level. Under this circumstance the bank interest rates should be lowered further so that producer could get convenient capital turnover. It is ordered that the interest

rates should reach the following standard by May 15: the maximal interest rate on one-month time savings is 18%, the maximal interest rate on loans is 36%. After receiving this telegraph each branch should transmit this order further and make arrangement to implement it immediately. In order to dispel misgivings of depositors, adjustable rates tied on inflation may be used to all deposits regardless of their amounts and nature. If withdraw increases, the central bank can offer money support.

Since prices become stable and normal, the speculation aspect of the interest rates of private owned banks and old-style banks diminishes. Therefore the supervision to them may be relaxed. ([26], May 12, 1950)

* * *

Principle of Interest Rate Administration

The major requirement of an interest rate policy is that it can be used to acquire funds, to manage credits, to restrict speculations, and to promote production. Interest rate administration must give consideration to three aspects: (i) depositors must be glad to deposit money, (ii) it must be advantageous to the management of enterprises valuable to the state and people, and (iii) it must give appropriate preferential treatment to the business of state owned and private owned financial institutions. Therefore the following is the principle of interest rate administration in 1951.

(i) Speaking in principle, state bank's deposit and lending rates to state entities should be low and the spread between lending rates and deposit rates should also

be low, but the yield spread must be large enough to cover bank expenses and a portion of bank profits.

(ii) The savings and lending rates to private individuals and enterprises are based on the interest rates determined by local interest rate committees and hence will be high and close to market rates. Lending rates should be determined according to (a) the supply and demand in the financial market, (b) the price level, and (c) the usual business profit margin.

(iii) State banks should take leadership through local interest rate committees in interest rate management of private banks and old-style banks in large and mid-sized cities.

(iv) Interest rates can not be set regardless of the market situation, but the bank rates should not become a follower of market rates and should not be adjusted and rescinded every day.

(v) There will be no restriction on lending rates in countryside in order to encourage free lending and to establish rural credit unions. ([27], February 9, 1951)

* * *

Director Chen Yun:

Current interest rates on private deposits in state banks are exactly equal to the rates in private banks and old-style banks, but interest rates on savings with maturities longer than two months in state banks are 10% to 20% higher than those in private banks and old-style banks. Lending rates in state banks are usually lower than the lending rates charged by private banks and old-style banks. On the other

hand, savings rates in either state banks, private banks or old-style banks are far below interest rates in black markets. Although banks have made great efforts to funnel money into industrial and commercial businesses, their demand can not be satisfied.

Wholesale prices have risen slowly nationwide and in big cities since this January, except in Xi'an where the prices have dropped. The effect of inflation on interest rates is that inflation reduces benefit of depositors and burdens of borrowers. Seasonal increase of prices was anticipated, but it is unexpected that the prices could rise or drop sharply in some regions.

Since we only investigated the general economic situation of the whole nation and did not take into account of the special situation in some specific regions, the implement of the interest rate reduction in last September faced a lot of resistance in view of the situation discussed above. Consequently our bank plan to carefully investigate the economic situation in each region before we can determine the direction and extent of the next interest rate adjustment. ([28], May 8, 1951)

* * *

Each Regional Bank and Each Branch in North Region:

In order to promote economic development, stimulate production and encourage flow of good and material, financial institutions should devote their major effort to support state and private enterprises which may be lack funds for production and transportation. The current lending rates which are as high as 46.8% take up a major portion of possible profits of common enterprises and generate high costs of production, transportation and marketing. These high rates hampered the

development of production directly and infringed consumers' interest indirectly, so that business initiative was dampened and business management became difficult. All these are bad for the entire economic development. In order to reduce business costs, promote production and trade, and mobilize idle money of large quantity, we adopt a policy to lower the current interest rates gradually. It is required that the interest rates should be reduced to a level close to the prewar rates before the fall season. The interest rate reduction consists of two steps; the first step in middle of July and the second at the end of September. The target rates are enclosed. ([29], July 2, 1951)

* * *

Each Regional Bank and Each Branch:

(i) According to recent reports from regional banks and branches, lending rates were reduced to the September target by almost all banks and branches; deposit rates, however, have only been reduced to the July target by most banks and branches.

(ii) In the recent interest rate adjustment, the prices increased slightly and market speculators seized the chance to cause trouble. In order to stabilize prices and financial markets and withdraw currency from circulation, each bank and branch should postpone further reduction of interest rates on private deposits and loans from the current adjusted levels (rates should not be raised if they were lowered already), but those rates tied to inflation must be lowered to the official target quickly. Since current interest rates vary widely from region to region, each local branch must pay close attention to the development of money and prices so that

national interest rates can be adjusted to a uniform level shortly. This gradual adjustment procedure must be complete by the end of December, 1951, and interest rates must be lowered to the September target by then. During this period each regional bank and each branch is expected to submit in writing to the central bank the current financial market situation and their opinion on interest rates at the end of each month. Here five tables of different interest rates on deposits and loans are enclosed for references. ([30], October 15, 1951)

* * *

Each Regional Bank and Each Province or City Branch:

Since the Movements Against Three Evils and Five Evils, prices have dropped step by step and black market lending activities have disappeared. From now on the prices will be more stable and industrial and commercial enterprises can earn normal profits. In order to speed up capital turnover in state enterprises, reduce costs for industrial and commercial businesses, encourage production and management in private enterprises, stimulate markets, allocate funds, and prepare for the high tide of construction, it is decided to overall reduce the current interest rates. Except for those telegraphed by the central bank, the directives are enclosed. ([31], June 21, 1952)

* * *

The State Council (The Fifth Office):

In order to practice economy, accumulate funds and promote the reform of credit accounting, the current deposit and lending rates should be adjusted appropriately.

In fact, the current interest rates on savings and deposits are too high and have to be lowered.

(i) Savings rates. Speaking in principle, in the future our savings rates should be slightly higher than the treasury rate, lower than the agriculture lending rates and close to the rate offered by investment companies.

(ii) Lending rates to state enterprises and trade co-operatives. The appropriate interest rates to socialist enterprises are used to propel implement of national economic projects, promote the enterprises to use working capital effectively and efficiently, strengthen business accounting, and accumulate a certain amount of credit capital. If the interest rates are too high, it becomes hard for enterprises to reduce costs; if the rates are too low, it is impossible to encourage enterprises to speed up capital turnover and implement economic accounting. A new interest rate table is enclosed. ([32], August 10, 1955)

* * *

People's Bank of China, Each Ministry of the State Council, Each Committee, Each Office, Each Directly Subordinate Organization, the Federation of Trade Co-operatives, Each People's Committee of Province, Autonomous Region, and Directly Subordinate City:

The report and request for instruction from the People's Bank of China on adjustment of current interest rates is approved; it is agreed that the adjustment is put into effect on October 1, 1955. The adjustment of deposit and lending rates to state enterprises, however, may be implemented on January 1, 1956. Now the report is enclosed and please inform your subordinate units and departments for implement. ([41], September 6, 1955)

* * *

The State Council (The Fifth Office):

Compared with the current lending rates, we believe that the savings rates are too high and should be lowered.

Recently bank savings in urban and rural areas have become one of the main sources of funds to support the great leap of industrial and agricultural production. In some provinces and cities the interest rates which local authorities offered to attract mass investments were determined according to the bank rates. If savings rates are too high, the state will face increasing expenditure and decreasing accumulation which are harmful to production. At the same time since the interest rates on local treasury bonds are relatively low, our bank rates will affect the issuance of these municipal bonds. Now people's income is increasing continuously along with the development of production; it becomes an established practice that people are industrious and thrifty in managing their households and that they save by cutting down expenses in order to support the Great Leap Forward. The fast development of people's communes also suggests that it is appropriate to reduce savings rates. Detailed plans of the interest rate adjustment are enclosed. ([33], September 5, 1958)

* * *

Vice Premier Li Xiannian and Premier Zhou:

In order to carry out the directive from the central government on devoting major efforts to cutting down social purchasing powers, local authorities everywhere are encouraging bank savings energetically and some provincial governments asked

us to increase interest rates on savings and deposits. We believe that an appropriate increase of savings rates is one of the measures which we must take in order to attract more bank savings, relax the tension of the current shortage of market supply of goods and material, and hence implement the directive of the central government. Therefore we propose two plans on savings rate adjustment.

The first plan: we raise the current interest rates on time savings appropriately; the interest rate on day-to-day savings remains unchanged.

The second plan: we make no change on the current interest rates on savings with maturities not longer than one year, but offer long term time savings of two and three years with (higher) interest rates.

The distinctions between the two plans are: (i) the first plan is emphasized on promoting time savings with maturities of one year and shorter and is more suitable to the current reality, hence more powerful in attracting bank savings; (ii) the second plan makes no change for the interest rates on savings with maturities of one year and shorter while promotes long term time savings of two and three years, and hence has less involvement. Since some provincial governments suggested raising current interest rates all together, we prefer the first plan. ([34], June 9, 1959)

* * *

Each Provincial Branch:

The report of the central bank on adjustment of interest rates on savings and deposits was approved by the State Council and will be implemented according to the first plan in the report. The adjustment date is July 1, 1959. This adjustment of interest rates should be announced orally and should not be published in

newspapers. Now a copy of the report of the central bank to the State Council on adjustment of interest rates on savings and deposits is sent to you. It is expected that the implement of the adjustment is planned promptly and reported to the Ministry of Finance and Commerce in your provincial government. The central bank will inform you how to adjust interest rates on time savings of some special kinds separately. ([35], June 17, 1959)

* * *

Comrade Xiannian and Premier:

Because of the prompt recovery of the national economy, bank savings in urban and rural areas have increased steadily since 1963, and hence reversed the trend of decreasing in the two years before 1963. According to opinions from different organizations, the current interest rates on time savings are too high.

We believe the principles on savings rate adjustment are: from the view point of promoting a new social habit of diligence and frugality and heightening people's awareness of socialist thinking, we must combine political mobilization and material rewards with an emphasis on political mobilization; the adjustment must give appropriate preferential treatments to the mass of staff and workers, and hence the interest rates on day-to-day savings and small amounts of time savings should be reduced little or not be reduced at all. Enclosed is our adjustment proposal in detail.

According to our past experience, bank savings will always increase regardless of the savings rate reduction under the current excellent situation in national politics and economy, because production is growing, the market is brisk, prices are stable, and people's life is improving. ([36], February 5, 1965)

* * *

People's Bank of China:

The report of February 5, 1965, is received. The State Council consented to your proposal on adjustment of the current interest rates on savings and deposits. Please implement it accordingly. ([42], March 23, 1965)

* * *

The State Council:

According to suggestions from local organizations and the directive of the State Council, we investigated the matter of interest rate adjustment and discussed it with some related comrades from provincial authorities. We also sought opinions of provincial governments in a finance symposium in August, 1970, and in the National Meeting of Planning this year. The following are relevant information and our proposal.

After the establishment of the People's Republic our bank interest rates were reduced eight times. These reductions played active roles in the movement of restricting and cracking down usurious loans in urban and rural areas and in the development and consolidation of our socialist economy. In order to suit the needs of socialist revolution and socialist construction, promote the development of industrial and agricultural production, and arouse enthusiasm from every aspect, we propose to have a complete adjustment on the current bank interest rates. ([21], August 3, 1971)

* * *

Each Revolutionary Committee of Province, Autonomous Region or Directly Subordinate City and Each ministry, Committee, Organization and Institution of the State Council:

The State Council approved the *Report and request of instruction on adjustment of bank interest rates* proposed by the Ministry of Finance. A copy is enclosed for implement.

Bank rate adjustment is a kind of work which requires a precise understanding of policies and is related to correctly handling the relations among the state, organizations and individuals. Propaganda and education must be enhanced in order to do it correctly. ([43], August 11, 1971)

Chapter 3

Empirical analysis of the new models

In this chapter we will apply the new models to yearly U.S.A. data from 1945 to 1992 and compare the results with the standard theory of the Fisher effect for the U.S.A. economy. The inflation rates we will use is computed from the consumer price index of all items taken from [12] and [17]. The interest rates are discount rates on new issues of 91-day U.S. treasury bills, not seasonally adjusted, from [11] and [17].

From Figures 7 and 8 we see that the inflation is not stationary over the time period from 1945 to 1992, but its first difference has a constant level and may be stationary. Therefore we will use the first difference of inflation in our ARIMA models and look at the short-run Fisher effect in the U.S. economy.

The model of the short-run Fisher effect is given by the following linear regressions:

$$\pi_{T+1} - \pi_T = \beta(i_T - i_{T-1}) + a_T$$

which is corresponding to time lag of inflation equal to 0;

$$\pi_{T+1} - \pi_T = \beta(i_T^{(k)} - i_{T-1}^{(k)}) + a_T$$

for time lag k with $1 \leq k \leq 11$;

$$\pi_T - \pi_{T-1} = \beta(i_T - i_{T-1}) + a_T$$

which is corresponding to time lag of inflation equal to 12; and

$$\pi_T - \pi_{T-1} = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + a_T$$

for time lag k with $13 \leq k \leq 23$. The SAS PROC ARIMA results on these linear regressions are given in Table 37. We observe that the best cases, characterized by large t values, are shortly before and around $k = 12$. For example when the time lag of inflation is 12 months, the short-run Fisher effect can be represented by

$$\pi_T - \pi_{T-1} = \begin{array}{l} .73457 \\ (.29082) \end{array} (i_T - i_{T-1}) + a_T \quad (6)$$

Since the t value in this case is 2.53, the probability of the coefficient of the interest rates being positive is larger than 99% and hence we may regard this result as an evidence of the short-run Fisher effect in the U.S. economy over the time period from 1945 to 1992.

Table 37 also lists the autocorrelations and inverse autocorrelations of the residuals a_T of the linear regressions. These autocorrelation estimates were calculated by the SAS PROC ARIMA procedure, but not by the usual SAS PROC GLM procedure. From Table 37 we notice that the residuals exhibit some large autocorrelation and inverse autocorrelation coefficients, notably at lag equal to two. Consequently the residuals in the above model is highly autocorrelated and the linear regressions are not good enough to imply the short-run Fisher effect.

The autocorrelations and inverse autocorrelations of the residuals in the above model indicate that the persistence of inflation must play a role in the relationships between inflation rates and interest rates. As in Barsky [2] we use ARIMA models to investigate the persistence. The general model is ARIMA($p, 1, q$):

$$W_T = \varphi_1 W_{T-1} + \cdots + \varphi_p W_{T-p} + a_T - \theta_1 a_{T-1} - \cdots - \theta_q a_{T-q}$$

where $W_T = \pi_T - \pi_{T-1}$ is the first difference of inflation. To determine the order of autoregressive part p and the order of moving-average part q in $ARIMA(p, 1, q)$ we look at the autocorrelations, inverse autocorrelations and partial autocorrelations of $W_T = \pi_T - \pi_{T-1}$ in Table 38, computed using SAS PROC ARIMA again. From Table 38 we observe that the autocorrelations, inverse autocorrelations and partial autocorrelations after the first two lags are essentially zero, and hence p and q may be chosen to be equal to 2. Tables 39 and 40 summarize the computation of the models $ARIMA(2,1,0)$ and $ARIMA(0,1,2)$. Since the residuals of the $ARIMA(0,1,2)$ model at lag 4 have a large inverse autocorrelation coefficient while the residuals of the $ARIMA(2,1,0)$ model are essentially not autocorrelated, the $ARIMA(2,1,0)$ model is a good model for the persistence of inflation:

$$\pi_T - \pi_{T-1} = \begin{matrix} .31027 & (\pi_{T-1} - \pi_{T-2}) - & .74019 & (\pi_{T-2} - \pi_{T-3}) + a_T. & (7) \\ (.10703) & & (.09450) & & \end{matrix}$$

The model in (7) describes the autoregressive nature of inflation. Since the first difference of inflation $\pi_T - \pi_{T-1}$ is also evidently related to inflation rates according to the model in (6), the autoregressive coefficients in (7) must contain certain influence of the short-run Fisher effect. It is, however, impossible to separate the influence of the Fisher effect from the persistence of inflation using the model in (7). On the other hand, we can see that the coefficient in the model of the short-run Fisher effect in (6) must have influence of the persistence of inflation, as evident from its highly autocorrelated residuals. It is also impossible to separate

the effects of the persistence of inflation from the Fisher effect using the model in (6). Indeed, questions of this kind were not solved by Barsky in [2] who nonetheless pointed out the co-existence of the Fisher effect and the persistence of inflation in models commonly used.

As asserted in the first chapter, we will study a new model which is an ARIMA model crosscorrelated with interest rates. In the case of the U.S. economy, we use the ARIMA(2,1,0) model; considering possible time lags of inflation against interest rates, the model is represented by the following equations:

$$\pi_{T+1} - \pi_T = \beta(i_T - i_{T-1}) + \varphi_1(\pi_T - \pi_{T-1}) + \varphi_2(\pi_{T-1} - \pi_{T-2}) + a_T$$

for time lag of inflation equal to zero,

$$\pi_{T+1} - \pi_T = \beta(i_T^{(k)} - i_{T-1}^{(k)}) + \varphi_1(\pi_T - \pi_{T-1}) + \varphi_2(\pi_{T-1} - \pi_{T-2}) + a_T$$

for time lag of inflation k between 1 and 11 months,

$$\pi_T - \pi_{T-1} = \beta(i_T - i_{T-1}) + \varphi_1(\pi_{T-1} - \pi_{T-2}) + \varphi_2(\pi_{T-2} - \pi_{T-3}) + a_T$$

for time lag of inflation equal to 12 months,

$$\pi_T - \pi_{T-1} = \beta(i_T^{(k-12)} - i_{T-1}^{(k-12)}) + \varphi_1(\pi_{T-1} - \pi_{T-2}) + \varphi_2(\pi_{T-2} - \pi_{T-3}) + a_T$$

for time lag of inflation k between 13 and 23 months. The SAS PROC ARIMA computing results are summarized in Table 41.

From Table 41 we observed that the highest t values for the null hypothesis of the coefficient β being zero are 2.69, 2.77, 2.97, 2.85, and 2.65 corresponding to time lags of inflation from 3 to 7 months. Since the sample size is 46, this means that the probability of the coefficient β being positive is larger than 99%.

When the lags are larger than 7, the t values become small. Note that the SAS PROC ARIMA procedure computes the correlations between any two estimates of the three coefficients β , φ_1 and φ_2 . For time lags from 3 to 7, the correlations between β and φ_1 are -.085, -.096, -.090, -.103 and -.126, while the correlations between β and φ_2 are -.080, -.075, -.092, -.111 and -.119; these correlations can be regard negligible. When time lags are larger than 7, the correlations become large. Therefore for the model with time lags from 3 to 7 the Fisher effect part $\beta(i_T^{(k)} - i_{T-1}^{(k)})$ and the autoregressive part $\varphi_1(\pi_T - \pi_{T-1}) + \varphi_2(\pi_{T-1} - \pi_{T-2})$ are essentially uncorrelated. In other words, our model successfully separates the effect of the persistence of inflation from the short-run Fisher effect when time lags of inflation are between 3 and 7.

In order to check the goodness of our model with time lags of inflation from 3 to 7 months let us look at Tables 42 through 46 where autocorrelations, inverse autocorrelations and partial autocorrelations of residuals are computed. We notice from Tables 42, 43 and 44 that for $k = 3, 4, 5$ the inverse autocorrelations of residuals are rather large; in particular, the ones for lag equal to 5 exceed two times of the standard errors. From Table 45 the inverse autocorrelations together with the autocorrelations and partial autocorrelations are all within the ranges of two times of standard errors. The autocorrelations, inverse autocorrelations and partial autocorrelations of residuals in Table 46 are even smaller and can be thought as essentially zero. Consequently we choose the equation with time lag of inflation equal to 7 as our final model:

$$\begin{aligned}
\pi_{T+1} - \pi_T &= \underset{(.20825)}{.55109} (i_T^{(7)} - i_{T-1}^{(7)}) + \underset{(.11426)}{.25468} (\pi_T - \pi_{T-1}) \\
&- \underset{(.09071)}{.76996} (\pi_{T-1} - \pi_{T-2}) + a_T. \tag{8}
\end{aligned}$$

Recall that in this model the inflation is lagged 7 months behind the interest rates, the correlations between the coefficient of interest rates and the coefficients of inflation are -.126 and -.119, and the autocorrelation analysis shows that the autocorrelations, inverse autocorrelations and partial autocorrelations of residuals are all contained well within the ranges of two standard errors.

Comparing this model with the one in (6), we conclude that only about .55109 in the coefficient .73457 in the model in (6) can be attributed to the short-run Fisher effect, while the rest is contributed by the persistence of inflation. Similarly, the model in (7) is not an actual description of the persistence of inflation, because the first difference of inflation indeed depends on interest rates. The best description of the persistence of inflation is the autoregressive part of the ARIMA model in (8).

Figure 7
U.S. Inflation Rates from 1945 to 1992

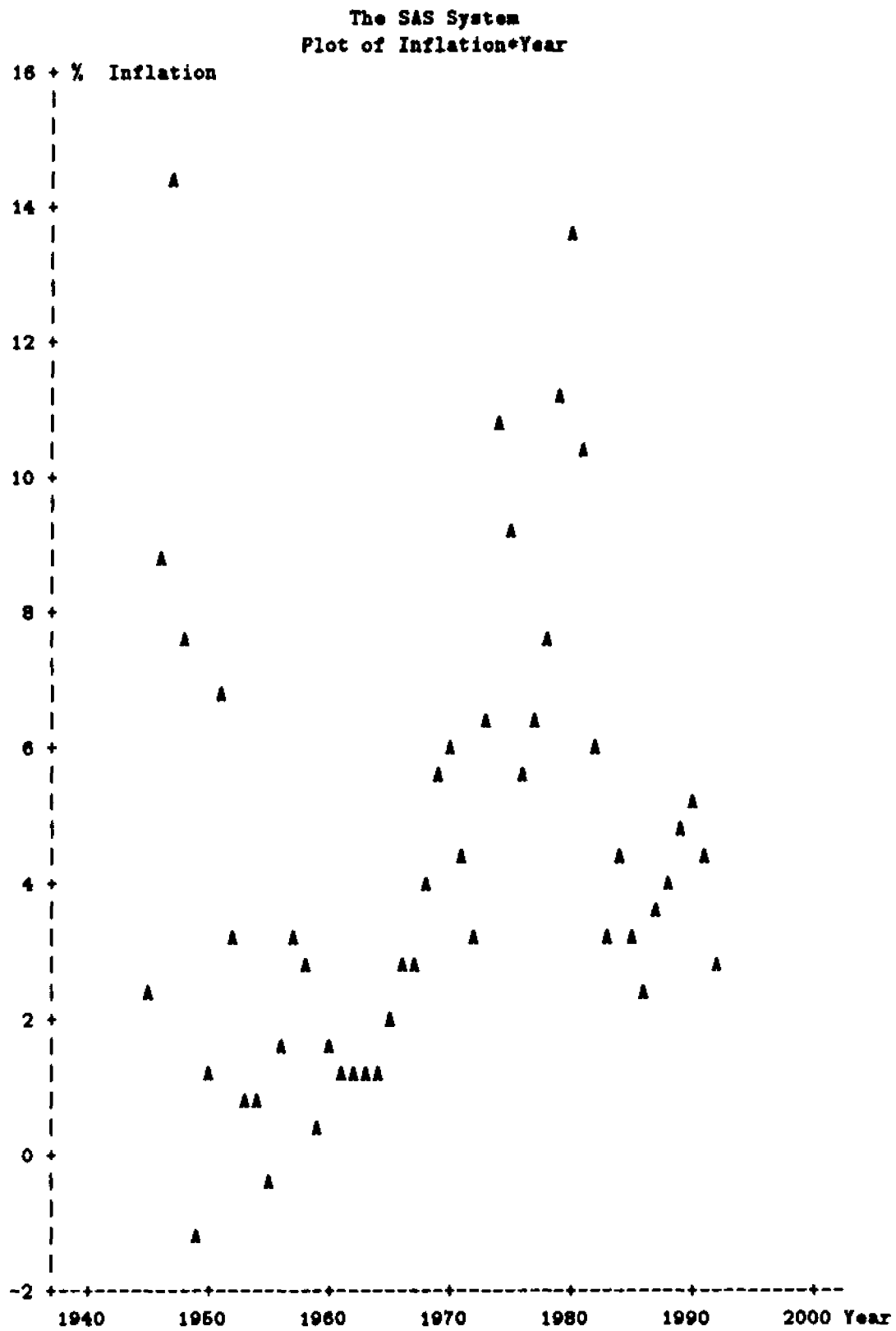


Figure 8
The First Difference of U.S. Inflation Rates from 1945 to 1992

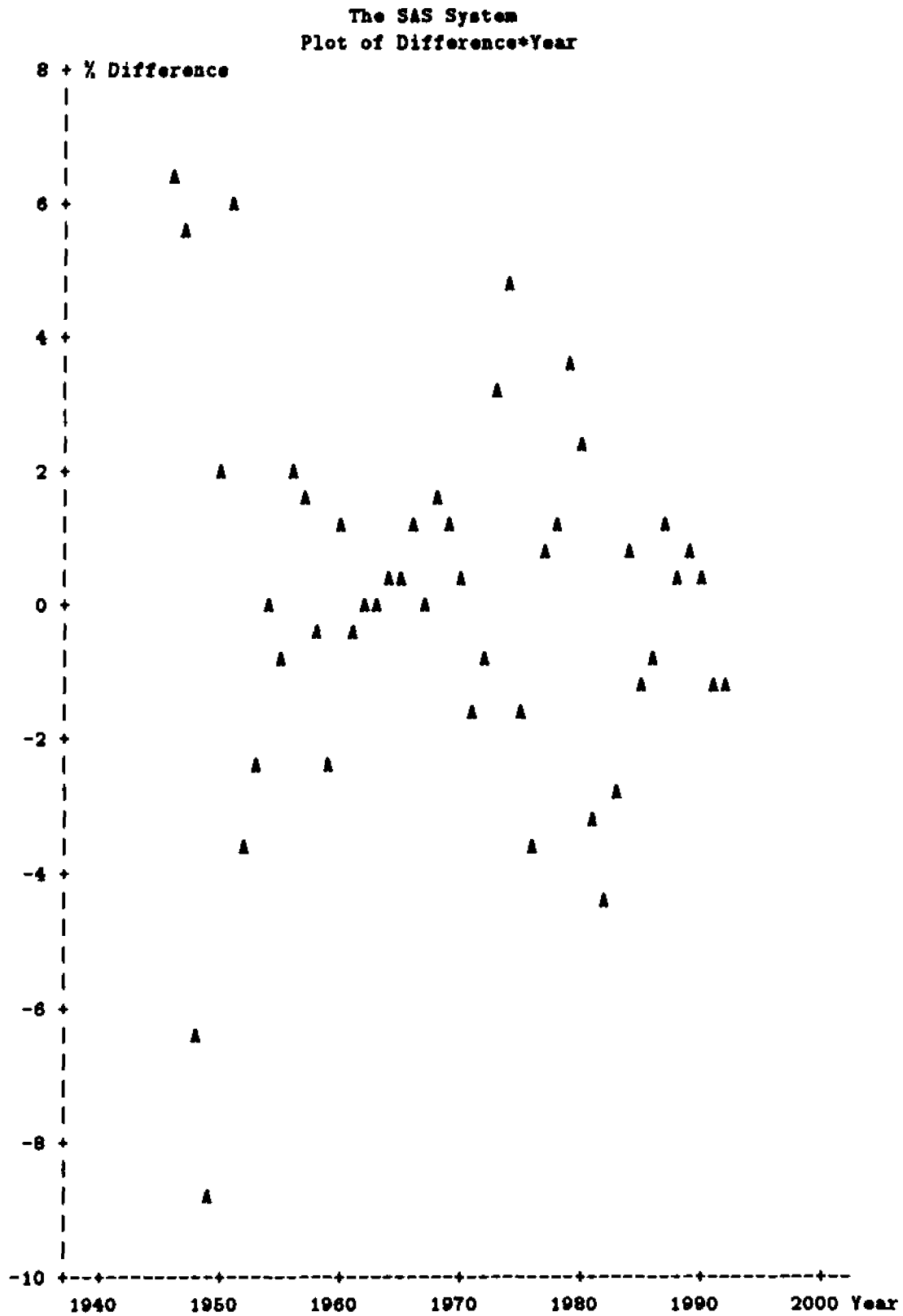


Table 37
 ARIMA(0,1,0) Models Estimation
 of the Short-Run *ex post* Fisher Effect on Yearly Inflation Rates
 Against Yearly Averages of Discount Rates on 91-Day Treasury Bills
 in the U.S. from 1945 to 1992

Lag	β (Std Error)	T for H0: $\beta = 0$	Autocorrelations of Residuals Lags 1-10	Inverse Autocorrelations of Residuals Lags 1-10
0	.41058 (.29724)	1.38	.116 -.557 -.121 .195 .050 .095 -.036 -.208 -.019 .138	-.370 .414 .054 -.179 .248 -.181 .087 .069 -.065 .069
1	.50070 (.29585)	1.68	.113 -.559 -.105 .203 .038 .084 -.032 -.199 -.024 .128	-.384 .420 .038 -.177 .248 -.187 .102 .058 -.051 .066
2	.56774 (.29740)	1.91	.107 -.562 -.089 .212 .025 .076 -.026 -.195 -.029 .123	-.391 .419 .032 -.184 .251 -.191 .107 .059 -.048 .087
3	.62145 (.29318)	2.12	.098 -.561 -.071 .220 .008 .071 -.014 -.193 -.034 .118	-.380 .405 .043 -.204 .256 -.190 .098 .077 -.060 .079
4	.66021 (.28740)	2.30	.089 -.558 -.057 .230 -.006 .067 -.005 -.195 -.038 .117	-.361 .386 .062 -.233 .264 -.187 .084 .104 -.076 .093
5	.72021 (.28884)	2.49	.083 -.559 -.041 .240 -.015 .057 .002 -.193 -.044 .115	-.353 .384 .051 -.231 .248 -.177 .080 .112 -.071 .095
6	.71890 (.28695)	2.51	.074 -.560 -.031 .241 -.015 .055 .005 -.195 -.046 .117	-.312 .391 .026 -.197 .198 -.144 .065 .122 -.058 .092
7	.70672 (.28154)	2.51	.064 -.558 -.022 .236 -.009 .055 .005 -.197 -.047 .116	-.257 .404 -.011 -.145 .127 -.100 .047 .132 -.037 .085
8	.70904 (.27764)	2.55	.052 -.548 -.013 .228 -.001 .050 .005 -.193 -.051 .116	-.190 .414 -.047 -.092 .050 -.054 .031 .140 -.006 .076
9	.69384 (.27168)	2.55	.040 -.537 -.011 .220 .009 .050 .004 -.192 -.054 .118	-.124 .411 -.056 -.072 .005 -.033 .026 .144 .021 .069
10	.67796 (.26567)	2.55	.029 -.526 -.012 .213 .015 .055 .004 -.195 -.055 .120	-.067 .399 -.048 -.078 -.014 -.032 .026 .147 .040 .067
11	.69330 (.26836)	2.58	.023 -.522 -.010 .214 .011 .059 .011 -.204 -.057 .124	-.040 .386 -.038 -.097 -.020 -.036 .020 .159 .044 .073

Table 37 (Continued)
 ARIMA(0,1,0) Models Estimation
 of the Short-Run *ex post* Fisher Effect on Yearly Inflation Rates
 Against Yearly Averages of Discount Rates on 91-Day Treasury Bills
 in the U.S. from 1945 to 1992

Lag	β (Std Error)	T for H0: $\beta = 0$	Autocorrelation of Residuals Lags 1-10	Inverse Autocorrelations of Residuals Lags 1-10
12	.73457 (.29082)	2.53	.118 -.586 -.171 .232 .106 -.017 -.032 -.177 -.079 .137	-.150 .512 .064 .123 .048 .173 .012 .196 .078 .044
13	.74132 (.29625)	2.50	.112 -.582 -.174 .234 .106 -.010 -.030 -.189 -.077 .146	-.099 .485 .108 .086 .078 .165 .021 .208 .081 .045
14	.73111 (.29876)	2.45	.107 -.580 -.177 .232 .111 -.002 -.031 -.200 -.075 .157	-.063 .475 .136 .075 .088 .165 .028 .213 .104 .043
15	.68024 (.29997)	2.27	.104 -.577 -.186 .223 .120 .015 -.037 -.212 -.071 .170	-.025 .473 .160 .075 .104 .156 .049 .204 .124 .036
16	.62333 (.29929)	2.08	.105 -.576 -.196 .216 .131 .028 -.047 -.219 -.065 .179	-.005 .476 .171 .080 .114 .148 .063 .195 .132 .032
17	.62069 (.30455)	2.04	.107 -.581 -.199 .217 .136 .034 -.053 -.223 -.064 .186	-.010 .482 .164 .083 .115 .139 .075 .183 .142 .026
18	.60872 (.30376)	2.00	.110 -.588 -.200 .216 .143 .038 -.062 -.224 -.060 .188	-.032 .497 .136 .098 .106 .129 .084 .168 .144 .023
19	.58209 (.29972)	1.94	.117 -.597 -.203 .214 .152 .040 -.069 -.226 -.054 .186	-.078 .519 .090 .123 .081 .136 .067 .166 .119 .029
20	.54247 (.29833)	1.82	.126 -.607 -.208 .213 .157 .046 -.071 -.232 -.050 .188	-.156 .545 .029 .154 .044 .149 .033 .174 .062 .038
21	.47650 (.29829)	1.60	.137 -.611 -.216 .210 .164 .051 -.075 -.231 -.055 .184	-.223 .566 -.027 .176 .016 .146 .029 .157 .084 .031
22	.41941 (.29325)	1.43	.146 -.614 -.226 .207 .170 .055 -.079 -.233 -.052 .184	-.270 .578 -.056 .190 .001 .152 .010 .157 .063 .033
23	.37623 (.29812)	1.26	.154 -.617 -.236 .204 .175 .060 -.083 -.235 -.049 .184	-.314 .588 -.078 .192 -.003 .145 .003 .152 .049 .034

Table 41

The ARIMA(2,1,0) Model on Yearly Inflation Rates Crosscorrelated with
the First Difference of Interest Rates with Time Lags
in the U.S. from 1945 to 1992

Lag	BUM1 ψ (Std Err)	T for H_0 : $\psi = 0$	AR1,1 φ_1 (Std Err)	T for H_0 : $\varphi_1 = 0$	AR1,2 φ_2 (Std Err)	T for H_0 : $\varphi_2 = 0$	Correlations of BUM1 with	
							AR1,1	AR1,2
0	.42159 (.20944)	2.01	.32208 (.11207)	2.87	-.76977 (.09057)	-8.50	-.069	-.084
1	.49199 (.20965)	2.35	.32117 (.11142)	2.88	-.77658 (.08910)	-8.72	-.065	-.087
2	.53386 (.20695)	2.59	.31657 (.11105)	2.84	-.78166 (.08799)	-8.86	-.069	-.086
3	.51912 (.19267)	2.69	.30573 (.11145)	2.74	-.78183 (.08789)	-8.90	-.085	-.080
4	.50390 (.18167)	2.77	.29722 (.11180)	2.66	-.78217 (.08776)	-8.91	-.096	-.075
5	.56891 (.19152)	2.97	.28847 (.11164)	2.58	-.78584 (.08704)	-9.03	-.090	-.092
6	.57540 (.20163)	2.86	.27187 (.11264)	2.41	-.78017 (.08844)	-8.82	-.103	-.111
7	.55109 (.20825)	2.65	.25468 (.11426)	2.23	-.76996 (.09071)	-8.49	-.126	-.119
8	.50466 (.21555)	2.34	.23977 (.11660)	2.06	-.75553 (.09369)	-8.06	-.153	-.120
9	.42239 (.21241)	1.99	.23549 (.11854)	1.99	-.74336 (.09596)	-7.75	-.181	-.105
10	.34452 (.20415)	1.69	.24005 (.11955)	2.01	-.73663 (.09709)	-7.59	-.195	-.083
11	.32886 (.20697)	1.59	.23852 (.11995)	1.99	-.73343 (.09760)	-7.51	-.199	-.068

Table 41 (Continued)

The ARIMA(2,1,0) Model on Yearly Inflation Rates Crosscorrelated with
the First Difference of Interest Rates with Time Lags
in the U.S. from 1945 to 1992

Lag	NUN1 ψ (Std Err)	T for H0: $\psi = 0$	AR1,1 φ_1 (Std Err)	T for H0: $\varphi_1 = 0$	AR1,2 φ_2 (Std Err)	T for H0: $\varphi_2 = 0$	Correlations of NUN1 with	
							AR1,1	AR1,2
12	.34002 (.21402)	1.59	.23556 (.11284)	2.09	-.73446 (.09631)	-7.63	-.202	-.050
13	.30760 (.21988)	1.40	.23841 (.11325)	2.11	-.73239 (.09666)	-7.58	-.211	-.026
14	.26269 (.22091)	1.19	.24515 (.11342)	2.16	-.73185 (.09676)	-7.56	-.221	.000
15	.17642 (.21020)	0.84	.26412 (.11277)	2.34	-.73351 (.09658)	-7.59	-.220	.022
16	.10371 (.19982)	0.52	.28182 (.11203)	2.52	-.73573 (.09632)	-7.64	-.217	.040
17	.09240 (.21340)	0.43	.28422 (.11237)	2.53	-.73609 (.09641)	-7.63	-.234	.066
18	.11335 (.22219)	0.51	.27816 (.11286)	2.46	-.73553 (.09671)	-7.61	-.245	.093
19	.15435 (.22470)	0.69	.26720 (.11299)	2.36	-.73507 (.09693)	-7.58	-.242	.111
20	.21072 (.22512)	0.94	.25383 (.11253)	2.26	-.73622 (.09681)	-7.61	-.228	.122
21	.21940 (.22011)	1.00	.25316 (.11280)	2.24	-.73726 (.09754)	-7.56	-.205	.117
22	.21130 (.20682)	1.02	.25745 (.11190)	2.30	-.73928 (.09713)	-7.61	-.185	.114
23	.22607 (.20755)	1.09	.25789 (.11108)	2.32	-.74170 (.09670)	-7.67	-.168	.115

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