保險開發硏究 第12卷 第1號(2001年 3月)

The Long-Run Fisher Effects in Korea

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The Fisher effect explains one-to-one relationship between nominal interest rates and inflation. This paper re-evaluates the long-run Fisher relation in Korea. Focusing on the structural break in the Fisher effect in Korea, we find two different subsample periods that produce different results. The first regime supports the Fisher relation, and the analysis of the second regime shows a large response of nominal interest rates to the expected inflation, which seems to be the tax effect in the Fisher relation proposed by Darby(1975).

I. Introduction

Determinations of the interest rates are one of the most important topics in the field of economics and finance. One of the simplest interest rate determination model is the Fisher hypothesis which shows the relationship between interest rates and inflation. The Fisher's(1930) hypothesis predicts one-to-one relationship between interest rates and expected inflation in the absence of tax effects. Summers(1983) illustrates that nominal interest rates go up to 1.5 (precisely 1.3 to 1.5) when the marginal tax rates are considered. This implies that the

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We would like to thank two anonymous referees for helpful comments.

Fisher effects after the tax consideration should be greater than one as predicted by Darby(1975). In contrast, Levi and Makin(1978) and Melvin(1982) investigate the Mundell-Tobin effect which is the negative relation between the expected inflation and the real interest rates via wealth effects.

The purpose of this paper is to identify the long-run relationship of the Fisher's hypothesis in Korea by using recently developed multivariate cointegration methodology. Cointegration analysis identifies the long-run relationship among nonstationary variables. The motivation of cointegration analysis is originated by the fact that the economic and financial time series are characterized as possessing stochastic trends (see Nelson and Plosser, 1982). Even though Rose(1992) concludes that the inflation rate does not follow a unit root after he analyzes the data generating process (DGP), it is widely accepted that the price levels are integrated of order two or I(2), which implies that the inflation rate follows stochastic trends. Mishkin(1992) examines the long-run Fisher effect by using the Engle-Granger(1987) cointegration methodology. Recently, Crowder and Hoffman(1996) apply Johansen's(1988, 1991) maximum likelihood estimator(MLE) to identify the long-run Fisher relation and conclude that there exists tax-adjusted Fisher effect as suggested by Darby(1975).

This paper extends the data set to the year of 1999 and analyzes the relation between interest rates and inflation in Korea by using an efficient estimation technique, Johansen cointegration test. The Johansen's multivariate cointegration methodology assumes constant cointegration vectors. We test stability of the cointegration vector and find regime shifts around 1986 to 1987. Interestingly, the large responses of nominal interest rates to the expected inflation during

1987 to 1999 exist, which seems to be tax effects on the Fisher relation predicted by Darby. These results are also confirmed by Dynamic OLS(DOLS), asymptotically equivalent to Johansen's method, proposed by Stock and Watson(1993).

The outline of the paper is as follows. Section II outlines the Fisher relation and explains that the real interest rate is stable under the steady state restrictions. Section III shows the methodologies and empirical findings. Conclusions are presented in Section IV.

II. Fisher Hypothesis

The Fisher's hypothesis(1930), one of the most influential economic theory, states one-to-one relationship between interest rates and expected inflation, which implies that the expected loss of the purchasing power of money caused by inflation is compensated by nominal interest rates.

The generalized Fisher relation can be derived by simple asset pricing model(Lucas, 1978, and Sargent, 1987). This version of the Fisher relation is used by Evans and Lewis(1995), and Crowder and Hoffman(1996). Chung and Crowder(1998) show that the Fisher relations exist for N currency denominations. They use the problem of maximizing expected utility[1] relying on the consumption C_t subject to the budget constraint and derive following two equations (1) and(2)

[1] They assume that the specific functional form of the utility function of the Hyperbolic Absolute Risk Aversion(HARA), $U(C_t)=C_t^{1-\gamma}/(1-\gamma)$, where γ is the coefficient to relative risk aversion.

$$r_t = \ln(\beta^{-1}) + \gamma E_t \Delta c_{t+1} \cdots\cdots (1)$$

$$i_t = r_t + E_t \Delta p_{t+1} + 1/2\, Var_t \Delta p_{t+1} - \gamma Cov(\Delta c_{t+1}, \Delta p_{t+1}) \cdots\cdots (2)$$

where γ_t and i_t represent the continuous compounded real and nominal interest rates, respectively. β and γ indicate the discounted factor and the coefficient to relative risk aversion, respectively. In addition, p_t is defined as the logged price of goods, and c_t is the logged consumption.

Equation (1) implies the behavior of the real interest rate. If the consumption growth is a stationary and bounded sequence, then the real interest rate must be a stationary and boundary sequence. Since consumption growth is well documented to be a stationary series (see Nelson and Plosser, 1982, Schwert, 1987, and Gali, 1990) the real rate is stationary.

Equation (2) states that the nominal interest rate is equal to the real interest rates (r_t) plus expected decline in purchasing power ($E_t\Delta p_{t+1}+1/2 Vart \Delta p_{t+1}$), minus a risk premium, $\gamma Cov(\Delta c_{t+1}, \Delta p_{t+1})$. The time series implication of equations (1) and (2) is that since the real interest rate in equation (1) is stationary, the rest of three terms in equation (2) should be stationary. If any of them are nonstationary, then their linear combination should be stationary. Specifically, most of evidences suggest that the inflation risk premium is not statistically significant (see Shome, Smith, Pinkerton, 1988 and Evans Wachtel, 1990). Therefore, the Fisher equation can be examined by cointegration framework, e.g. if nominal interest rates and expected inflation rates are integrated of order one (I(1)), then the linear combination of these series should be I(0). Thus, the Fisher equation does not work if inflation rates do not have unit roots based on the result of Rose(1988).

By assuming that expectations are unbiased and rational and the risk premium is stationary, equation (2) can be written as follows.

$$i_t = \alpha + \pi_{t+1} + \varepsilon_t \cdots\cdots (3)$$

where α involves the mean of the real interest rates and the risk premium and ε_t is a rational expectations forecast error, which is an autocorrelated stationary error term. Assuming that the real interest rate is constant, and nominal interest rates and inflation rates are I(1), respectively, and these variables are cointegrated, then the Fisher hypothesis implies that nominal interest rates and inflation rates have one-to-one relationship. Again, if one of two variables is not I(1) as presented by Rose(1988), then the equation (3) is spurious and the Fisher hypothesis does not hold.

Assuming the nominal returns are taxed, then equation (3) can be written by,

$$[1-\tau]i_t = \alpha + \pi_{t+1} \cdots\cdots (4)$$

where τ is the average marginal tax rate.

Then nominal interest rates can be as follows.

$$i_t = \left[\frac{1}{1-\tau}\right]\alpha + \left[\frac{1}{1-\tau}\right]\pi_{t+1} + \upsilon_t \cdots\cdots (5)$$

where ν_t has the same statistical properties with ε_t. The difference between equations (3) and (5) is clear. The equation (3) implies that for one percentage increase in the expected inflation rate, nominal interest rate increases one percentage. However, equation (5) implies that the Fisher effects after the tax consideration should be greater than one as explained by Darby(1975). For example, if the marginal tax rate is 20%, then τ is 0.2 and $1/(1-\tau)$ is 1.25. The Fisher equation will be tested by cointegration framework in the next section if nominal interest rates and inflation rates follow I(1) processes.

III. Empirical Analysis

1. Data and Univariate Analysis

Monthly observations of the Consumer Price Index are used for calculating inflation rates and the yields on 3-year corporate bond are used over the period from September 1975 to January 1999. These data set are provided by the database from the Bank of Korea. Twelve-month ahead basis of annualized inflation is used as the proxy of expected inflation rates. The series are plotted in Figure 1.

The first issue for time series analysis is to determine the degree of integration of each series - unit root tests. The controversial series is the order of integration for inflation rates. Rose(1988) found that inflation rates follow stationary series. If it is true, then the Fisher relation does not hold. In this section several different methodologies are employed to examine unit root for inflation and interest rate to

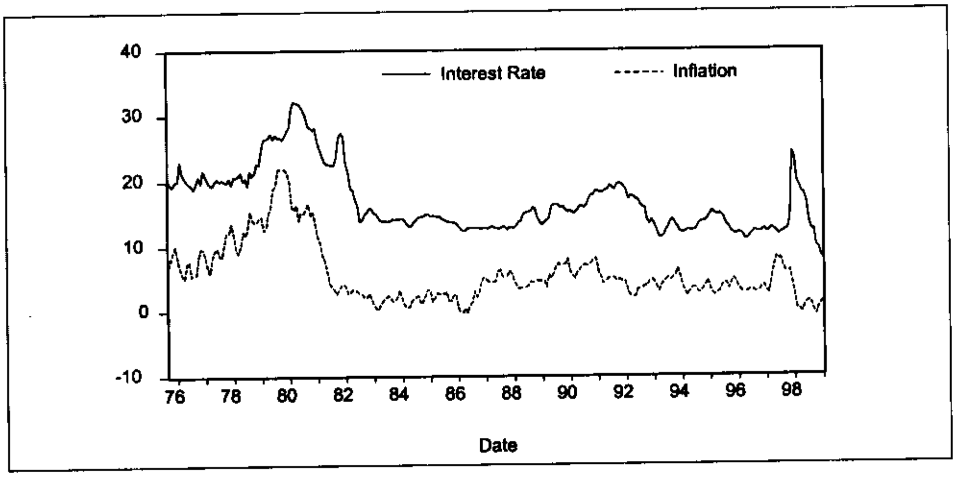

Figure 1. Plots of Data for Interest Rates and Inflation

provide robustness to the results. The Augmented Dickey Fuller(ADF, 1979), Phillips and Perron(PP, 1986), and Kwiatkowski, Phillips, Schmidt, and Shin(KPSS, 1992) are used to test the unit root hypothesis.

Two tests of the univariate unit root - the Augmented Dickey Fuller test(ADF, 1979), and the Phillips Perron test(PP, 1988) are considered. The test statistics are listed in Table 1 by using lag truncations of 3, 5, 7, and 10.

According to Table 1, it is clear that inflation and interest rate follow unit root processes. Two unit root tests take the null to be the unit root against the alternative of stationarity. Another method of unit root test is proposed by Kwiatkowski, Phillips, Schmidt, and Shin(KPSS, 1992) which takes the null of stationarity. The idea of KPSS test comes from the view that the unit root test has low power against local alternatives. KPSS statistic can be calculated as

Table 1. Unit Root Tests(ADF and PP)

Lag Truncation	Inflation		Interest Rate	
	ADF test	PP test	ADF test	PP test
3	-1.89	-1.98	-1.77	-1.64
5	-2.07	-1.96	-2.03	-1.69
7	-1.96	-1.97	-1.51	-1.68
10	-1.45	-1.87	-1.41	-1.61
5% Critical Value	-2.86	-2.87	-2.86	-2.87

Note: ADF and PP imply the Augmented Dickey Fuller test and the Phillips Perron test, respectively.

$$\eta_{\mu} = \frac{\sum_{t=1}^{T} S_t^2}{T^2 s^2(k)} \quad \cdots\cdots (6)$$

where S_t is the partial sum of the residuals from a regression of the series on a constant, T is the number of observations and $s^2(k)$ is a consistent estimate of the long run variance.[2] The results of KPSS test are shown in Table 2.

Table 2. KPSS Tests for Stationarity

Lag Truncation (k)	Inflation	Interest rates
3	2.252	3.259
5	1.538	2.226
8	1.061	1.539
12	0.768	1.112

Note: Critical values are given by KPSS(1992). 10%=0.347, 5%=0.463

The KPSS test indicates that inflation rates and interest rates are nonstationary in level. Based on three unit root tests, we can conclude that both series are following I(1) processes.

2. Multivariate Analysis

In the previous section, we show that each variable possesses the unit root

[2] The Newey-West procedure is used to obtain consistent estimates of the long-run variance.

which is the first requirement of the cointegration test. Now we can proceed to analyze the long-run relationship of the Fisher equation by using the maximum likelihood procedure proposed by Johansen(1988) and Dynamic OLS method developed by Stock and Watson(1993).

The 11 lags for cointegration analysis are selected by likelihood ratio criteria. The formal tests whether the cointegration vector include a constant term are also conducted.[3] Johansen and Juselius(1990) and Johansen(1994) define the model $H_1(r)$, where r represents the number of cointegration vector, as the unrestricted intercepts and no trends in vector autoregressive model and the model $H_1^*(r)$ is defined as restriction on intercepts and no trends in the VAR model by allowing a constant in equilibrium relationship, while the model $H_0(r)$ does not allow the constant term or the deterministic trend.

The likelihood ratio (LR) statistic to test the hypothesis $H_1(r)$ with $H_1^*(r)$ is as follows;

$$T \sum_{i=r+1}^{p} \ln\left[\frac{1-\lambda_i^*}{1-\lambda_i}\right] \quad \cdots\cdots(7)$$

where λ represents eigenvalues of associated model, p is the number of variables, and T is the number of observations. This statistic follows χ^2 distribution with $(p-r)$ degrees of freedom. The LR test of $H_1^*(r)$ with $H_1(r)$ is given by;

$$T \sum_{i=1}^{r} \ln\left[\frac{1-\lambda_i}{1-\lambda_i^*}\right] \quad \cdots\cdots(8)$$

[3] See Johansen and Juselius(1990) and Johansen(1994) for the procedure to test the specification of cointegration relation.

which follows χ^2 distribution with r degrees of freedom. The likelihood ratio tests for specification are denoted in Table 3.

Table 3. Likelihood Ratio Tests for Specification

	λ_1	λ_2	LR Stat	df
$H_0(r)$	0.03348	0.0029	15.86	1
$H_1(r)$	0.08653	0.0151	0.03	1
$H_1^*(r)$	0.08705	0.01516	-	-

The LR test statistic for $H_1(r)$ versus $H_1^*(r)$ is 0.03 resulting in non-rejection of $H_1^*(r)$ at the 5% level of significance and for $H_0(r)$ versus $H_1^*(r)$ is 15.86. Since we reject the hypothesis of $H_0(r)$ at the 5% level of significance, the desirable specification is allowing a non-zero constant term in the cointegration relationship.

The results of multivariate cointegration test by Johansen is in Table 4. Both tests of maximum eigenvalues and trace tests indicate that there are one cointegration vectors at the 5% level of significance.

Based on the one cointegration relation, Johansen methodology provides a cointegration vector. The estimated cointegration vector should be following form of [1 $-\beta\pi$ Constant][4] indicated by equations (3)

Table 4. Results of Cointegration Tests for Full Sample

Null Hypothesis	Maximum Eigenvalue Test			Trace Test		
	λmax	5%	10%	Trace	5%	10%
r≤0	24.59	15.67	13.75	28.72	19.96	17.87
r≤1	4.12	9.24	7.52	4.12	9.24	7.52

Note: Critical values are from Osterwald-Lenum(1992) and (5). The estimated value for cointegration vector is [1.0 -1.11 -10.18].

As discussed in section II, the simplest form of the Fisher hypothesis implies one-to-one relation between interest rates and the expected inflation. Johansen methodology enables us to test this one-to-one relation. To test for the coefficient of the Fisher equation, we impose the restriction that the coefficients of nominal interest rates and inflation rate are same, and then compare the characteristic roots of the unrestricted and restricted models. The test statistic can be calculated as follows.

$$T \sum_{i=1}^{r} \ln\left[\frac{1-\lambda_i^*}{1-\lambda_i}\right] \cdots\cdots (9)$$

where λ_i and λ_i^* represent the unrestricted and restricted characteristic roots, respectively, and T is the sample size. This statistic follows χ^2 distribution with degrees of freedom equal to the number of restrictions placed on the beta coefficients.

Testing hypothesis of one-to-one relation yields a test statistic of 1.264 implying that there is one-to-one relation between two time series over the period between 1975 and 1999.[5]

The results of cointegration analysis over whole sample period indicate that the tax effect in the Fisher relation proposed by Darby(1975) is missing.

Figure 2, which plots the estimated equilibrium relationship between the nominal interest rates and inflation, however, indicates a structural

[4] β_π is the coefficient of inflation. The constant term implies the mean of the ex-post real interest rate minus the risk premium plus one-half the conditional variance of inflation.

[5] This statistic is following the $\chi^2(1)$ distribution.

break around 1979 to 1987. To confirm that the cointegration system over the estimated period is stable, we conduct the recursive stability test. The cointegration procedure by Johansen assumes that the long run relationship is stable over the sample period. This proposition, however, may not be correct if there are regime shifts over the sample period. The regime shifts may come from some exogenous economic events.

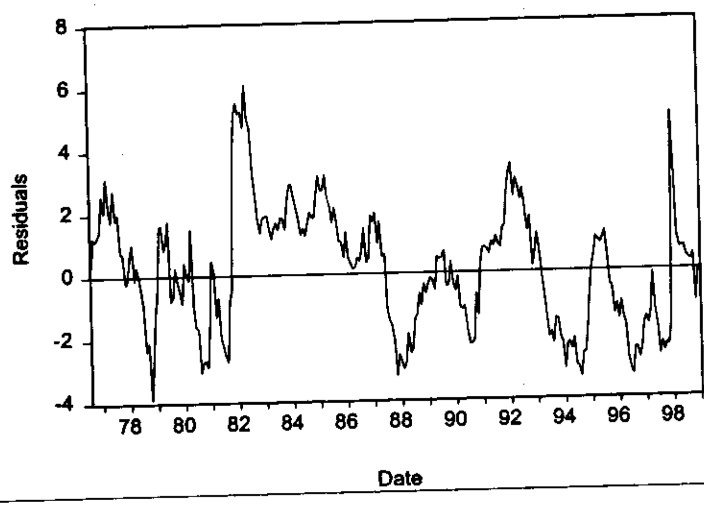

Figure 2. Plots of Equilibrium Relationship over the Full Sample

To test for the stability of cointegration system, we employ the recursive likelihood ratio (LR) test of constant cointegration space proposed by Hansen and Johansen(1993). The suggested test for the constancy of the cointegration space is based on the likelihood ratio test for a known cointegration vector of the full sample. The main idea, thus, is to examine the long-run parameter under the assumption of constant short-run relations. The recursive stability tests produce a series of likelihood ratio tests at each iteration, where the hypothesis is $\beta_t = \beta$ where t= T_0, . . ., T. The recursive statistics which follow a $\chi^2(r(p-r))$ distribution, are presented graphically as in Figure 3.

Figure 3. plots the normalized recursive LR statistics of constant cointegration space against time. Since each iteration for the test statistics is normalized by the 95% of critical value, the values of normalized recursive LR statistics which is greater than one imply the rejection of the hypothesis that the cointegration vector is constant over the sample period. Instability is apparent in Figure 3, specifically before and after around 1987. Based on the stability analysis, we split the data into two part and conduct the subsample analysis for the Fisher relations in the next section.

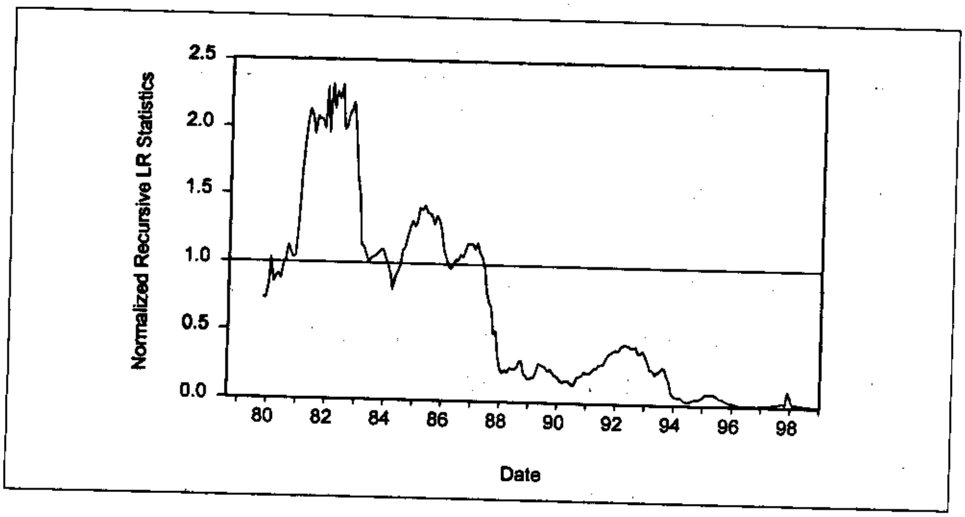

Figure 3. Recursive LR Tests of the Constant Cointegration Space over the Full Sample

3. The Fisher Relation: Subsample Analysis

Based on the recursive stability analysis of the constant cointegration space we spilt the period into two parts - the first period from September 1975 to December 1986, and the second period from January 1987 to January 1999. Then we conduct cointegration tests for long run Fisher hypothesis and its stability test for both sample periods.

The result of cointegration analysis in Table 5 is showing that there is only one cointegration vector at the 5% level of significance.[6] Furthermore, Figure 4 indicates that there is no structural break during the first sample period since all recursive LR statistics are below one.

Table 5. Results of Cointegration Tests (Sep. 1975 - Dec. 1986)

Null Hypothesis	Maximum Eigenvalue Test			Trace Test		
	λ max	5%	10%	Trace	5%	10%
r≤0	29.42	15.67	13.75	32.58	19.96	17.87
r≤1	3.16	9.24	7.52	3.16	9.24	7.52

Note: Critical values are from Osterwald-Lenum(1992)

The computed cointegration vector for the first period is [1 -0.96 -12.13]. It is interesting that the coefficient of the expected inflation is less than that of the full sample, but still close to one. The next step is

6 For the first period, we conduct all kinds of unit root tests. The results are the same as the full sample. The lags used for the first period are six based on the LR test.

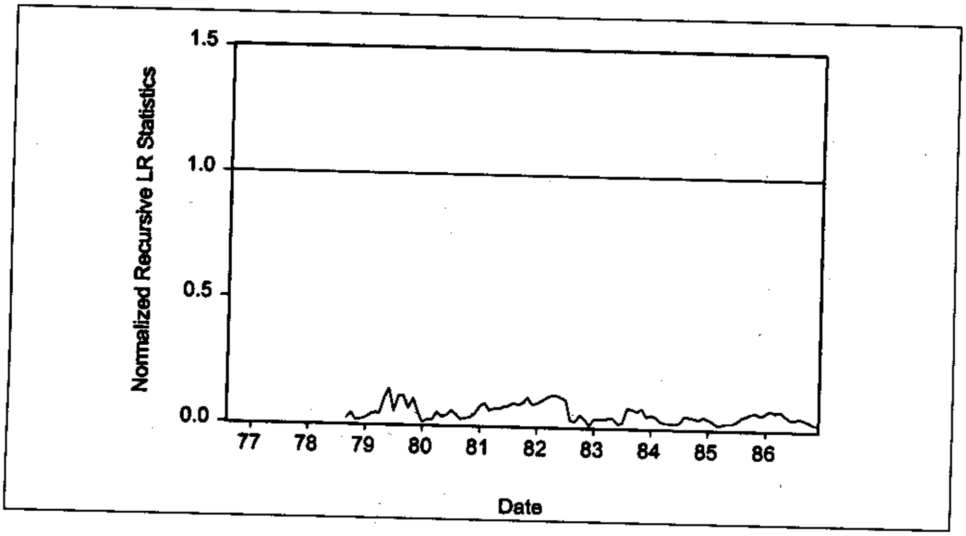

Figure 4. Recursive LR Tests of the Constant Cointegration Space over Sep. 1975 to Dec. 1986

to test one-to-one relationship between interest rates and inflation. Testing hypothesis of one-to-one relation yields a test statistic of 0.179 which is distributed as a $\chi^2(1)$ implying that there is one-to-one relation and no tax effect between two time series over 1975 to 1986.

We also conduct the same tests for the second sample period, Jan. 1987 to Jan. 1999. The results of cointegration analysis are presented in Table 6 indicating that there is one cointegration vector ensuring the Fisher relation.[7] Like that of the first sample period, Figure 5 indicates that there is no structural break during the second sample period.

[7] For the second sample period, we conduct all kinds of unit root tests. The results are the same as the full sample. The six lags are used for the second sample period based on the LR test.

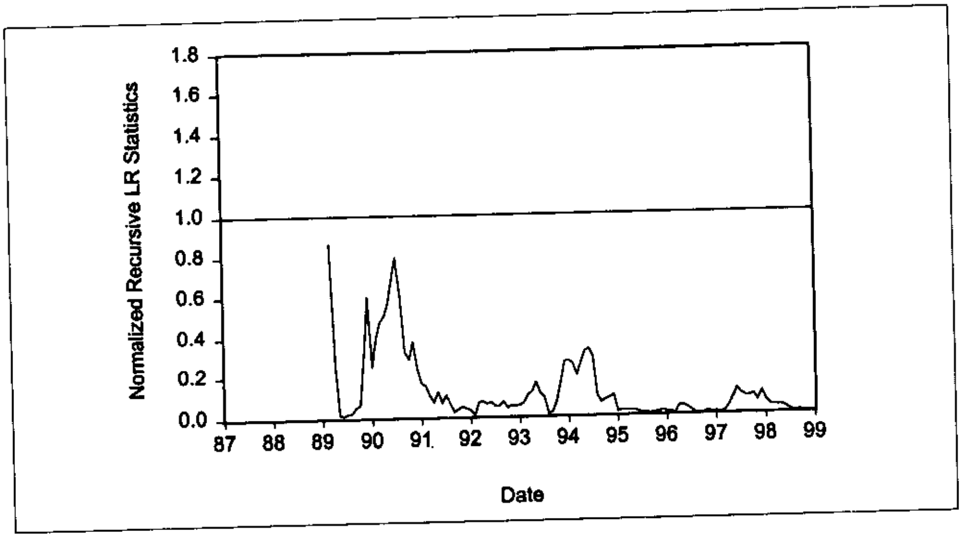

Figure 5. Recursive LR Tests of the Constant Cointegration Space over Jan. 1987 to Jan. 1999

Table 6. Results of Cointegration Tests (Jan. 1987 - Jan. 1999)

Null Hypothesis	Maximum Eigenvalue Test			Trace Test		
	λmax	5%	10%	Trace	5%	10%
r≤0	48.80	15.67	13.75	55.50	19.96	17.87
r≤1	6.70	9.24	7.52	6.70	9.24	7.52

Note: Critical values are from Osterwald-Lenum(1992)

The estimated cointegration vector for the second period is [1 -1.92 -5.90].[8] Now, the cointegration vector is dramatically changing. Specifically, the coefficient of the expected inflation, which seems to be reflecting more than the tax effects in the Fisher relation. Tax effects of Fisher relation in Korea are inconclusive since it is hard to believe the

[8] The standard deviation for the coefficient of expected inflation rate is 0.61.

large coefficient in inflation reflects tax effects during the second subsample. However, it is interesting that the coefficient of the expected inflation is similar to that of Summers(1983) who illustrates the nominal interest rates go up 1.3 to 1.5 if we consider the large asymptotic standard deviation of 0.61 as denoted in footnote (8). It is also meaningful to test one-to-one relationship between interest rates and the inflation. Testing hypothesis of one-to-one relation yields a test statistic of 3.94 by rejecting the null. This result implies there are some evidences for the tax effect in the Fisher relation.[9]

We also use the DOLS estimation method to test for robustness of Johansen's. As described by Stock and Watson(1993), the DOLS equation to be estimated is as follows.

$$i_t = \alpha + \beta_1 \pi_{t+1} + \sum_{i=-k}^{k} \theta_i \Delta\pi_{t-i} + \zeta_t \quad \cdots\cdots\cdots\cdots (10)$$

where k represents the leads for the differenced expected inflation rate. The estimated coefficients are summarized in Table 7.

Table 7. Results of DOLS Tests [10]

Time Period	Parameter Estimates		t-statistics
	α	β_1	$H_0: \beta_1 = 1$
Sep. 1975-Dec. 1986	12.63(0.26)	0.92(0.028)	2.86
Jan. 1987-Jan. 1999	7.29(0.78)	1.51(0.19)	2.68

[9] This analysis assumes the marginal tax rate is constant during the sample period. More accurate approach is to adjust the data based on the estimated marginal tax rate and test for one-to-one relation between the adjusted interest rates and the inflation rates. This will be left for the next research.

[10] Because we are using monthly data 12 lags and leads are used. Numbers in brackets represent the standard deviations.

Table 7 presents the parameter estimates of the DOLS. The coefficient of the expected inflation rate in the first sub-period is similar to Johansen's, while the coefficient of the second period is smaller than Johansen's. However, the striking feature of the results of the DOLS is that tax effects in the Fisher relation exist in the second period. Note that the null hypothesis of $\beta_1=1$ for both cases are rejected.

Then the questions may arise "why are the coefficients of the expected inflation rates different across the subsample periods?". We can find some answers in the environmental changes in economic and financial markets in Korea.

The one of possible explanations can be addressed on the liberalization policy of interest rates in Korea and international financial market integrations which are the trend of worldwide globalization of capital markets.[11] Chung and Lee(1999) find that the interest rates in Korea share the long - run linkage with the four industrialized countries - the US, the UK, Japan, and Germany, and that this long - run linkage is getting stronger after 1989. Crowder(1996) shows the international convergence of inflations during both fixed and floating exchange rate regimes and that this trend of convergence is much more strong in the floating exchange rates regimes. More importantly, Crowder(1997) and Chung and Crowder(1998) show that there exist international Fisher relations with tax effects. In this context, the liberalization policy of interest rates in Korea and international financial market integration affect the behavior of interest rate in Korea.

[11] One referee suggests that regime shifts of the monetary policy in late 1980's may be the possible sources of structural break.

IV. Conclusion

This study investigates the long run relationship of traditional Fisher hypothesis in Korea. The results indicate that there is structural break in the Fisher relations in Korea. By analyzing the subsample periods, we find two different regimes of the Fisher relations. The first regime supports the one-to-one Fisher relations. Interestingly, we find a large sensitivity of nominal interest rates during the second subsample of 1987 to 1999.

The main contribution of this study is that the structural break exists in Fisher relation in Korea and the analysis of Johansen cointegration test and DOLS in the second subsample shows a large response of nominal interest rates to the expected inflation, which seems to be the tax effects in the Fisher relation proposed by Darby(1975). The caveat of this study is that we show only empirical results of tax effects and structural break in the Fisher relation in Korea. As one of the possible sources of structural break in the Fisher relation, we conclude that the financial market development and the globalization of capital markets in Korea affect the behavior of interest rates. However, we did not address the sources of structural breaks directly in this paper. This issue will be left for further research.

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