Taylor Principle Supplements the Fisher Effect: Empirical Investigation under the US Context

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ABSTRACT
This paper reviews the short- and long-run dynamics of interest rate and inflation of the United States. Basing upon quarterly as well as monthly data over the period 1957 to 2010, we find evidence that interest rate behaviour of the Federal Reserve is consistent with the Taylor principle in short run and with the Fisher hypothesis in long run. Entire sample justifies the existence of a long run cointegrating relationship between federal funds rate and inflation characterised as the Fisher effect. When data are split into different subsamples, the cointegrating relationship disappears. Interest rate dynamics of pre-1980 and post-2001 neither track Fisher hypothesis nor Taylor principle, rather represent substantial discretion.

KEYWORDS: *Fisher Effect, Monetary Policy, Taylor Principle.*

JEL CLASSIFICATION: *E43, E52, E59*

INTRODUCTION

At the beginning of the twentieth century Yale University economist Irving Fisher modelled that in the long-run money growth affects both the nominal rate of interest and inflation one for one, therefore does not affect the real rate of interest- which later became familiar as the Fisher effect. Since then academics and researchers have been investigating the existence of the Fisher effect by using time series and panel data for different countries over long span but there is no common conclusion regarding the time horizon when Fisher effect actually holds, if at all. Empirical justification of Fisher effect lies in the unit root behaviour of both nominal interest rate and inflation so that there is long run equilibrium characterised by cointegrating relation between the two series. This paper carefully revisits the issue of the relationship between interest rate and inflation with the aim of investigating whether actually there exists a one-for-one correspondence between these two series. If the nominal rate of interest responds to inflation just one for one then the real rate of interest would remain unchanged, thus monetary policy would be neutral. John B. Taylor (1993), on the other hand, proposes monetary policy rule that clearly contradicts with the Fisher hypothesis. Our objective is to investigate whether the US data supports any one-for-one response of interest rate to inflation or interest rate is more responsive to inflation so that the Taylor principle, as opposed to the Fisher relation, holds. To the best of our knowledge there is no literature available that address the seemingly reverse views of the Fisher effect

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and Taylor rule. There are papers however reviewing the Fisher effect and Taylor rule separately.

Barsky (1987) finds negative correlation between the US commercial paper rate and contemporaneous inflation for the period 1860 to 1939 but a strong positive correlation for 1950 to 1979. Rose (1988) demonstrates that the US interest rate and inflation are integrated of different order, therefore rules out the possibility of any long run cointegration between them. Mishkin (1991) does not find any short run Fisher effect in US data but in the long run the Fisher effect occurs which is consistent with Fisher's own modelling. Kesryyely (1994) discovers a long-run equilibrium relationship between interest rate and inflation, validating the existence of the Fisher effect in Turkish data over post-1980 period. MacDonald and Murphy (1989), Dutt and Gosh (1995) do not find the existence of the Fisher effect in Canadian data. Contrary to this, Crowder (1997) observes the existence of traditional Fisher effect in Canadian data over four decades although the equilibrium relationship between interest rate and inflation is not entirely stable over the period due to the appearance of structural breaks. Using hundred years of UK data since 1990, Granville and Mallick (2004) find one-for-one relation between nominal rate of interest and expected inflation. Similar results are obtained by Berument and Jelassi (2002) for 16 out of sample 26 countries. Jensen (2006) applies the unconventional technique of fractionally integrated model to show that monetary shock does not cause a permanent change to the inflation rate. Using time series data of 17 developed economies Jensen finds inflation to be a slow, mean reverting, fractionally integrated process in all 17 countries and therefore the long-run Fisher effect cannot be tested. A survey on 15 OECD countries conducted by Beyer et al. (2009) shows that there is a break in the cointegration relation that introduces a spurious unit root that leads to a rejection of cointegration but once this break is taken into account the linear Fisher equation holds well. Herwartz and Reimers (2011) suggest the validity of the Fisher hypothesis only during the inflation targeting regime when inflation is essentially low because in the case of accelerating inflation the basic relation between interest rate and inflation breaks down. They also argue that in most cases interest rate and inflation exhibit a long-run equilibrium relationship with inflation coefficient less than unity.

This paper confirms the occurrence of the long-run Fisher effect and addresses an additional feature of the short term interest rate which is characterized by the Taylor principle. We carry out research on the basis of quarterly as well as monthly US data over the period 1957 to 2010. We find evidence of long-run Fisher effect although there is no evidence of short-run Fisherian relation between interest rate and inflation. As opposed to the Fisher relation, the post-1980 data exhibits strong response, rather than one-for-one response of the interest rate to inflation that was emphasised by Taylor (1993). This finding acts in accordance with the stylized facts of the Federal Reserve during post-Volcker regime when monetary policy turned out active. Strong response of nominal interest rate to inflation accounts for positive real rate of interest in the event of rising inflation such that monetary policy gets inflation stabilized. This clearly contrasts with the Fisher hypothesis which suggests the superneutrality of money and therefore inactive monetary policy.

The remainder of the paper is organised as follows. Next section reviews the theoretical background of the Fisher effect and Taylor principle. Section 3 illustrates data and methodology used in the analysis. Section 4 presents empirical results and section 5 summarises.

1. THEORETICAL BACKGROUND

1.1 Fisher effect

An increase in money growth leads to an equal increase in nominal rate of interest and inflation- leaving real rate of interest unchanged, which is know as Fisher effect or Fisher hypothesis.

Real rate of interest is derived from equation (2.1) below. This analysis is based on Blanchard (1999).

$$1 + r_t = \frac{1 + i_t}{1 + \pi^e} \text{..... ....} \quad (2.1)$$

Where, i_t and r_t represent nominal and real rates respectively, and π^e denotes expected inflation. Equation (2.1) follows the link equation, $1 + r_t = \frac{(1 + i_t)P_t}{P_{t+1}^e}$ and the definition of inflation $\pi^e = \frac{P_{t+1}^e - P_t}{P_t}$, where P_t and P_{t+1}^e stand for current price and expected future price respectively.

Real rate is obtained by further manipulating (2.1).

$$r_t = \frac{1 + i_t}{1 + \pi^e} - 1 = \frac{1 + i_t - 1 - \pi^e}{1 + \pi^e} = \frac{i_t - \pi^e}{1 + \pi^e} \approx i_t - \pi^e$$

$$\Rightarrow r_t = i_t - \pi^e$$

Expansion of money stock increases both i_t and π^e at the same rate, therefore r_t remains unchanged via $r_t = i_t - \pi^e$, which is the basic proviso of Fisher hypothesis.

Under rational expectation assumption, observed inflation $\pi_t = \pi^e + \varepsilon_t$, where ε_t is random disturbance term. Using this, nominal rate of interest is expressed below as a function of inflation

$$i_t = r_t + \pi_t + \eta_t \text{..... .....} \quad (2.2); \qquad (\eta_t \equiv -\varepsilon_t)$$

Equation (2.2) illustrates that change in inflation rate should be followed by equal changes in the nominal interest rates when the real interest rate is constant. The response of the nominal interest rate to inflation is termed as 'Fisher coefficient' which is suggested to be 1.

Crowder (1997) argues that tax adjusted Fisher effect should be larger then 1. If overall rate of tax is τ then the relation between after tax nominal interest and inflation turns out,

$$(1 - \tau) i_t = r_t + \pi_t + \eta_t$$

i.e., $$i_t = \frac{1}{1 - \tau} r_t + \frac{1}{1 - \tau} \pi_t + \frac{1}{1 - \tau} \eta_t$$

Fisher effect, $\frac{1}{1 - \tau} > 1$; given, $\tau < 1$

The estimable form of Fisher hypothesis is

$$i_t = b_1 + b_2\pi_t + \eta_t ..... \quad ..... \quad (2.3)$$

Impact of money supply on inflation works through the dynamic aggregate demand relation. Blanchard (1999) presents static version of AD as: $Y = Y\left(\frac{M}{P}, G, T\right)$. Here $\frac{M}{P}$ is real supply of money; G and T are fiscal components.

Ignoring fiscal role, $Y = Y\left(\frac{M}{P}\right)$

Assuming specific dynamic form of aggregate demand,

$$Y_t = \Phi\frac{M_t}{P_t} ..... \quad ..... \quad ..... \quad (2.4) \; ; \; \Phi > 0$$

Equation (2.5) describes the relation between money growth, output growth and inflation which is obtained by log-linearizing the above expression:

$$\hat{Y}_t = \hat{M}_t - \pi_t ..... \quad ..... \quad ..... \quad (2.5)$$

Where

Output growth, $\hat{Y}_t = \frac{dY_t}{Y_t}$

Money growth, $\hat{M}_t = \frac{dM_t}{M_t}$

Inflation, $\pi_t = \frac{dP_t}{P_t}$

If output growth falls below the nominal growth of money then the difference is showed up in inflation through equation (2.6).

$$\pi_t = \hat{M}_t - \hat{Y}_t ..... \quad ..... \quad ..... \quad (2.6)$$

For example, a 5% increase in money should be followed by 5% increase in output so there is no inflation, but if output growth is, say, 2% then there would be a 3% increase in inflation. Under constant inflation, expansion in money leads to lower interest rate and thus higher output growth.

Money growth and inflation have one for one correspondence, implying no change in real variables. Real variables, however, can only be influenced in the short-run whereas in the long-run real variables converge to their natural levels and policy only alters the level of prices.

In long run, expected inflation is equal to actual inflation $(\pi^e = \pi)$ and real interest rate sticks at natural rate $(r_t = r_n)$, hence $i_t = r_n + \pi_t$. Also in the long run output growth is zero, therefore inflation equals money growth, i.e., $\pi_t = \hat{M}_t$. This follows, $i_t = r_n + \hat{M}_t$, according to which a certain percent increase in money growth corresponds to an equal percent increase in nominal rate of interest that is equal to increase in inflation. Finally, the difference between nominal rate of interest and inflation- the real rate of interest remains unchanged- this is the Fisher effect.

In short run, an expansionary monetary policy reduces nominal rate but that does not stay long because given the Phillips curve relation, once output rises above natural rate, inflation starts increasing since unemployment falls below natural rate. Substantial increase in inflation, when exceeds the growth of nominal money, causes a negative real growth of money leading to an increase in nominal rate of interest. Inflation expectation remaining unchanged the real rate of interest goes up and gets back to its initial level. Finally, nominal interest rate reaches a higher level equal to the real interest rate plus the new higher rate of growth of money.

Fisher effect is most likely to appear in long run though there is literature demonstrating the validity of the effect in short run as well (see e.g. Granville & Mallick, 2004). In general, there is a link between monetary policy and stabilization. Disconnection between monetary policy and inflation stabilization may be a random occurrence. For example, during wartime the central bank has to provide huge liquidity to the government or in the event of financial instability monetary authority has to preserve the investors' interest. But there is enough evidence to infer that monetary policy transmits into inflation.

1.2 Taylor Principle

Macroeconomic stabilization requires a more than one for one response of interest rate to inflation- which is known as Taylor principle due to Taylor (1993). Complex structure of monetary policy is simplified to a large extent by this characterisation suggesting that if inflation is above target then the nominal rate of interest should be adequately increased such that the real rate of interest increases and that reduces inflation. Indeed, Taylor principle evolves from Taylor rule that was proposed by John Taylor at Carnegie Rochester Conference in 1993, described by equation 2.7 below

$$i_t^* = \bar{r} + \pi_t + \beta_\pi(\pi_t - \pi^*) + \beta_y y_t \quad .... \quad .... \quad .... \quad (2.7)$$

where i_t^* and π^* measure target rates of interest and inflation respectively; $\bar{r}$ is equilibrium real rate of interest; π_t, y_t, β_π and β_y are current period's inflation and output gap and corresponding stabilization parameters respectively.

Assuming $\bar{r} - \beta_\pi \pi^* = \alpha$ and $\beta_y = 0$, reduced form of the Taylor rule appears as $i_t^* = \alpha + (1+\beta_\pi)\pi_t$

According to the above generalization, policy only aims at inflation stabilization and does not regard output at all.
Taylor principle is reflected in the coefficient of π_t. Given positive β_π, $1+\beta_\pi > 1$ which is Taylor Principle- instructing more than one-for-one increase in nominal rate of interest in the event of rising inflation. If β_π is set equal to zero, then the nominal interest rate responds to inflation just one-for-one. Such adjustment would describe a situation where

real rate of interest is constant, therefore stationary. But if Taylor principle holds then real rate of interest would become nonstationary in the world of variable inflation.

In order to explain monetary policy transmission mechanism, Walsh (2010) uses one simple New Keynesian variety macroeconomic model comprising IS curve, Phillips curve and Taylor-type monetary policy rule.

$$y_t = E_t y_{t+1} - \phi(i_t - E_t \pi_{t+1}) \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots (IS); \qquad (\phi > 0)$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \text{(Phillips Curve)}; \ (\beta, \kappa > 0)$$

$$i_t = \delta \pi_t + v_t \ \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \text{(Policy rule)}; \qquad (\delta > 1)$$

y_t and y_{t+1} represent output gap in period t and t+1 respectively, measured as the difference between actual output and potential output. v_t represents independent and identically distributed (i.i.d.) monetary policy shocks.

One can intuitively show that in the event of inflation, sufficient increase in the nominal rate of interest according to the policy rule can lead to a fall in output via IS relation. In the New Keynesian model since output is proportional to marginal cost, a fall in output would correspond to a fall in marginal cost because of increase in labour supply and eventually a fall in inflation via the Phillips relation. In this case monetary policy is active. But one-for-one response of interest rate to inflation would turn the policy neutral. This analysis clears the fact that active monetary policy is consistent with Taylor principle whereas inactive policy with Fisher hypothesis.

2. DATA AND METHODOLOGY

We use quarterly and monthly US data over the period 1957 to 2010. Interest rate and CPI series have been retrieved online from International Financial Statistics of the International Monetary Fund (IMF). Although the study mainly focuses the results based on federal funds rate, we also look at three other measures of interest rate in the context of the US, e.g., Treasury bill rate, 3-month commercial paper rate and 10-year government bond yield rate. Annual inflation rates for each quarter and month are computed respectively as *100*(log(CPI)-log(CPI(-4)))* and *100*(log(CPI)-log(CPI(-12))).* In addition to the whole sample, we also split data into three other subsamples to capture the impact of regime change (pre- and post-Volcker era) and to track the recent deviation from rule-like policy setting (post-2001 period).

Stationarity properties have been examined by applying ADF unit root test with and without trend in the regression equation. Lag length is selected automatically on the basis of Schwarz information criterion (SIC). Two-step least squares procedure is applied to estimate the error correction model. After making sure that nominal rate and inflation are I(1), we run least square regression to estimate cointegrating relationship $i_t = b_1 + b_2 \pi_t + \eta_t$ and generate the residual series $\hat{\eta}_t = i_t - \hat{b}_1 - \hat{b}_2 \pi_t$ in order to examine the stationarity of the series as an evidence of cointegration. Lagged residual, $\hat{\eta}_{t-1} = i_{t-1} - \hat{b}_1 - \hat{b}_2 \pi_{t-1}$ is the measure of cointegrating error or disequilibrium error.

In the second step OLS approach is applied to estimate error correction model comprising two equations below:

$$\Delta i_t = \alpha_{10} + \alpha_{11} \hat{\eta}_{t-1} + \omega_i \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \ (2.8)$$

$$\Delta \pi_t = \alpha_{20} + \alpha_{21} \hat{\eta}_{t-1} + \omega_\pi \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots (2.9)$$

The model's sensible specification is constrained by nonzero value of at least one of the error correction coefficients α_{10} and α_{21}. Stability requires, $-1<\alpha_{11}\leq 0$ and $0\leq\alpha_{21}<1$. The above specification of error correction modelling is outlined from Hill et al. (2007, p. 349).

We find both the interest rate and inflation to be I(1) when the whole sample is considered. For all other subsamples either Federal funds rate or inflation or both are found stationary. Quarterly and monthly data produce identical results except for the subsample spanning the period 2001-2010. In this sample null hypothesis of unit root in federal funds rate can be rejected when quarterly data is used but the decision is altered in the case of monthly data. ADF unit root test results are summarised in Table 2.1.

Since the necessary condition for cointegration is satisfied over the entire period of 1957 to 2010, cointegration test is carried out only for this sample. Comovement of interest rate and inflation are introspectable form diagrammatic presentation. Figure 1 generates some feel that interest rate and inflation do move together, thereby hinting a potential long run relation.

Table 1. ADF Test for Interest Rate and Inflation

	Interest rate			**Inflation**		
Period	ADF $\tau-$statistic	5% critical value	decision	ADF $\tau-$statistic	5% critical value	decision
1957-2010	-2.54** ^{m} -2.75**	-3.43 ^{m} -3.42	do not reject the null of unit root	-2.23* ^{m} -3.08**	-2.88 ^{m} -3.42	do not reject the null of unit root
1957-1980	-3.15** ^{m} -2.52**	-3.46 ^{m} -3.43	do not reject the null of unit root	-4.30** ^{m} -1.21*	-3.46 ^{m} -2.87	reject the null of unit root but do not reject when data is monthly
1981-2010	-4.55** ^{m} -5.33**	-3.45 -3.43	Reject the null of unit root	-4.55** ^{m} -4.56**	3.45 ^{m} 3.42	reject the null of unit root
2001-2010	-3.38* ^{m} -2.07*	-2.94 ^{m} -2.89	Reject the null of unit root but do not reject when data is monthly	-2.58* ^{m} -1.64*	-2.94 ^{m} -2.89	do not reject the null of unit root

Source*:* authors

*ADF test includes a constant term but no trend in the test equation.

** ADF test includes a constant term as well as trend in the test equation.

^{m} indicates results on the basis of monthly observation.

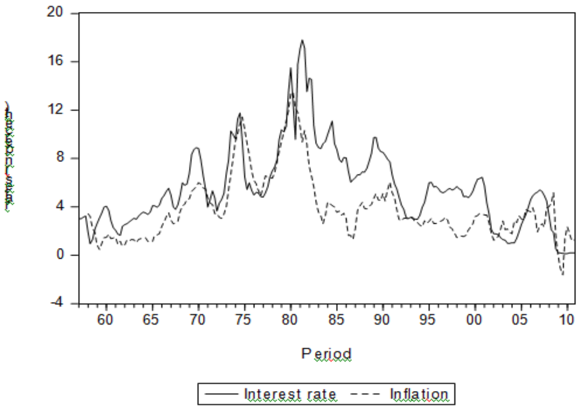

Figure 1. Interest rate and inflation over 1957-2010
Source*:* authors

Our study points to two distinct principles in terms of real interest rate. If the Fisher effect holds then the real rate of interest remains unchanged, but the Taylor principle, by definition, requires a variation in the real rate of interest so that monetary policy turns out ‘active’. Real interest rate series is created by taking the difference between nominal rate of interest and inflation. Figure 2 shows that the average real rate of interest was not too much fluctuating before 1980 but considerably varying afterwards with an apparent jump around 1980. This designates the variable attitudes of policymakers before and after 1980. Paul Volcker, when appointed chairman of the Federal Reserve in 1979, introduced the drastic change in policy behaviour by paying intense attention to inflation stabilization while disregarding other objectives. Dramatic increase in the nominal rate of interest in the early period of Volcker amounts to the corresponding increase in real rate of interest.

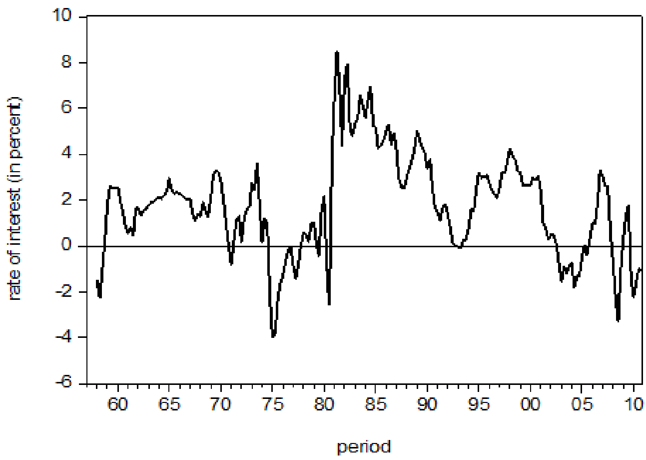

Figure 2. Real rate of interest over 1957-2010
Source*:* authors

3. EMPIRICAL RESULTS

Having examined the time series properties of the nominal rate of interest and inflation, we estimate the relation between these two variables when the nominal rate of interest is considered as the dependent variable. Estimation results are summarised in Table 2. The only supposedly reliable estimates are obtained over the sample period 1957-2010 because for this sample both interest rate and inflation series are I(1). More importantly the residuals obtained from the OLS regression are I(0), thereby evidencing a long run cointegrating relationship. The estimates obtained for the subsample over 1957-1980 may not be reliable because of the integration properties of the two series involved. While the interest rate is integrated of order 1, inflation rate is trend stationary. If the trend is not included in the ADF test regression then the inflation series becomes integrated of the same order as interest rate. For intuitive reasoning we also let the residuals undergo the test for nonstationarity and find them I(0). The estimated error correction model underlying this sample period has correct signs for both error correction coefficients though only one coefficient corresponding to change in inflation is found significant. Overall we do not come to the conclusion that interest rate and inflation in this period maintain a long-run Fisherian relationship.

Sample period 1981-2010 is more interesting to the policymakers and researchers since a significant change in policy, featured as strict inflation aversion, took place in the beginning of this period. Empirical interest comes from the fact of stationary behaviour of the interest rate as well as inflation. ADF unit root tests, on the basis of quarterly and monthly data, show that inflation and interest rates are I(0), thus the underlying regression is not spurious. However, although nonspurious but any long run relation based on cointegration is unlikely to appear since the variables are not integrated of order 1. We run OLS regression of interest rate on inflation where estimates of inflation coefficients are obtained 1.58 and 1.54 under quarterly and monthly data with standard error equal to 0.14 and 0.06 respectively. These estimates do not match with the Fisher hypothesis but deliberately match with the Taylor principle. In general, Taylor principle suggests an inflation coefficient above unity and in particular Taylor (1993) suggests a value of 1.50. From this viewpoint, our current estimates provide substantial evidence to surmise that monetary policy, after Volcker's appointment, complies with the Taylor principle.

Table 2. OLS estimates of $i_t = b_1 + b_2\pi_t + \eta_t$

Period	Quarterly				Monthly			
	$\hat{b}_1$	$\hat{b}_2$	R^2	DW	$\hat{b}_1$	$\hat{b}_2$	R^2	DW
1957-2010	1.95 (0.26)	0.95 (0.06)	0.58	0.20	1.98 (0.16)	0.95 (0.03)	0.57	0.07
1957-1980	1.91 (0.26)	0.81 (0.04)	0.79	0.56	1.93 (0.16)	0.81 (0.03)	0.76	0.20
1981-2010	0.43 (0.42)	1.59 (0.11)	0.63	0.29	0.57 (0.24)	1.54 (0.06)	0.61	0.09
2001-2010	0.55 (0.49)	0.76 (0.18)	0.32	0.29	0.70 (0.28)	0.70 (0.10)	0.29	0.07

(Numbers in parentheses indicate standard error of estimate)

Source*:* authors

Interest rate and inflation over 2001 to 2010 seem to be I(0) and I(1) respectively when quarterly frequency is used but monthly observations exhibit the existence of unit root in both series. The residuals obtained from regression are I(0) in quarterly and monthly cases, thereby predicting a possible cointegration but the worst is that none of the four error correction coefficients (two for monthly and two quarterly) is found significant. Therefore we conclude that there is no cointegrating relationship between the nominal rate of interest and inflation over this sample period. Even the estimated inflation coefficient is below unity, thus conflicting with either the Fisher hypothesis or the Taylor principle. This finding is not surprising in the view that monetary policy of the Federal Reserve in recent years do not adhere to any particular rule, rather signifies a substantial amount of discretion (see e.g., Taylor 2010). The above analysis clears that there are two sample periods producing reliable estimates that can well explain the underlying policy behaviour. The entire period between 1957 and 2010 demonstrates the possibility of the occurrence of Fisher effect and the post- 1980 period justifies the evidence of the Taylor principle, thus active monetary policy. We next estimate the error correction model for the former sample period.

(2.10) and (2.11) represent cointegrating relation under quarterly and monthly data respectively.

$$i_t = 1.95 + 0.95\pi_t + \hat{\eta}_t ; \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (2.10)$$

$$i_t^m = 1.98 + 0.95\pi_t + \hat{\eta}_t^m ; \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (2.11)$$

Since interest rate and inflation are I(1) over the period 1957 to 2010, any linear combination of them, e.g., residuals, is likely to be I(1) but in special case when both series are cointegrated then the linear combination can be I(0). We obtain residuals $\hat{\eta}_t = i_t - 1.95 - 0.95\pi_t$ and $\hat{\eta}_t^m = i_t^m - 1.98 - 0.95\pi_t$.

Null hypothesis of unit root in $\hat{\eta}_t$ can be rejected at 5% level of significance since ADF test statistics appears -3.02 when 5% critical value is -2.88. For monthly observations these values are -2.65 and -1.95 respectively. Stationary residuals predict potential cointegrating relationship. Cointegration implies that interest rate and inflation share similar stochastic trends and they never diverge too far from each other. In the present case residuals are stationary which confirms the existence of cointegration between nominal rate of interest and inflation, therefore the regression is not spurious and the estimates are super-consistent.

Cointegrating error in the previous period for quarterly observations,

$$\hat{\eta}_{t-1} = i_{t-1} - 1.95 - 0.95\pi_{t-1}$$

Error correction model (ECM)

$$\Delta i_t = \alpha_{10} + \alpha_{11}(i_{t-1} - 1.95 - 0.95\pi_{t-1}) + \omega_i \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (2.12)$$

$$\Delta \pi_t = \alpha_{20} + \alpha_{21}(i_{t-1} - 1.95 - 0.95\pi_{t-1}) + \omega_\pi \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (2.13)$$

Estimation results of the above ECM are documented in Table 3.

Table 3. Error Correction Model Estimates

Variables	Error correction coefficient estimates	R^2	DW
Δi_t	-0.07 0.03*	0.02	1.46
$\Delta \pi_t$	0.04 0.02*	0.01	1.22

*standard error of estimate

Source: authors

We obtain plausible estimates of both error correction coefficients in terms of signs and magnitudes although the one due to $\Delta \pi_t$ is insignificant.

$\hat{\alpha}_{11} = -0.07$, which is significant, implying that when $i_{t-1} > 1.95 + 0.95\pi_{t-1}$, Δi_t falls, thereby driving the system toward equilibrium relationship. Estimated value indicates a 7% adjustment in each quarter from disequilibrium toward equilibrium. Monthly estimate of this coefficient is -0.02 which is significant, predicting 2% correction in each month. Insignificant error correction coefficient of second equation suggests that $\Delta \pi_t$ does not react to the cointegrating error. This outcome questions the underlying mechanism of the Fisher effect because Fisher effect will hold only if there is corresponding changes in price that could change real growth of money in the following period. The coefficient is however significant at 10% level of significance and we expect a slow adjustment of inflation, thereby vanishing the cointegrating error in the long run. More intuitively, although not reported in the table but the error correction coefficient attributable to change in inflation, while considering monthly data, is 0.01 which is significant, thus revealing a 1% correction performed by inflation when the system is departed from equilibrium.

We got 216 quarterly observations and 648 monthly observations nevertheless they yield the same value of Fisher coefficient which is 0.95. Even then we can't certainly infer that the estimated equation represents the Fisher equation because in order to be consistent with the Fisher hypothesis, inflation coefficient should be 1 but in this particular case it is 0.95. However, the Wald test does not reject the null of this coefficient being equal to 1. This non-rejection may provide some evidence of the occurrence of the Fisher effect.

The results are robust to different measures of inflation and interest rates. We use quarterly GDP deflator inflation rate as an alternative measure of inflation that marks no changes in empirical findings. In addition to the federal funds rate, three other measures of nominal interest rates have been used, e.g. Treasury bill rate, 3-month commercial paper rate and 10-year govt bond yield rate. Figure 3 demonstrates the close connection of four different proxies of interest rate.

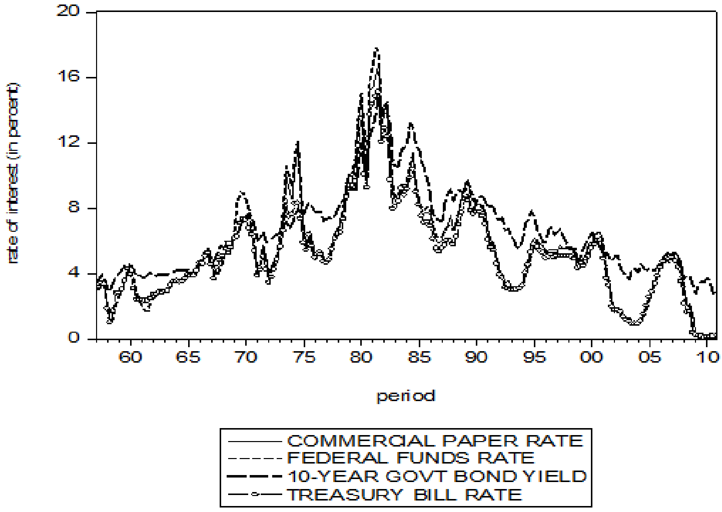

Figure 3. Different measures of interest rate in the US

All the measures of interest rate produce similar results except one distinction with regard to the stationarity property. 10-year govt bond yield rate is found I(1) over the sample 2001 to 2010 although three other measures of interest rates are stationary in this period. Since the inflation rate of this subsample is I(1), we hoped cointegration between 10-year govt bond yield rate and inflation rate but the residuals generated from the regression of 10-year govt bond yield rate on inflation are also I(1), therefore the possibility of potential cointegration is ruled out.

The sample period spanning 1981-2010 appears as a likely source of obtaining reliable least square estimates since both the nominal rate of interest and inflation of this sample are stationary, but the problem of endogeneity is prone to generating biased and inconsistent estimates. Endogeneity problem is detected by applying the technique of artificial regression recommended by Hill et al. (2007) which conforms to the Hausman test. In order to get rid of this problem, we employ the two-stage least square estimation method where four lags of interest rate and inflation are used as the instruments, making sure that there is no problem of weak or invalid instruments. Tests for endogeneity and instruments' validity are documented in Appendix. Two-stage least square (2SLS) approach produces inflation coefficient 1.76 over the period under consideration, which is lager than the OLS estimate. Monthly data also yield slightly larger estimate of inflation coefficient. We find enough evidence to argue that the post-1980 interest rate policy of the Federal Reserve coheres with the Taylor principle. The above-unity inflation coefficient evidences the nonappearance of the Fisher effect in this period, rather justifies the existence of active policy. The notions of the Fisher hypothesis and Taylor principle are essentially contrasting as the Fisher hypothesis requires unit coefficient of inflation whereas Taylor principle, by definition, implies inflation coefficient above unity.

CONCLUSION

On the basis of more than 50 years' quarterly and monthly data under the US context, the Fisher effect is revisited and the notion of Taylor principle is introduced to find an explanation why the Fisher effect probably disappears since 1980. In our study the Fisher effect, in its weaker form, occurs only if the entire sample is taken into account- weaker in the sense that the estimated Fisher coefficient falls below unity. We could not show the validity of the Fisher effect in any of three other subsamples. Full sample spanning 1957-2010 exhibits the existence of cointegrating relationship between interest rate and inflation and thus an underlying error correction model. Both the coefficients of error correcting term have plausible signs though the response of the change in inflation to previous period's disequilibrium error is less significant.

Federal behaviour takes a drastic turn around 1980 when Paul Volcker was appointed as the chairman. Interest rate jumps to a very high level during the early 80s followed by a gradual decline. Until 1980 policy seems to be inactive as the response of interest rate to inflation was not that strong to lead to a low inflation in subsequent periods. Real rate of interest is found more or less constant when the economy experienced high inflation. Post-1980 regime, on the other hand, is featured as period of active monetary policy.

Volcker period interest rate policy is found to obey the Taylor principle characterised by the inflation coefficient above unity. This special feature rules out the possibility of the existence of the Fisher effect during the post-1980 period. The Taylor principle assures that interest rate responds to inflation more than one-for-one while the Fisher hypothesis requires a one-for-one response of the nominal rate of interest to inflation so that the real the rate of interest is unchanged. We find our results robust to different measures of inflation and interest rate. Instrumental variable (IV) approach, as an alternative technique of estimation, is applied to overcome the endogeneity problem and the estimates are obtained rather more plausible. We did not however take econometric account of structural break. But without delving further into the issue, there is no reason to argue that the nonexistence of Fisher effect is due to the structural break in data because in the history of the Federal Reserve Volcker's appointment and subsequent policy revision is the unbendable example of structural break and the period in which we did not find cointegration is the Volcker-onward period when any further break is unlikely to appear. Nevertheless, further enquiry is advocated to justify our finding that at least in last three decades the Fed's policy behaviour does not correspond to the Fisher effect as this has been seemingly invalidated by the Taylor principle.

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APPENDIX

Endogeneity and Instruments' Validity

We assume eight instruments altogether, namely four lags of interest rate and four of inflation. In the first stage, inflation is regressed on a constant and eight instruments and then residual is saved from this regression.

$$\pi_t = \gamma_0 + \gamma_1\pi_{t-1} + \gamma_2\pi_{t-2} + \gamma_3\pi_{t-3} + \gamma_4\pi_{t-4} + \varpi_1 i_{t-1} + \varpi_2 i_{t-2} + \varpi_3 i_{t-3} + \varpi_4 i_{t-4} + \vartheta_t \ldots \quad (A.1)$$

OLS estimate of the above is

$$\pi_t = 0.47 + 0.92\pi_{t-1} - 0.23\pi_{t-2} + 0.06\pi_{t-3} - 0.04\pi_{t-4} + 0.24 i_{t-1} - 0.11 i_{t-2} + 0.11 i_{t-3} - 0.16 i_{t-4} + \hat{\vartheta}_t$$

Residual,

$$\hat{\vartheta}_t = \pi_t - 0.47 - 0.92\pi_{t-1} + 0.23\pi_{t-2} - 0.06\pi_{t-3} + 0.04\pi_{t-4} - 0.24 i_{t-1} + 0.11 i_{t-2} - 0.11 i_{t-3} + 0.16 i_{t-4}$$

In second stage an "artificial regression" is performed by including the residual obtained in the first stage as an additional explanatory variable. If the estimated coefficient of this artificial variable is found significant then the problem of endogeneity is confirmed.

Artificial regression

$$i_t = \beta_1 + \beta_1\pi_t + \xi\hat{\vartheta}_t + \Theta$$

OLS estimate of the artificial regression is obtained

$$\underset{(se)}{i_t} = -\underset{(0.40)}{0.14} + \underset{(0.11)}{1.76}\pi_t - \underset{(0.33)}{1.61}\hat{\vartheta}_t + \hat{\Theta}$$; (standard errors in parentheses)

Null hypothesis $H_0 : \xi = 0$ is rejected against the alternative hypothesis $H_A : \xi \neq 0$ since the computed value of *F*-statistic under Wald test is 24.35, thus the problem of endogeneity is detected.

Test for instruments' validity is rather straightforward which lies in the first stage of the approach mentioned above. Joint test for the significance of the coefficients in (A.1) is carried out.

$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \varpi_1 = \varpi_2 = \varpi_3 = \varpi_4 = 0$ against the alternative hypothesis that at least any one of these coefficients is nonzero. As a rule of thumb, it is suggested that if the *F*-test statistic takes a value less than 10, then the null is accepted and the instruments are weak. We obtain *F*-value equal to 111.73, thus soundly reject the null and rule out the possibility of having weak instruments.