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Problems Involved in Estimating Taylor Rule with US Data

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This paper briefly reviews historical background of Taylor (1993) rule and identifies key shortcomings of extant literatures while estimating the rule. Using both monthly and quarterly data for the period between 1957 and 2010, the study finds the possibility of spurious regression due to the nonstationarity of either federal funds rate or inflation or both. The paper argues that properly estimating Taylor rule may be a big concern, but the rule can describe monetary policy of US economy fairly well, therefore standard way of estimating Taylor rule should be emphasized rather than rejecting the rule.

Field of Research: Taylor Rule, US Monetary Policy.

1. Introduction

Estimating a good monetary policy reaction function with proper specification has become a subject of enormous interest among the researchers since last two decades. Although the definition of a good policy rule is largely normative, Taylor (1999), in the context of the US, describes a good monetary policy rule as one in which the interest rate responds to inflation and real output more aggressively than it did in the 1960s and 1970s, or than during the time of international gold standard, and more like the 1980s and 1990s. Whatever way a good rule is defined or formulated, a policy mistake of course has several devastating implications like price and output instability and eventual economic turbulences. It is widely accepted that well designed monetary policy can counteract macroeconomic disturbances and dampen cyclical fluctuations in prices and employment, thereby improving overall economic stability and welfare (Orpahanides, 2007).

Taylor (1993) contributed to this field with a very simple characterisation of the Federal Reserve's monetary policy. He claimed that expressing the federal funds rate as a linear function of current inflation's deviation from an inflation target and the output gap was not only a good description of previous monetary policy in the US, but also a reasonable policy recommendation (Österholm, 2003). Since its inception, Taylor rule gained tremendous currency from the researchers around the world. Enormous enthusiasm grew over the fact that, even being a hypothetical rule, time paths of Taylor's proposed interest rate almost overlapped with actual federal funds rate during the period 1987-92. Whilst the Taylor rule has reached widespread fame and popularity, versions of it have been used in empirical studies without paying much attention to the time series properties of the included variables and properties of the estimated models. Such objections might have translated into suspicions of misspecification of the rule. Shift in regime is another important issue that has to be addressed while using Taylor rule as a

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policy guidepost. For example, the estimated Taylor rule with US data for entire period is substantially different from those estimated for pre-Volcker and Volcker periods. This paper takes into account the issues mentioned and finds the standard way of estimating Taylor rule that could be representative for the United States. Section II of the paper briefly discusses few other monetary policy rules that use quantity of money or price of money as the policy instrument, section III is about the Taylor rule and transmission mechanism, section IV documents the shortcomings of extant literature while empirically deals with Taylor rule, section V depicts data and methodology, section VI is about econometric findings and sections VII concludes.

2. Monetary Policy Rules

J B Taylor (1998) defines monetary policy rule as a description- expressed algebraically, numerically, graphically- of how the instruments of policy, such as the monetary base or the federal funds rate, change in response to economic variables. Svensson (1998) defines monetary policy rule as a prescribed guide for monetary policy conduct. A good variety of monetary policy rules has been proposed over time. One important difficulty with these proposals, however, is that in some cases the concepts involved are not under the control of the central bank and thus the proposals are not operational (Orphanides, 2007). A policy rule should have a clear choice of policy instrument such that the rule is practical, simple and transparent to communicate, implement and verify. Policy instrument could be either quantity of money (*M*) or price of money- short term interest rate (*i*).

2.1 Friedman’s K-Percent Rule

The simplest variant of monetary policy rule is Milton Friedman’s *k*-percent rule.

$$MV = PY \quad \text{....} \quad \text{....} \quad \text{....} \quad (A.1)$$

Where *M, V, P* and *Y* stand for stock of money, velocity of money, price level and real output respectively.

In logarithmic form, $m + v = p + y$

$$\Delta m + \Delta v = \pi + \Delta y \quad \ldots \ldots \ldots \; (A.2)\,; \qquad \text{where, } \pi \equiv \Delta p$$

$$\Delta m = \pi^* + \Delta y^* - \Delta v^* \quad \ldots \ldots \ldots \; (A.3)$$

Selecting the constant growth of money, *k*, to correspond to the sum of a desired inflation target, π^*, and the economy’s potential growth rate, Δy^*, and adjusting for any secular trend in the velocity of money, Δv^*, suggest a simple rule (*A.3*) that can achieve, on average, the desired inflation target π^*. This money growth targeting rule stabilizes inflation and output provided that the velocity of money were fairly stable. Key advantage of constant money growth rule is that the implementation of this rule requires very little information. If velocity remains unchanged then the only required element to calibrate the rule is the economy’s natural growth of output. Another advantage is the robustness of the rule to different models. The rule does not rest on the specification of any particular model therefore robust to model misspecification.

Friedman's rule can be linked to McCallum rule. Nominal income growth (Δx) is the sum of inflation (π) and real output growth (Δy),

i.e., $\Delta x = \pi + \Delta y$, $\Rightarrow \Delta x^{*} = \pi^{*} + \Delta y^{*}$ ... ... $(A.4)$.
(A.3) and (A.4) together relate money growth to nominal income growth. $\Delta m = \Delta x^{*} - \Delta v^{*}$ ... ... $(A.5)$

2.2 McCallum Rule

McCallum (1988) rule is augmented Friedman's constant growth rule that incorporates deviation of nominal income growth from steady state as an additional determinant of money growth.

$$\Delta m = \Delta x^{*} - \Delta v^{*} - \phi_{\Delta x}(\Delta x - \Delta x^{*}) \text{ ... ... } (B.1)$$

McCallum showed that if a rule such as $B.1$ (for example with $\phi_{\Delta x} = 0.5$) had been followed, the performance of the US economy likely would have been considerably better than actual performance, especially during the 1930s and 1970s (Orphanides, 2007).

Monetary aggregate is policy instrument in both Friedman's constant money growth rule and McCallum's rule but several factors complicate the use of money stock as a policy instrument. One factor is attributable to the instability of demand for money due to temporary disturbances or due to persistent changes resulting from financial innovation. Besides, monetary aggregate as a policy instrument is gradually losing attraction because of its definitional vagueness. In principle, a good policy rule should dictate the behaviour of a variable that the monetary authority can control directly and accurately but the choice of monetary aggregate like M1 may weaken the rule as M1 itself is not controllable (see Orphanides, 2007). As opposed to quantity of money, price of money i.e., short term interest rate as a policy instrument is gaining popularity among the central bankers.

2.3 Wicksell's Rule

Interest rate based monetary policy rule was first proposed by Wickshell (1898). Wicksell argues that theoretically price stability would be obtained if interest rate is set equal to natural rate. But natural rate is unobservable hence Wickshell suggested a rather realistic rule, "If prices rise, the rate of interest is to be raised; and if prices fall, the rate of interest is to be lowered; and he rate of interest is henceforth to be maintained at its new level until a further movement in prices calls for a further change in one direction or the other" (Wicksell, 1898, p. 189).

Notationally,

$$\Delta i = \theta\pi \;\ldots\ldots\ldots\; (C.1)$$

Wickshell's rule was simple but it only takes account of price stability, does not regard real economic activity therefore did not attract much attention in policy discussions. Taylor (1993) rule is an interest rate rule that incorporates both price stabilization and real economic activity. Next section provides a brief detail of Taylor rule and its evolution.

3. Taylor Rule

Taylor rule is a linear algebraic rule described by equation (1.1) below that specifies how the Federal Reserve must adjust its funds rate following deviations of inflation and output from targets.

$$i_t = \bar{r} + \pi_t + \beta_\pi(\pi - \pi^*) + \beta_y y_t \;\;\ldots.\;\ldots.\;\ldots.\;\; (1.1)$$

Where,

i_t : nominal rate of interest

$\bar{r}$: long run equilibrium real rate of interest,

π_t: rate of GDP-deflator-inflation over the previous four quarters,

π^*: target rate of inflation and

y_t: percentage deviation of real output from potential (target) output.

Taylor rule recommends a target for the level of nominal interest rate (i_t) that depends on four factors. First factor is the equilibrium real interest rate $(\bar{r})$. Second factor is the current inflation rate (π_t). When added together these two factors provide a benchmark recommendation for the nominal interest rate that would keep inflation at its current rate, provided the economy is operating at its potential. Third factor is inflation gap adjustment factor based on the gap between the inflation rate and a given target rate of inflation. This factor recommends raising the interest rate above the benchmark if inflation is above the target and lowering the interest rate below benchmark if inflation is below the target. Fourth factor is an output gap adjustment factor based on the gap between real GDP and potential GDP. This factor recommends raising interest rate above the benchmark if the gap is positive and lowering interest rate below the benchmark if the gap is negative. The third and fourth factors summarise two objectives of monetary policy- targeting stable rate of inflation while promoting maximum sustainable growth. These adjustment factors can also be seen as incorporating both long-run and short-run goals. The inflation gap adjustment factor incorporates the central bank's long-run inflation goal. The output gap adjustment factor incorporates the view that in the short-run policy should lean against cyclical winds (Kozicki, 1999).

The use of the equilibrium real rate in the Taylor rule emphasises that real rates play a central role in formulating monetary policy. Although the nominal interest rate is identified as the instrument that policymakers adjust, the real interest rate is what affects real economic activity. In particular, the rules clarify that real interest rates will be increased above equilibrium when inflation is above target or output is above its potential.

Taylor (1993) sets both the long run equilibrium real interest rate and the target inflation rate equal to 2, and β_π are β_y set equal to 0.5. Using these values, equation (1) can be rewritten as,

$i_t = 1 + 1.5\pi_t + 0.5y_t$ .... (1.2), it follows that $\frac{\partial i_t}{\partial \pi_t} = 1.5 > 1$. This indicates a one percent increase in inflation rate results in more than one percent increase in nominal rate of interest and vice versa. This is termed as Taylor's principle instructing that central bank should react more than 1-1 to inflation in order to lower the current inflationary pressure. The mechanism is straightforward. If nominal rate of interest is increased more than one percent following a one percent increase in inflation, real rate of interest will rise and demand will fall that will eventually dampen inflationary pressure. Equation (1.2) also signifies that if both inflation rate and real GDP are on target then Federal Funds rate would be 4% or 2% in real term. By linking interest rate decision to inflation and economic activity, Taylor rules offered a convenient tool for studying monetary policy while abstracting from a detailed analysis of demand and supply of money (Orphanides, 2007).

4. Empirical Shortcomings

Estimable form of Taylor rule (2) is obtained by manipulating equation (1.1).

$$i_t = \beta_1 + \beta_2\pi_t + \beta_3 y_t \quad \text{.... ....} \quad (2)$$

$$\text{where, } \beta_1 \equiv \bar{r} - \beta_\pi \pi^*, \beta_2 \equiv 1 + \beta_\pi \text{ and } \beta_3 \equiv \beta_y$$

A large number of papers have estimated Taylor rule with above specification. But proper attention is not paid on time series properties of the variables in question. For example interest rate and inflation are most likely to be I(1) whereas output gap is I(0). The mixture of stationary and nonstationary variables in regression process involves high possibility of spurious results. Although there is no substantial consensus in this, for example, Sims, Stock and Watson (1990) argue that nonstationarity of variables in Taylor rule does not create much problems. As opposed to this, Clements and Hendry (1993), Hendry (1995), view that omission of a possible cointegrating relationship leads to a misspecification with potential error in forecasting. This point was also raised by Granger (2004) in his Nobel Lecture of Time Series Analysis.

Siklos and Wohar (2004) indentified some key concerns in estimation process of Taylor rule. These factors have been addressed earlier by Granger as well.

First, Taylor-type rules are frequently modified by incorporating interest rate smoothing term. This gains support from the behaviour of central banks who often prefer a smooth path of interest rate. Sack and Wieland (2000) argue that interest rate smoothing may be deliberate or just the result of monetary policy reacting to persistent macroeconomic conditions. Empirical estimates of Taylor rules find high and significant inertia. Influential papers of Dueher and Rasche (2004), Goodhart (1999), Sack (1998), Sack and Wieland (2000), Collins and Siklos (2000) investigated the theoretical and practical reasons of central bank's action of interest rate smoothing.

Secondly, although there is uncertainty regarding the constancy of real rate of interest nevertheless real rate of interest, as a convention, is measured as the difference between average nominal rate and average inflation rate. Target rate of inflation π^* can then be derived from estimation results by using the identity $\beta_1 \equiv \bar{r} - \beta_\pi \pi^*$; or assuming some target inflation rate, real rate of interest can be calculated from the same identity. Whatever way real interest rate is computed there is a near consensus that real rate is time dependent. More importantly, structural shift in real rate corresponds to structural breaks in inflation rate. Siklos and Granger (1997), Siklos and Wohar (2004) argue, since real interest rate variable incorporates one or more possible cointegrating relationships, the existence of an error correction term in Taylor rule equation is most likely to hold. They further argue, given well documented shifts in monetary policy, it is conceivable that a cointegrating relationship may be turned on, or off, in a regime sensitive manner.

Third, Interest rate reaction estimation is not robust to different measures of inflation. Taylor (1993) proposed GDP deflator inflation over the previous four quarters as the argument of policy rule. In subsequent time, authors used other measures of inflation like CPI inflation, core CPI inflation, CPI less food and energy and private sector forecast inflation. Even when a particular index is chosen, there are more choices to make- annual or quarterly; if annual, then whether average of quarterly numbers or a growth rate over the 4 quarters (Carare and Tchaidze, 2004). Even though the differences between these various calculations could be minimal in a case of low and stable inflation, extant literatures experimented the rule with variety of inflation measures noticing a substantial variation in estimated policy parameters.

Fourth, lack of consensus regarding output gap measurement in Taylor rule is a key issue to be addressed. Taylor in his original paper proposed the computation of potential output by putting a time trend to real GDP. Among others, McCallum and Nelson (1999) and Woodford (2001) dissented with the use of time trends as estimates of potential output. They mentioned dual reasons: first, the resulting output gap estimates might be overly sensitive to the chosen sample; second, de-trending ignores the potential impact of permanent shocks on output (Siklos and Wohar, 2004). Judd and Rudebusch (1998) and Clarida,Gali and Gertler (2000) measured potential output using the Congressional Budget Office's (CBO) estimates and by fitting a segmented trend and quadratic trend to real GDP. Majority papers estimate potential output by applying Hodrick-Prescott (HP) filter when quite few uses band-pass filter. Kozicki (1999) finds that Taylor's proposed target interest rate is not robust to different measures of potential output and thus output gap.

Fifth, Several authors criticise Taylor rule as being backward looking because Taylor recommended an interest rate that is determined by contemporaneous inflation and output gap. Contemporaneous setting requires the central bank should know the current quarter values of real GDP and the price index when setting the federal funds rates for that quarter but in practice the Federal Reserve gets provisional data on real GDP one month after the end of the quarter and final data after three months. Because of persistence of both inflation and output gap, such timing difference, however, does not involve much policy implications as researched by Levin, Wieland and Williams (1999), McCallum and Nelson (1999) and Rudebusch and Svensson (1999). Moreover, Taylor (1993) cleared the argument stating that ".. the interest-rate policy rule written in "real" terms with the lagged inflation rate serving as a proxy for expected inflation". Still, proponents of forward looking models, for example Clarida, Gali and Gertler (1998, 2000), Orphanides (2001), and Svenssson (2003), find it more powerful to replace current inflation and output gap by their respective *t*-period ahead's values. Forward-looking model is advocated due mainly to the presence of lags in the monetary transmission mechanism. However, Rudebusch and Svensson (1999), Levin, Wieland, and Williams (2003), and Orphanides and Williams (2007) investigate the optimal choice of lead structure in the policy rule in various models and do not find a significant benefit from responding to expectations out further than one year for inflation or beyond current quarter for output gap. Indeed, Levin, Wieland, and Williams (2003) show that rules that respond to inflation forecasts further into the future are prone to generating indeterminacy in rational expectations model (see Taylor and Williams, 2010).

Lack of consensus regarding econometric techniques surrounding Taylor rule is also a leading concern. Backward looking rules are estimated by using OLS and forward looking models by GMM. Several econometric problems have been detected by Carare and Tchaidze (2004).

1. Regressing interest rate on inflation and output gap may produce some result that may not be the Taylor Rule, rather it may be the reflection of something else- a long term relationship between nominal interest rate, inflation and output gap. For example, Minford et al (2002) demonstrate that a Friedman type money supply policy rule is mathematically non-distinguishable from a Taylor rule.
2. Dealing with high serial correlation of the variables in Taylor Rule is another big econometric question. Past work on this does not seem to address this issue with proper attention. Most common is to estimate the rules with OLS or GMM using Newey-West HAC estimators, and instrumental variables for the forward looking rules. What is worth noting is that while papers estimating Taylor rules commonly treat interest rates as stationary but, as mentioned earlier, it is highly likely to be nonstationary. King and Kurmann (2002), Hendry and starr (1993) found US interest rates stationary in first differences, therefore nonstationary in levels. Of course, there are papers with empirical finding of stationary interest rate series. Structural break in interest rate series indeed gives rise to the unit root property. However, there is economic reason that cointegration exists between variables in

Taylor rule. For example, real interest rate in the Taylor rule reflects the Fisher equation relating the nominal interest rate to expected inflation, and these two series may be statistically attracted to each other in the long-run if real interest rates are believed to be stationary (Carare and Tchaidze, 2004). Besides, the inflation and output gap variables in Taylor rule capture the trade-off between inflation and output variability and there are sound arguments to expect that an underlying relationship exists between these two variables. Granger and Newbold (1974) document that if variables are found not be cointegrated then regression in levels will be spurious.

3. Estimates based on the simple rule may not be always reliable and they are not robust to difference in assumptions of estimators. Jondeau et al (2003) show that over the baseline period 1979-2000 alternative estimates of the Federal Reserve reaction function using several GMM estimators and a maximum likelihood estimator yield substantially different parameter estimates. Carare and Tchaidze (2004) document that estimation results may also not be robust with respect to sample, to different set of instrumental variables or order of lags. This difference may be the result of misspecification of the model or of the moment conditions.
4. Policy recommendation based on small sample estimation is not advisable. Special care should be taken in the context of the countries that have a short period of stable data. Alternative use of long sample usually underlies regime shift hence shifts in parameters. For example, estimated coefficients of Taylor rule are significantly different under pre-Volcker and Volcker chairmanship in the Federal Reserve.
5. Few papers looked into the difference between policy parameters obtained with real data and ex-post revised data. Empirical evidence is that real time policy recommendations differ considerably from those obtained with ex post revised data and that estimated policy reaction functions based on ex post revised data provide misleading descriptions of historical policy and obscure the behaviour suggested by information available to the Federal Reserve in real time.

5. Data and Methodology

Quarterly and monthly US data on Federal Funds rate, GDP at 2005 prices, industrial production, CPI (all items) and GDP deflator for the period between 1957 and 2010 have been collected from IFS online source which is available at http://www.imfstatistics.org/imf/*. All series have been seasonally adjusted by applying moving average methods.

Output gap, $y = (\hat{y} - y^*) \times 100$; where, $\hat{y} = \log(real\,GDP)$ and y^* stands for potential output that is obtained by taking Hodrick-Prescott (HP) filter of $\hat{y}$. To examine robustness one more measure of output gap is computed by using industrial production series. Extant literature utilizes latter measure of output gap but Taylor (1993) recommended real GDP instead of industrial production while computing output gap. We find substantial difference in estimation results under alternative measures of output gap. Potential output, however, is unobservable and there is no consensus which measure should be

* Access requires personal user ID and password.

representative. Taylor termed this as trend real GDP which equals 2.2 percent per year from 1984:Q1 to 1992:Q3. In this study we have a long sample hence without restricting at 2.2 percent we use HP trend as the measure of potential output, y^*.

Annual inflation rates for each quarter and month are computed by taking percent log difference of CPI and GDP deflator: i.e., $100 \times (\ln(CPI) - \ln(CPI(-k)))$ and $100 \times (\ln(GDP\,deflator) - \ln(GDP\,deflator(-k)));\ k = 4\,and\ 12$ for quarterly and monthly measurements respectively. Taylor (1993) suggested to take account of the rate of inflation over the previous four quarters, i.e., $\frac{1}{4}\sum_{j=0}^{3}\pi_{t-j}$ where, $\pi_t = 400(\ln(GDP\,deflator) - \ln(GDP\,deflator(-1)))$. These two measures of quarterly inflation have same results and do not affect estimation outcome. What really matters is that CPI inflation and GDP deflator inflation have different repercussion on Taylor rule estimation.

We perform unit root tests on federal funds rate, inflation and output gap. Augmented Dickey Fuller test is used with or without constant and trend. Unit root test is run for the whole sample and each subsample.

In the first instance Taylor rule is estimated for the whole period by applying OLS. In order to address the variable attitudes of different Chairmen at Federal Reserve Taylor rule is then estimated under different chairmanship. Policy response coefficients get significantly larger values under Volcker period who was strict-inflation-averse. We also replicate the work of Clarida, Gali and Gertler (2000) who estimated Taylor rule for the periods 1960-1979 and 1979-1998 by using generalized methods of moments (GMM). The paper also investigates the results of Hetzel (2000) and Orphanides (2001) by estimating Taylor rule for 1965-1979, 1979-1987 and 1987-1992. For every sample we perform unit root test for each series and attempt to identify the best sample period having stationary interest rate, inflation and output gap that could likely generate nonspurious regression outcome. Following Siklos and Wohar (2004) we rely exclusively on OLS estimation since these are adequate for bringing out the types of econometric problems relevant to the understanding of Taylor rules.

6. Empirical Findings

Figure 1 shows the existence of structural break in the dynamics of interest rate and inflation. It is evident that inflation rates deliberately increase until 1980 and decrease onward which gives rise to the fact of shifting means that makes the series nonstationary.

Figure 1: Federal funds rate, inflation and output gap dynamics during 1957-2010

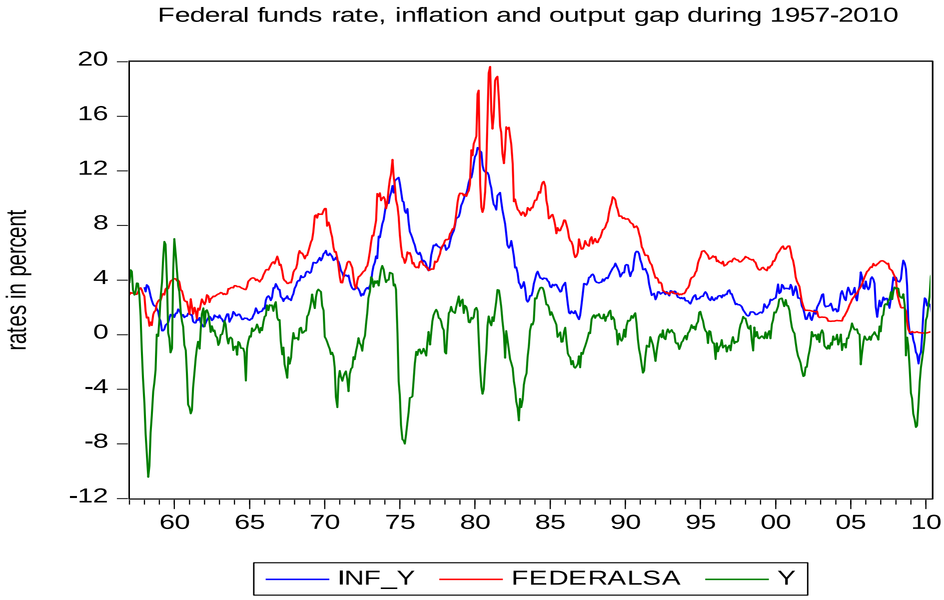

Figure 2: Federal funds rate, inflation and output gap dynamics during 1957-1980

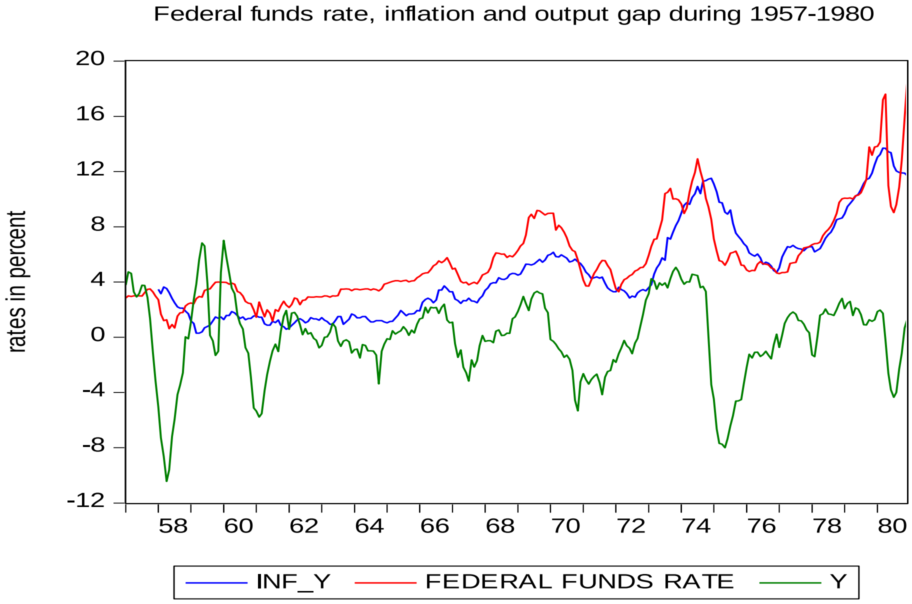

Figure 3: Federal funds rate, inflation and output gap dynamics during 1981-2003

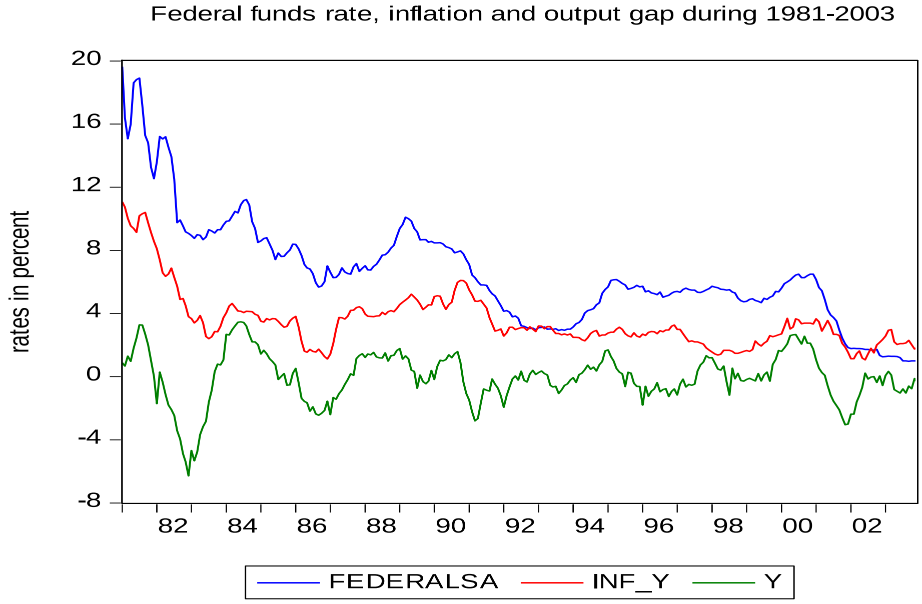

Figure 4: Federal funds rate, inflation and output gap dynamics during 1987-1992

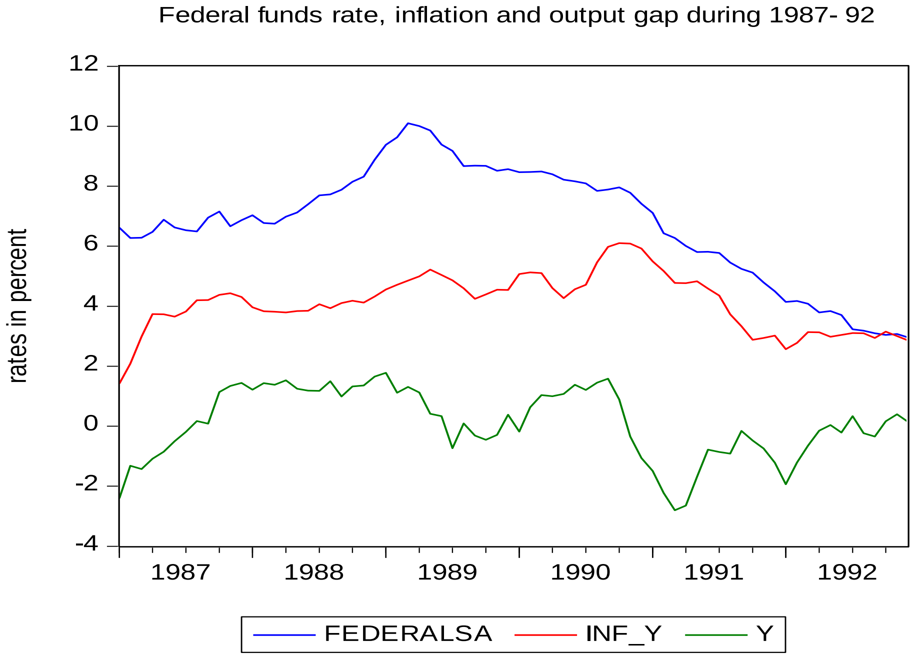

Table-1: Unit root test for different series

Period	Probability values for ADF *t*-statistic		
	federal funds rate	inflation	output gap
1957M1-2010M6	0.09	0.13	0.00
1957M1-1980M12	0.87	0.03	0.00
1981M01-2003M12	0.01	0.00	0.00
1987M01-1992M12	0.17	0.02	0.03
2003M01-2010M12	0.40	0.02	0.03

Table-1 shows that only for 1981-2003 federal funds rate, inflation and output gap are stationary. We accept this sample as ideal for estimation purpose. For other samples, either federal funds rate, or inflation or both are nonstationary.

Table- 2: Estimates of Taylor rule. (numbers in parentheses represent p-values of corresponding *t*-statistics)

Year	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	Method	R^2	*D-W* stat
1958M1-2010M6	2.15	0.91	0.28	OLS	0.60	0.08
	(0.00)	(0.00)	(0.00)			
1958Q1-2010Q2	2.19	0.90	0.22	OLS	0.61	0.19
	(0.00)	(0.00)	0.03			
1958M1-1980M12	1.99	0.80	0.36	OLS	0.87	0.35
	(0.00)	(0.00)	(0.00)			
1960Q1-1979Q4	2.48	0.70	0.63	OLS	0.84	0.69
	(0.00)	(0.00)	(0.00)			
	2.58	0.63	0.76	GMM	0.83	0.71
	(0.00)	(0.00)	(0.00)			
1965M01-1979M12	2.75	0.66	0.40	OLS	0.84	0.27
	(0.00)	(0.00)	(0.00)			
1965Q1-1979Q4	2.58	0.67	0.29	OLS	0.85	0.67
	(0.00)	(0.00)	(0.00)			
1965Q1-1987Q2	3.83	0.71	0.14	OLS	0.46	0.22
	(0.00)	(0.00)	(0.31)			
1979M01-1987M12	6.56	0.64	0.29	OLS	0.56	0.22
	(0.00)	(0.00)	(0.13)			
1979Q1-1987Q4	6.07	0.71	-0.01	OLS	0.58	0.67
	(0.00)	(0.00)	(0.54)			
1979Q1-1998Q4	3.64	0.92	0.02	OLS	0.63	0.30
	(0.00)	(0.00)	(0.92)			
1981M01-2003M12	1.12	1.56	0.09	OLS	0.71	0.10
	(0.04)	(0.00)	(0.62)			
1981Q1-2003Q4	1.11	1.57	0.18	OLS	0.71	0.27
	(0.08)	(0.00)	(0.39)			
1987M01-1999M12	2.56	0.99	0.45	OLS	0.49	0.09
	(0.00)	(0.00)	(0.00)			
1987Q1-1999Q4	2.43	1.00	0.54	OLS	0.72	0.37
	(0.00)	(0.00)	(0.00)			
1987M01-1992M12	1.70	1.23	0.42	OLS	0.52	0.13
	(0.32)	(0.00)	(0.03)			
	2.87	1.02	-1.38	IV	0.48	0.23
	(0.00)	(0.00)	(0.00)			
	1.88	1.17	0.44	GMM	0.52	0.12
	(0.24)	(0.00)	(0.01)			
2003M01-2010M06	1.16	0.49	0.12	OLS	0.26	0.04
	(0.13)	(0.06)	(0.51)			

Table- 2 summarizes estimation results for different periods starting from 1957 to second quarter of 2010. There are few observations worth noting. First, Estimation results do not vary with data frequency being either monthly or quarterly. Second, monetary policy for the entire period cannot be described by the Taylor rule because estimated inflation coefficient is smaller than 1 but both the estimates of inflation and output gap coefficients are statistically significant. This finding is not impractical because pre-Volcker period monetary policy rarely cared inflation stabilization. Third, estimates of response coefficients get larger and significant over time. For example, until 1987 the estimates of inflation coefficient and output gap coefficients were 0.71 and 0.14 whereas during 1987-1999 these are 1.23 and 0.42 respectively. This finding is consistent with Hetzel (2000) who observed an increase in response coefficients over time. However, there is one conflicting result with Hetzel who found increase in response coefficients over 1965-1979, 1979-1987 and 1987-1999 but our estimates of response coefficients do not increase over the first two sample periods although they increase over 1965-1987 and 1987-1999. Fourth, estimation results are compatible with the superiority of forward looking version of the rule. Both OLS and GMM estimates for the period 1987-1992 are plausible which act in accordance with the findings of Orphanides (2001) who examined the merits of forward lookingness in policy rule. GMM estimate of inflation response is larger than unity thus capable of fighting inflation, and output gap coefficient is 0.44 which is very close to Taylor's proposed value. Fifth, our findings support the research of Clarida, Gali and Gertler (2000) who find considerable differences in two different samples 1960-1979 and 1979-1998. Sixth observation is about time series property of different series. Among different subsamples in Table-2 one or more series are found nonstationary hence a mixture of I(0) and I(1) series questions the reliability of above results. But, all three series are found I(0) during 1981-2003 and R^2 is also fairly large, therefore results of this period can be representative. Estimate of inflation coefficient for this period is above unity, capable of fighting inflation. Although inflation coefficient estimate abides be Taylor's principle but output gap coefficient is far below the one recommended by Taylor. This may be due to policymaker's attention to too much caring inflation disregarding output during post Great Inflation period. Finally, we find the worst estimates during 2003-2010 when both inflation and output gap coefficients get insignificant with a very low R^2. This deviation of the Federal Reserve from commitment may be due to the fact that, recently they focused rather on fiscal affairs which in fact generated several economic turmoil including the Great Recession.

7. Conclusion

The paper views that extant literatures are less careful in addressing the background issues related to estimating Taylor rule. It has become a convention to measure inflation and output gap by using CPI and industrial production but Taylor (1993) proposed GDP deflator inflation and real GDP gap instead. We find evidence that estimates of response coefficients in Taylor rule significantly vary with these measurements. Our study is also critical to the reluctance of past studies toward time series properties of variables in Taylor rule. To address this problem we split data into ten different subsamples and perform unit root test for each. Almost in all cases either federal funds rate or inflation or both are found nonstationary while output gap is stationary. Combination of stationary and nonstationary series questions the reliability of past results. Because of such unreliability Christensen and Nielsen (2003) reject the traditional Taylor rule as a representation of US monetary policy in favour of an alternative stable long run cointegrating relationship between the federal funds rate, the unemployment rate and long run interest rate over the period 1988-2002 though Österholm (2003) does not find the existence of cointegration.

This paper also finds at least one sample period 1981-2003 where federal funds rate, inflation and output gap are stationary. Regression outcome from this sample is also representative with high value of R^2 and inflation coefficient above unity. Our empirical estimates further reflect that in recent times Federal Reserve has deviated from commitment, monetary policy got accommodative and output gap coefficient became insignificant. Although it cannot be confirmed without further research but we suspect, the Great Recession after 2007 took place due to the Great Deviation from rule that is recently addressed by Taylor (2010b).

There is no strong argument why Taylor rule cannot describe monetary policy of a well-organised economy with developed financial market like the US. What is needed is to develop the standard way of estimating Taylor rule by taking proper account of time series properties. Most common is to suggest differencing the I(1) series that indeed solves the problem of nonstationarity but at the same time collapses implications of Taylor rule. De-meaning data may be an alternative solution to above problem.

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