Estimating Taylor Rules in a Real Time Setting

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ABSTRACT

This paper demonstrates how the use of revised data distorts our understanding of past monetary policy decisions. Three problems are addressed – the use of (i) contemporaneous rather than lagged data, (ii) revised rather than unrevised data; and (iii) leads of data, unavailable at the time of policy setting, for estimating potential output.

In order to evaluate each of these distortions separately, I have estimated Taylor rules using different sets of estimates of output gap and inflation for three sub-samples, corresponding to chairmanship terms of Arthur Burns, Paul Volcker, and Alan Greenspan. Three series of estimates are constructed – series based on revised estimates of data for the whole post-war sample; series based on truncated (excluding leads) subsamples of revised data; and series, similar to the previous one, but based on unrevised data.

Although using revised data may produce significantly misleading conclusions, the inclusion of leads of the data when estimating the potential level of the economy has a much bigger impact, producing coefficients which may have a value less than half of the true one. At the same time, the use of contemporaneous rather than lagged data does not seem to have a big effect on the final results.

Among other things, I demonstrate that the U.S. monetary policy was less active during Burns' chairmanship, and much more anti-inflationary during Greenspan's, than traditional analysis would suggest.

Keywords: Monetary policy, Taylor rule, real time data.

JEL classification: E52, E58.

1 Introduction

Since the publication of John Taylor's article in 1993, monetary rules and topics related to the conduct of monetary policy have been the subject of enormous interest, both for academicians and policy makers. Special attention has been given to simple monetary rules, which are attractive primarily because of their transparency and supposed efficiency.

While finding an optimal policy remains paramount, the analysis of past monetary policy has also been the focus of a substantial part of the economic literature. What is very common in this kind of research, however, is the employment of highly unrealistic assumptions about data availability.

Three problems stand out – (i) the employment of contemporaneous rather than lagged variables as indicators of a state of an economy; (ii) the use of cleaned up, revised data; and finally, (iii) a reliance on data which were not available at the moment of policy designing. The first ignores the so called "information lag", while the last two add (or in fact, subtract) substantial noise to (from) the fundamentals.

Overall, as Orphanides (1998b) states, a disregard of these issues leads to wrong conclusions about past policies and may also result in an incorrect design of future ones, since the evaluation of alternative policies is distorted by the use of an incorrect information set.

Several authors have recently attempted to recreate the environment within which policy design had been happening. Croushore and Stark (1999) have compiled a real-time data set for the variables as they were known at each point in time in the past, and have shown that, in some cases, different vintages of data lead to different empirical results. Faust et al. (2000) have looked at real time and ex-post estimates of output growth for G7 countries, and have found a systematic statistically significant bias in preliminary estimates.

A series of papers by Athansios Orphanides (1998a, 1998b, 2000a, 2000b) has examined the Taylor rules based on unrevised data for output gap and inflation, as well as on forecasts for these variables, available at the moment of policy design. He demonstrated that policy recommendations in real time are quite different, and, in particular, showed that what is claimed by Clarida et al. (1997) and Taylor (1999) to be an inappropriate monetary policy by the Fed during the 1970s, might rather be considered as appropriate, albeit based on incorrect, systematically underestimated output gap numbers.

This paper goes beyond by looking at each of the above mentioned distortions separately, in an attempt to provide some quantitative characterizations. I estimate 4 different specifications of the Taylor rule, starting with the most common and, in fact, the least proper one, and proceeding through the next three, arriving at the most appropriate one.

The very first specification (the least proper one) links the instrument variable to the contemporaneous target ones (which have not been realized yet at the moment of making a decision); bases the gap estimates on the whole dataset for output (both lags and leads included); and uses revised estimates (taking into account information which was not available).

The second specification uses more appropriate gap estimates, which are based on *lags only*, thus excluding leads of the data during computations. While the second specification links the instrument variable to contemporaneous estimates of targets, the third specification uses *lagged* estimates.

Finally, the fourth specification (the most appropriate one) continues to use lagged "lags only" gap estimates, but takes a step further towards reality by basing estimates on *unrevised* data.

Following Judd and Rudebusch (1998), I analyze three time periods: 1970.1 – 1978.1, 1979.3 – 1987.2 and 1987.3 – 1994.4, which correspond to the chairmanships of Arthur Burns, Paul Volcker and Alan Greenspan respectively[1].

My analysis suggests that the use of "leads and lags" gap estimates in place of "lags only" ones distorts the results the most, while the use of contemporaneous instead of lagged variables the least. As to characterizing the related monetary policy, my results are in line with the conclusions drawn by Clarida et al. (1997) and Taylor (1999), which indicate that monetary policy was more passive during the 1970s. Also, as opposed to traditional analysis, my estimates suggest a much more anti-inflationary policy during Greenspan's chairmanship term.

The rest of the paper contains six sections. Section 2 provides an overview of the Taylor rule. Sections 3, 4 and 5 examine each of the "steps", and Section 6 provides an overview of the results.

[1]Similar to Lansing (2000), I stop the sample in 1994:4 in order to exclude the influence of the new-economy shifts in the trend on the monetary policy.

2 Overview of the Taylor Rule

Taylor (1993) proposed a simple formula, which, as it turned out, very closely approximated the actual path of the quarterly Federal Funds Rate during the 1987.1 – 1992.3 period:

$$i = 1 + 1.5\,\pi + \ 0.5\,y,$$

where the annual inflation π is measured by the growth rate of the GDP deflator, and y is the percentage difference between actual and potential outputs, with potential output being approximated by a log-linear trend of real GDP over the 1984.1 – 1992.3 period.

This particular rule (both its functional form and a particular set of coefficients) originated from research conducted at the Fed in the early 90s (see Bryant et al. 1993). Its main advantage is that, in a wide variety of macroeconomic models, it performs as well as other more sophisticated ”medicines” which take into account a broader set of indicators. That is a very important and desirable feature for a policy rule, as a unique consensus amongst economists about the best way to describe an economy is still absent.

The rule captures the main essence of monetary policy – adjustment of an instrument (an overnight interest rate) every time the target variables – inflation and/or output – deviate from their respective long-run (equilibrium, target) levels. Adjusting interest rates with respect to movements in inflation reflects the long-run goal of monetary policy (a stable and low inflation rate), while adjusting interest rates with respect to movements in output gap reflects an anti-cyclical short-run objective (”leaning against the wind”). It also represents a preemptive policy, as a positive output gap may signal a future increase in inflation.

The size of the coefficients thus reflects the degree of aggressiveness of the policy maker

– the larger the coefficients, the more aggressive the policy in response to deviations in the fundamentals. This observation has equipped economists with yet another way of analyzing monetary policy – by evaluating the average response of an instrument variable to target ones, and comparing it to the theoretical suggestions (Clarida et al. 1997, 1998; Judd and Rudebusch, 1998; Nelson, 2000).

The Taylor rule assumes that real interest rate is being adjusted around some target level r^* every time inflation or output gap deviate from their respective target levels, which are assumed to be π^* and 0 correspondingly:

$$r = r^* + C_\pi(\pi - \pi^*) + C_y y \tag{1}$$

where real interest rate is given by the nominal interest rate and inflation differential $r = i - \pi$.

After re-arranging the terms, one obtains:

$$i = (r^* - C_\pi \pi^*) + (1 + C_\pi)\pi + C_y y = C + (1 + C_\pi)\pi + C_y y \tag{2}$$

This arrangement implies that if C_π is greater than 0 (or if inflation response is greater than 1), then real interest rate will be increased every time inflation increases.

All the estimations in this paper are being done with an OLS/Newey-West (Newey and West, 1987) procedure, thus accounting standard errors for possible heteroscedasticity and autocorrelation.

Apart from the coefficient estimates and their standard errors, I also report implied values for the average real interest rate and inflation during the corresponding periods. These values were calculated as follows.

It is easy to see from (2) that the target levels for inflation and real interest rate cannot be uniquely retrieved (identified), since they are tied together in the constant term. However, making an assumption about the value of one of them allows for calculating the value of the other.

$$\widehat{\pi^*} = \frac{r^* - \widehat{C}}{\widehat{C_\pi}} \qquad \widehat{r^*} = \widehat{C} + \widehat{C_\pi}\pi^* \tag{3}$$

This observation provides a way of testing the plausibility of the obtained estimates and/or of the specification of the rule by analyzing the implied values. Taylor (1993) assumed a 2% level, both for π^* and r^*. Alternatively, one can assume a target level for one (or both) of the variables equal to an end-of-sample value or an average rate over the sub-sample[2] (see Judd and Rudebusch, 1998).

Finally, R^2 provides a way of measuring of how systematic the monetary policy was, with low levels indicating a very discretionary one.

3 "Lags & Leads" and "Lags Only" Gap Specifications

3.1 Problems with a traditional approach

When estimating a Taylor rule, usually the whole path for output is being detrended in order to obtain potential output estimates, and the residuals are used as output gap estimates. Thus, at each point gap estimates depend both on lags and leads of the data, while in reality

[2] An assumption that the real interest rate has been on average maintained around the target level, implies that so was inflation if and only if output gap was maintained around 0 as well:
$\overline{r} - r^* = C_\pi(\overline{\pi} - \pi^*) + C_y\overline{y}$

the policy makers observe only lags.

Figure 1 illustrates the issue. When at point A, a policymaker cannot distinguish between two scenarios. In the first case, there is a minor correction and output will continue to grow, while in the second case, the economy is at the turning point of a cycle. Depending on which path will realize, the estimates of output gap at point A, are going to be very different – in the first case negative and small in absolute value, while in the second case, positive and big in absolute value.

Exclusion of the leads of the data from the information set may have a drastic effect on the estimates. Orphanides and van Norden (1999) have compared real time and ex-post gap estimates and concluded that the main source of the gap estimate errors is not consequenet revisions of the published data, but rather the lack of information on the future evolution of the economy, something which helps to improve understanding of the current state of the economy.

In this section I compare the "lags and leads" and "lags only" estimates of the output gap. Note that both types of estimates are constructed using revised data[3]. I construct "lags and leads" estimates of the output gap by detrending the whole of a 1947.1 – 1999.2 GNP sample, and "lags only" estimates by detrending current and lagged observations of

[3]Data for revised nominal and real GNP (1947.1 – 1999.2) measured in 1992 dollars are downloaded from the DRI Web Database, while data for the Federal Funds Rate (1954.3 – 1999.4) come from the St. Louis Federal Reserve Bank's web site.

the data:

$$y_t^{LL} = \ln(Y_t) - trend\{\ln(Y_{1947.1}), ..., \ln(Y_{1999.2})\}$$

$$y_t^{LO} = \ln(Y_t) - trend\{\ln(Y_{1947.1}), ..., \ln(Y_t)\}$$

Thus, "lags only" estimates are obtained by detrending truncated, consequently increasing sub-samples of the data, as opposed to Taylor's original paper, which not only used "too much of the future", but also "too little of the past", starting the sample only in 1984.1. Using such a recursive method can be viewed as incorporating learning of the state of the economy into the model.

As of inflation, throughout this paper it is measured by an annual growth rate of the GNP deflator.

Concerning the choice of a filtering technique, the most common ones in the economic literature are linear (Taylor, 1993), quadratic (Clarida et al. 1997) and Hodrick-Prescott[4] (Taylor, 1999). The first two however, are very sensitive to the expansions or contractions of the time frame that serves as a base for calculations. For instance, expanding a base time frame so that it would include an earlier segment with a severe recession results in a steeper linear trendline, and thus overestimates the gap for the early dates of the original segment, while underestimating it for the later ones.

The HP filter is more robust with respect to expansions or contractions of the base time frame (unless a sample is very short), becoming somewhat of a standard in the economic

[4] In the case of a Hodrick-Prescott filter, one also has to choose a value for the "penalty" parameter, which determines how smooth a trend is. Suggested value for the quarterly data is 1600.

literature. One should note, however, that due to its higher flexibility, it produces smaller on average gap estimates than a linear or a quadratic trend would produce. Also, as St. Amant and van Norden (1997) show, it assigns different weights to different points – more to endpoint observations, and less to ones in the center of the sample.

3.2 Unrobustness and unreliability of "lags & leads" estimates

Before estimating the rule, let me use an example to show how misleading the use of "lags and leads" estimates can be. Figure 2 provides different estimates of the output gap in 1984.1, obtained by using rolling sub-samples of the data. The very first segment of the data starts in 1975.3 and has 1984.1 as an endpoint, thus producing an estimate which can be treated as a "lags only" one. The next segment starts in 1975.4 and has 1984.2 as an endpoint. The very last segment starts in 1984.1, ends in 1992.3, and produces what Taylor (1993) obtained as an estimate. The most appealing one would probably be the estimate obtained with a 1979.4–1988.2 segment, for which 1984.1 would be a centerpoint.

The graph shows that all detrending techniques (linear, quadratic, and HP) produce the very first estimate higher than an average and the very last one lower than an average. Not only the value but the sign changes as well. Only the estimates obtained with a quadratic trend are consistently positive (although they substantially change in value, starting with 5.62% and ending with 0.55%). The HP filter produces positive for most of the time estimates (ranging from 3.61% to 0.09%), and negative for the two at the end of the sample (-0.33% and -0.71%). The estimates obtained with a linear trend change sign as much as 3 times. While the "lags only" estimate is positive (2.82%), the estimates obtained with both the 1979.4-1988.2 segment and the 1984.1-1992.3 segment are negative (-0.07% and -2.08% correspondingly).

Figure 3 demonstrates the reason for such a volatility. The very first estimate (using for instance, a linear trend) is obtained with trendline I. It is affected by the recession during the early 80s (close to the endpoint), and thus, is flatter than it would have been otherwise. This produces a large positive estimate. As the new datapoints become available, and the new estimates are obtained, the 80s recession slides towards the end and out of the base time frame, making the trend steeper. Estimates become smaller since the output is less volatile, and can be approximated with a high precision by even a simple linear trend (trendline II). Later on, the estimates become affected by the recession of the early 90s. Again, this causes the trend to become flatter, but this time producing a negative estimate for the 1984.1 gap, as this point is on the other side of the time segment (trendline III).

Overall, Figure 2 demonstrates that the "lags and leads" estimates are very unrobust[5], as, apart from the choice of a detrending technique and the length of time frame, they also depend in a large degree on the choice of the particular time segment used. Fixing the starting point at 1947.1, and using the HP filter effectively allows for avoidance of all these issues.

In fact, using "lags only" estimates serves as a better justification of the policy. At this particular point in time, the Fed was raising interest rates ($FFR_{1983.4} = 9.43$, $FFR_{1984.1} =$

[5] Sample standard deviations for the estimates are 0.90 (linear detrending), 0.96 (quadratic), and 0.72 (HP), while means are 0.47, 1.49, and 1.12 correspondingly.

	INFL	GAP	CNST	R^2
BURNS (LL)	0.83	0.69	1.63	0.56
(1970.1 – 1978.1)	(0.21)	(0.20)	(1.30)	
BURNS (LO)	0.57	0.07	2.86	0.21
(1970.1 – 1978.1)	(0.35)	(0.27)	(1.91)	
VOLCKER (LL)	1.11	0.12	4.42	0.76
(1979.3 – 1987.2)	(0.17)	(0.16)	(0.84)	
VOLCKER (LO)	1.31	0.37	3.32	0.79
(1979.3 – 1987.2)	(0.18)	(0.21)	(0.85)	
GREENSPAN (LL)	1.94	1.05	-0.91	0.91
(1987.3 – 1994.4)	(0.25)	(0.14)	(0.86)	
GREENSPAN (LO)	3.51	1.05	-5.83	0.83
(1987.3 – 1994.4)	(0.32)	(0.18)	(1.07)	

Table 1: Taylor Rule with Contemporaneous Target Variables

9.69, $FFR_{1984.2} = 10.56$), while inflation in all three quarters was below average and falling ($\pi_{1983.4} = 4.33$, $\pi_{1984.1} = 4.26$, $\pi_{1984.2} = 3.73$; average inflation during Volcker's chairmanship was 5.69).

Using gap estimates, which are negative or positive but small, would not justify the tightening of the monetary policy, while using gap estimates that are based on a 1975.3 – 1984.1 time segment provide a good explanation – the interest rate has been increased as a response to what seemed at the moment as a large and positive output gap.

3.3 Estimation results

Table 1 shows the results of the rule estimation for the three sub-samples, using both "lags and leads" and "lags only" estimates of the output gap. One can see that the coefficients obtained with the "lags only" specifications may differ greatly from the ones suggested by the "lags and leads" specifications.

Taylor (1993, 1999) has emphasized the importance of the condition $1 + C_\pi > 1$, arguing that it is a necessary stability condition (see page 5). Estimations done by Clarida et al. (1997) and Taylor (1999) explain the failure of monetary policy in the 1970s based on violation of this very condition, producing estimates of inflation response lower than unity. Meanwhile, their estimations of the monetary policy in the 1980s and 1990s result in inflation response coefficient greater than 1.

At the same time, Orphanides (2000a), using real time Greenbook estimates and coefficients proposed by Taylor (1993) with an inflation response of 1.5, shows that the resulting path is, in fact, very similar to the historical one. This observation suggests that the monetary policy was poorly designed as a result of incorrect estimates of the state of the economy, rather than policymakers' mistakes.

My "lags only" specification shows that for the Burns sub-sample, both response coefficients are lower than the "lags and leads" specification would suggest (0.57 and 0.07 rather than 0.83 and 0.69), and are in fact, statistically indistinguishable from zero, thus supporting the point of view of Clarida et al. and Taylor, and contradicting Orphanides' conclusions. Also note that fit (measured in terms of R^2) has significantly deteriorated (from 0.56 to 0.21).

Although using "lags only" gap estimates does not make the monetary policy during Burns' term look better, it does provide a more reasonable characterization of the policy during Volcker's term. When evaluating monetary policy for a Volcker's chairmanship term using the "lags and leads" estimates, the inflation response is not statistically different from one (1.11 with a standard error of 0.17). At the same time, using the "lags only" estimates produces an inflation response, which is statistically greater than 1 (1.31 with a standard error of 0.18), thus suggesting a more plausible description for the policy, which is being considered successful in bringing down inflation.

In addition to that, the "lags and leads" specification suggests a gap response unreasonably close to zero, as opposed to the "lags only" one (0.12 and 0.37 correspondingly). Fit, in fact, has improved, although only slightly (from 0.76 to 0.79).

The most striking result is the difference in estimates of inflation response for Greenspan's term. While "lags and leads" specification suggests the value of 1.9, "lags only" specification suggests response of 3.5, almost twice as large. At the same time, both specifications result in the same value for the output gap response (1.05). Although R^2 is lower for the "lags only" specification, it is still high (0.83 instead of 0.91).

Figure 6 demonstrates the reasons for differences in coefficients. During the 1987.3 – 1990.1 period, "lags only" estimates of the gap were practically zero, and thus all the movements in the nominal interest rate were caused by movements in inflation.

Indeed, the graph shows that the path that the Federal Funds Rate followed was an "exaggerated" version of the inflation path. As inflation rose by 1.2% between 1987.1 and 1989.1, by 1989.2 the interest rate had increased by 2.9%, or 2.3 times bigger, whereas "lags only" output gap increased only by 0.48%, which is one sixth of an increase in the interest rate.

However, over these two years, the "lags and leads" gap grew by 2%. Once the "lags and leads" gap estimates, which were consistently positive throughout this period, are used instead of the "lags only" ones, movements in the Fed's instrument become in part mistakenly attributed to the high levels of production.

In the end, note, that although the coefficients suggested by my "lags and leads" specification are different from those of Taylor (1993) due to different filtering technique and use of a different time frame, they are still within the usually suggested range of 1.4 – 2.0 for the inflation response and 0.5 – 1.0 for the gap response (see Rudebusch, 2000).

4 Contemporaneous and Lagged Targets

The previous section has demonstrated that reliance on observations that have not yet been realized when estimating the potential level of output may have a drastic effect on the estimated coefficients of the rule. However, not only policy makers do not observe the future path of fundamentals, they do not observe their current values either.

McCallum (1997) points this out by saying that "... it is unrealistic to pretend that monetary policymakers can respond to the true value of current-period realizations ... for nominal or real GDP (or GNP) or the price level"[6].

Hence, the next step in estimating the rules is to link the Fed's instrument to the lagged rather than the contemporaneous values of the target variables, thus correcting for "an information lag". Table 2 shows the results obtained using lagged "lags only" (revised!) fundamentals y_{t-1} and π_{t-1} as regressors.

[6]See page 39.

	INFL	GAP	CNST	R^2
BURNS (Contemp)	0.57	0.07	2.86	0.21
(1970.1 – 1978.1)	(0.35)	(0.27)	(1.91)	
BURNS (Lagged)	0.48	0.33	3.60	0.12
(1970.1 – 1978.1)	(0.35)	(0.31)	(1.97)	
VOLCKER (Contemp)	1.31	0.37	3.32	0.79
(1979.3 – 1987.2)	(0.18)	(0.21)	(0.85)	
VOLCKER (Lagged)	1.32	0.38	3.02	0.82
(1979.3 – 1987.2)	(0.15)	(0.16)	(0.67)	
GREENSPAN (Contemp)	3.51	1.05	-5.83	0.83
(1987.3 – 1994.4)	(0.32)	(0.18)	(1.07)	
GREENSPAN (Lagged)	3.63	1.46	-6.10	0.83
(1987.3 – 1994.4)	(0.32)	(0.15)	(1.16)	

Table 2: Taylor Rule with Lagged Target Variables

As can be seen from Table 2, the inclusion of lags in place of contemporaneous target variables does not have such a big effect.

The biggest change in estimated coefficients is for the Burns' sub-sample. The point estimator for the inflation response is even lower (0.48 instead of 0.57), while the gap response is bigger (0.33 instead of 0.07), though still statistically indistinguishable from 0. Fit has again worsened (from 0.21 to 0.12).

For the Volcker's sub-sample there is hardly any difference at all between lagged and contemporaneous specifications. Coefficients for the lagged specification differ only in the second decimal (1.32 and 0.38 versus 1.31 and 0.37), while fit has slightly improved (from 0.79 to 0.82).

Finally, for the Greenspan sub-sample, the lagged specification suggests even higher coefficients (3.63 and 1.46 versus 3.51 and 1.05), while fit remains the same (0.83).

Overall, as can be seen, the results obtained with y_{t-1} and π_{t-1} are very similar to those obtained with y_t and π_t. Indeed, one should not expect them to differ too much as all of the variables exhibit extremely high persistence. The following AR(1) regressions have been estimated with a simple OLS procedure for the 1970:1-1994:4 sample, and though should not be expected to explain the behavior of the variables, they serve as a good illustration:

$$i_t = 0.93 i_{t-1} + 0.51 \qquad R^2 = 0.86$$

$$\pi_t = 0.98 \pi_{t-1} + 0.10 \qquad R^2 = 0.94$$

$$y_t^{LO} = 0.89 y_{t-1}^{LO} + 0.01 \qquad R^2 = 0.80$$

5 Revised and Unrevised Data

The previous two sections have analyzed two common empirical misspecifications of the rule – the use of "lags and leads" gap estimates and the use of contemporaneous target variables. As I have demonstrated, the first may have a big impact on the outcome of analysis, while the second does not make much of a difference.

The last misspecification to be corrected is the use of revised data. In this section I estimate the monetary rules using unrevised variables, i.e. as they were known on the 15th of the middle month of a subsequent quarter[7]. Fundamentals will be specified in terms of lags, and output gap will be estimated using the "lags only" specification.

Broadly speaking, there are 3 kinds of revisions. First, there are revisions which occur within the quarter after the initial release of the data. These can be found in the Survey of Current Business, usually labeled *preliminary* (released during the first month after the

[7]Unrevised data are downloaded from the Croushore/Stark dataset, available at Philadelphia Federal Reserve Bank's website. The source of the Croushore/Stark dataset is either the Survey of Current Business, a Special Supplement to the Survey of Current Business, or the BEA's bi-annual National Income & Product Accounts.

quarter), *revised* (second month), and *final* (third month). The difference between them is insignificant and hardly has any effect on estimated coefficients, as these data revisions are minor and usually affect only the two last datapoints at most.

Once a year (in July), more thorough revisions are made, by which the data are revised for the previous 3 years (12 datapoints). Those changes take into account newly available data, such as the IRS tabulation of business tax revenues and the Census Bureau's annual surveys. Orphanides (1998a) shows that these are of substantial size and do distort the outcome of the analysis.

Finally, every 5 years, the so called benchmark revisions are made. Those take into account the Census data which are available less often than annually, but may also reflect changes in the base year (for example, 1992 versus 1996), in methodology (for example, a switch from a fixed-weighting procedure to a chain-weighting one), and sometimes in accounting. For instance, since 1992, some types of software, which had been treated before as intermediate goods, become classified as final goods, and thus, become included as GDP/GNP components. Such changes obviously may alter the data to a great degree.

The presence and possible effect of revisons on the data is nothing new in the economic literature. Several papers have tried to evaluate them and have found that revisions are not forecastble, as they reflect new previously unavailable information, rather than a statistical improvement of previously inaccurate measurements ("news" rather than "noise")[8].

[8] Mankiw and Shapiro (1985) demonstrated that the Bureau of Economic Analysis estimates can be treated as efficient statistical forecasts of the final estimate, and that the revisions in fact, are unforecastable.

Likewise, Faust, Rogers and Wright (2000) show that, although for most of the G7 countries preliminary estimates of the GDP growth have a systematic bias (which means that revisions are, in fact, forecastable), this is not the case for the US.

Specification	LINFL	LGAP	CNST	R^2
BURNS (Revised)	0.48	0.33	3.60	0.12
(1970.1 – 1978.1)	(0.35)	(0.31)	(1.97)	
BURNS (Unrevised)	0.66	0.41	2.77	0.26
(1970.1 – 1978.1)	(0.31)	(0.29)	(1.66)	
VOLCKER (Revised)	1.32	0.38	3.02	0.82
(1979.3 – 1987.2)	(0.15)	(0.16)	(0.67)	
VOLCKER (Unrevised)	1.34	0.42	3.17	0.80
(1979.3 – 1987.2)	(0.18)	(0.18)	(0.76)	
GREENSPAN (Revised)	3.63	1.46	-6.10	0.83
(1987.3 – 1994.4)	(0.32)	(0.15)	(1.16)	
GREENSPAN (Unrevised)	2.90	0.83	-2.97	0.75
(1987.3 – 1994.4)	(0.27)	(0.17)	(1.11)	

Table 3: Taylor Rule with Unrevised Data.

Figures 4 and 5 show the size of revisions. One can see that they are not that big. For the three sub-samples the means of revisions of inflation are 0.37, 0.10 and 0.29. In relative terms (size of revision/revised value ratio), they are not particularly large either – 0.08, 0.01, and 0.09 correspondingly. For the output gap[9], the means of revisions are 0.17, 0.17, and 0.00, and in relative terms -0.35, 1.15, and 0.01. High value of mean revision in relative terms for the Volcker's chairmanship term can be explained by only one outliner: for 1979.3 the output gap estimator based on unrevised data was only 0.03, while using revised data it was -0.74. When excluding this observation, mean drops to 0.41.

Table 3 demonstrates the results of estimations.

For the Burns' sub-sample, the use of unrevised data slightly increases both the fit and the coefficient estimates. The point estimator for the inflation response, however, remains

[9]Until 1993, GNP rather than GDP was used as a main indicator of national output. "Lags and leads" and "lags only" estimates of the gap are calculated using GNP. Unrevised estimates up until 1993 are calculated using GNP, and afterwards using GDP. As one can see from Figure 5, it does not have much of an effect on the results.

Specification	INFL	GAP	CNST	R^2
Burns 1	0.83 (0.21)	0.69 (0.20)	1.63 (1.30)	0.56
Burns 2	0.57 (0.35)	0.07 (0.27)	2.86 (1.91)	0.21
Burns 3	0.48 (0.35)	0.33 (0.31)	3.60 (1.97)	0.12
Burns 4	0.66 (0.31)	0.41 (0.29)	2.77 (1.66)	0.26
Volcker 1	1.11 (0.17)	0.12 (0.16)	4.42 (0.84)	0.76
Volcker 2	1.31 (0.18)	0.37 (0.21)	3.32 (0.85)	0.79
Volcker 3	1.32 (0.15)	0.38 (0.16)	3.02 (0.67)	0.82
Volcker 4	1.34 (0.18)	0.42 (0.18)	3.17 (0.76)	0.80
Greenspan 1	1.94 (0.25)	1.05 (0.14)	-0.91 (0.86)	0.91
Greenspan 2	3.51 (0.32)	1.05 (0.18)	-5.83 (1.07)	0.83
Greenspan 3	3.63 (0.32)	1.46 (0.15)	-6.10 (1.16)	0.83
Greenspan 4	2.90 (0.27)	0.83 (0.17)	-2.97 (1.11)	0.75

1 – "Lags and leads" specification of the gap, revised data, contemporaneous target variables;
2 – "Lags only" specification of the gap, revised data, contemporaneous target variables;
3 – "Lags only" specification of the gap, revised data, lagged target variables;
4 – "Lags only" specification of the gap, unrevised data, lagged target variables.
Burns: 1970.1 – 1978.1; Volcker: 1979.3 – 1987.2; Greenspan: 1987.3 – 1994.4.

Table 4: All Specifications of the Rule.

below 1.

For the Volcker's sub-sample, a switch to unrevised data has practically no effect on the outcome of analysis, with changes in the point estimators being less than 0.04.

For Greenspan's chairmanship term, the use of unrevised data produces milder response coefficients – 2.90 instead of 3.63 for inflation, and 0.83 instead of 1.46 for output gap. However, only the change in the output gap response is statistically significant.

6 Overview and Comparison of Results

This section brings together and compares the effects of all three misspecifications. Table 4 reports the results from estimations using all variations of the rule.

Overall changes can be as large as 250%. Note that change from the 2nd specification to the 3rd one is the smallest[10], while the "lags and leads"/"lags only" switch has a much bigger impact on the results than the revised/unrevised data switch.

Although, the distortions caused by revisions are smaller than the distortions caused by the inclusion of "lags and leads" gap estimates in place of "lags only" ones, they are still very important. Not only are they of substantial size; they also "correct" dramatic conclusions one might make on the basis of specification 3, which by itself, for example, suggests an enormous response to movements in inflation during Greenspan's term.

In recent years, a number of authors have evaluated Taylor rules as part of an effort to characterize U.S. monetary policy over the past several decades. Although specifications do differ, many of them have arrived at very similar conclusions (both qualitatively and quantitatively) – namely, that there was an inadequately low response to inflation during the 60s and early 70s which destabilized the economy, and a higher response during the Volcker and Greenspan chairmanships, which brought down inflation and stabilized the economy. My results suggest that although *qualitatively* the traditional story stands confirmed, *quantitatively* (i.e. in terms of point estimators) it is very different.

Comparing specifications 4 and 1, one can note that:

a) during Burns' chairmanship, policy was, in fact, less active in both dimensions than traditional analysis would suggest. Although statistically the difference between the coefficients in the first and the last specifications is not substantial, the point estimators are quite

[10] The only exception is a huge (in relative terms) change in output gap coefficient for the Burns' subsample. It can be explained by an unreasonably low estimate of 0.07 for specification 2.

lower for the latter.

b) Volcker's policy was more active in both dimensions, being more anti-inflationary, yet also aiming at the output gap to a much higher degree. While the 1st specification produces response coefficients of nominal interest rate to movements in inflation and output gap of 1 and 0 correspondingly, the results for the 4th specification are much more sensible.

c) Greenspan's policy was much more anti-inflationary than specification 1 would suggest, but less active in response to movements in output gap. In particular, notice that while the 1st specification implies that the real interest rate response to changes in inflation is about 1, the very last specification suggest that it is almost twice larger.

Finally, note that low R^2 indicates that during Arthur Burns' term monetary policy was very chaotic, as opposed to Volcker's and Greenspan's chairmanships when policy was much more systematic, sending a clear message to agents about the Fed actions.

These results are very different from what Orpahnides (1998a) reports. His estimation of a Taylor rule for the 1987-1992 period, using real time data collected from the Fed's Greenbook, produces estimates of inflation response that are lower than 1 (0.79, and 0.82) with an output gap response that is slightly higher (0.65). His explanation is that the monetary policy was forward looking, and he finds much more reasonable estimates for the coefficients once Greenbook forecasts are used in place of lags[11].

The last issue I would like to look at in this paper is the implied values for target inflation and real interest rate, reported in Table 5 and calculated according to (3). First, following

[11] As the data set which Orphanides used is not yet publicly available, I was not able to examine what caused such different results.

Specification	$\pi^* \Rightarrow$	$\widehat{r^*}$	$\widehat{\pi^*}$	$\Leftarrow r^*$
Burns (2 × 2)	2.00	2.09	2.26	2.00
Volcker (2 × 2)	2.00	3.85	-3.44	2.00
Greenspan (2 × 2)	2.00	0.83	2.62	2.00
Burns (averages)	6.35	0.53	8.55	0.15
Volcker (averages)	5.69	5.04	5.40	5.01
Greenspan (averages)	3.48	2.37	3.61	2.48

Table 5: Implied Values for Target Inflation and Real Interest Rate

Taylor (1993), I assume that one of the targets is equal to 2%. Next, I assume that one of the targets is equal to the average level over the sub-sample[12] and look at the implied value for the other target.

Table 5 shows that Taylor's "double duex" assumption of a 2% value for both inflation and real interest rate targets does not fit. It produces self-consistent results only for the Burns' sub-sample, but a 2% level is very far from the average of 0.15% for the real interest rate and 6.35% for inflation during this sub-sample.

For Volcker's chairmanship, assumption of a 2% target for the real interest rate produces a negative target for inflation of -3.44%, while assumption of a 2% target level for inflation during Greenspan's chairmanship results in a 0.83% target for the real interest rate which is much lower than the usually assumed values.

On the contrary, assuming targets that are equal to averages turns out to be quite reasonable at least for the Volcker and Greenspan sub-samples.

Alternatively, one may argue that for Paul Volcker's chairmanship the target rate of inflation was neither 2% nor 5.69%, but somewhere around 2.5 – 3.5%, as during this period inflation rates took a dive from around 10% to somewhere below 3%. Taking into account

[12] Averages are calculated using revised data.

the clearly anti-inflationary character of policy during this period implies that later values may be closer to the target. Assumption of an inflation target around 3% produces a target for the real interest rate of 4.02 – 4.36%.

Two further questions need to be addressed in this line of research.

The first concerns the use of forecasts for designing monetary policy. It seems intuitively appealing to assume that monetary policy is forward looking and thus based on forecasts of the inflation and output gap rather than their lagged values. Even where this is not the case, forecasts may be suggesting more about the economy, and thus their inclusion into a policy maker's information set may potentially improve the estimates of the equilibrium values, as they allow an avoidance of the "end point" problem.

Finally, the use of incorrect ("lags only") estimates of the gap (which are used while designing policy) instead of the correct ("lags and leads") ones (which build a future path of the economy), complicates a proper evaluation of the efficiency of the rules. Since it would be virtually impossible to theoretically obtain an efficient frontier (due to the nonlinear and recursive nature of the problem), I plan to construct one using simulation techniques.

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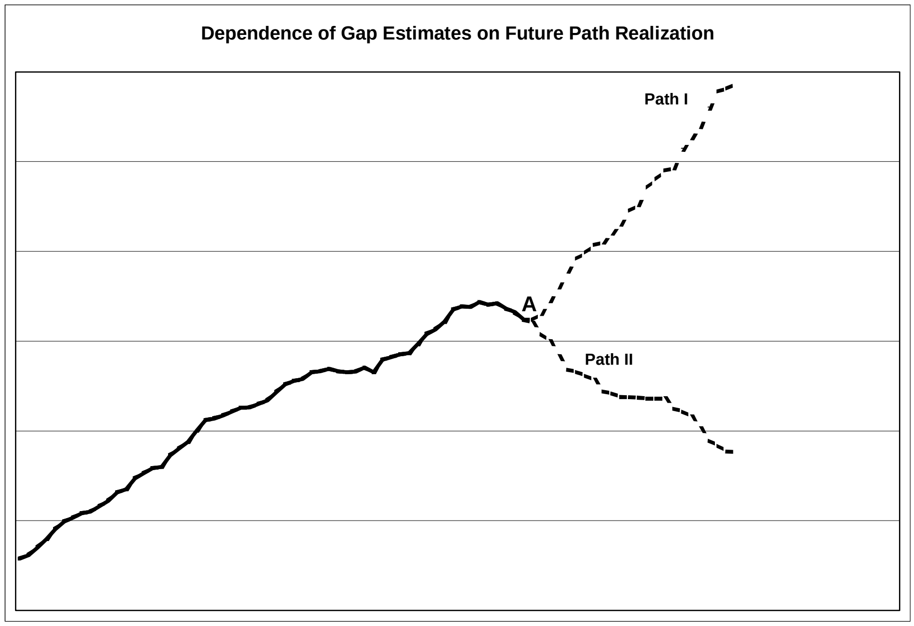

Figure 1: Dependence of Gap Estimates on Future Path Realization

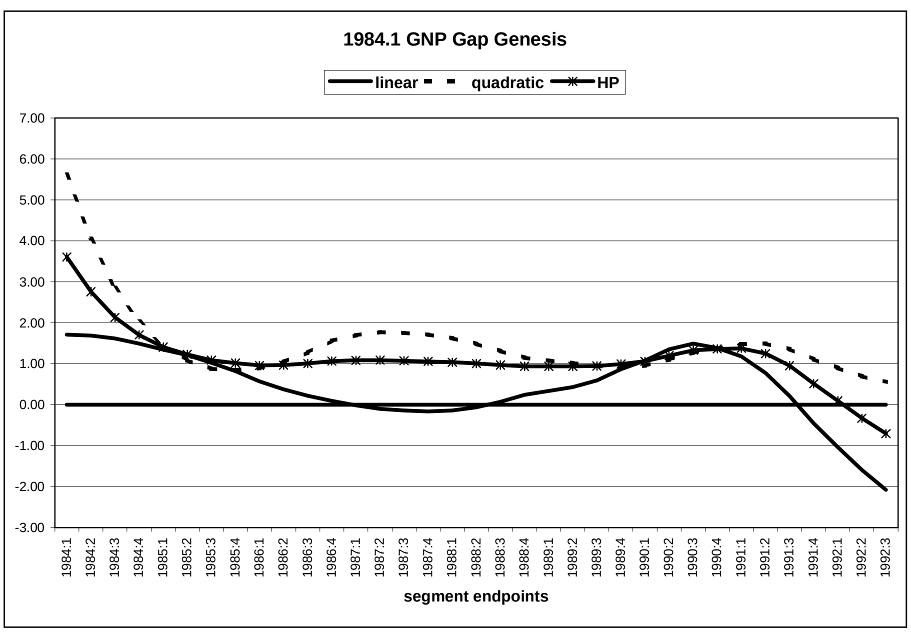

Figure 2: 1984.1 Gap Genesis

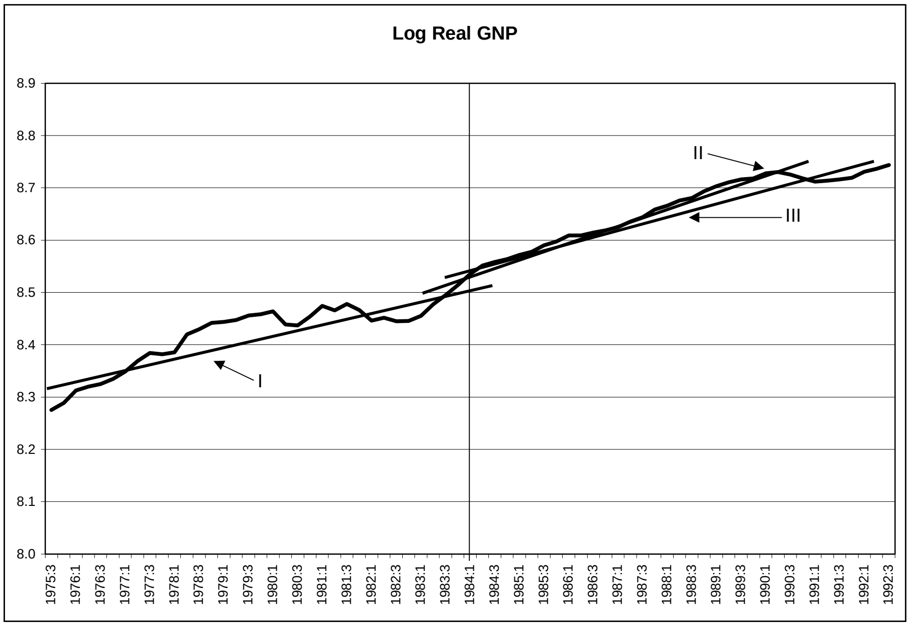

Figure 3: Log Real GNP with Linear Trendlines

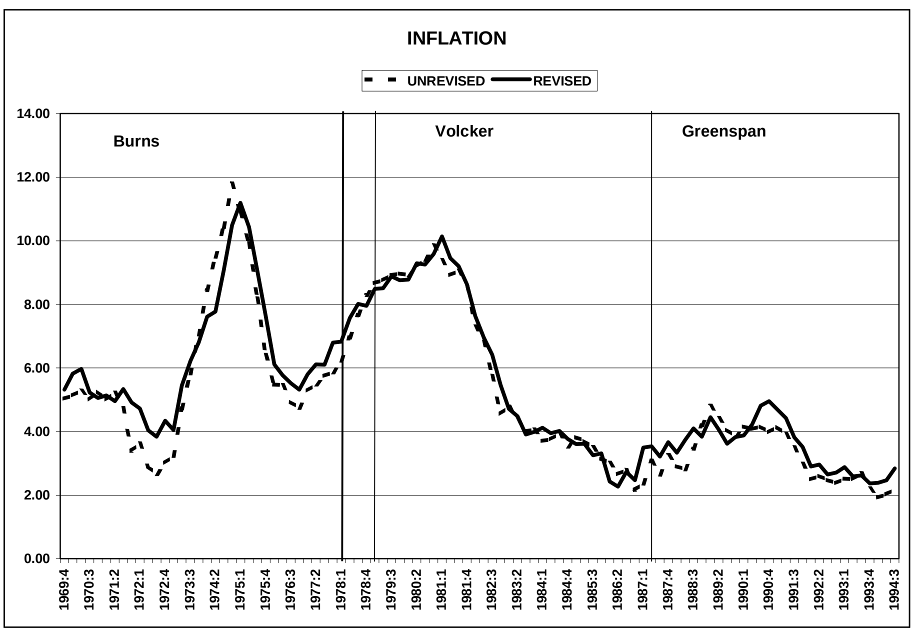

Figure 4: Inflation: Unrevised and Revised

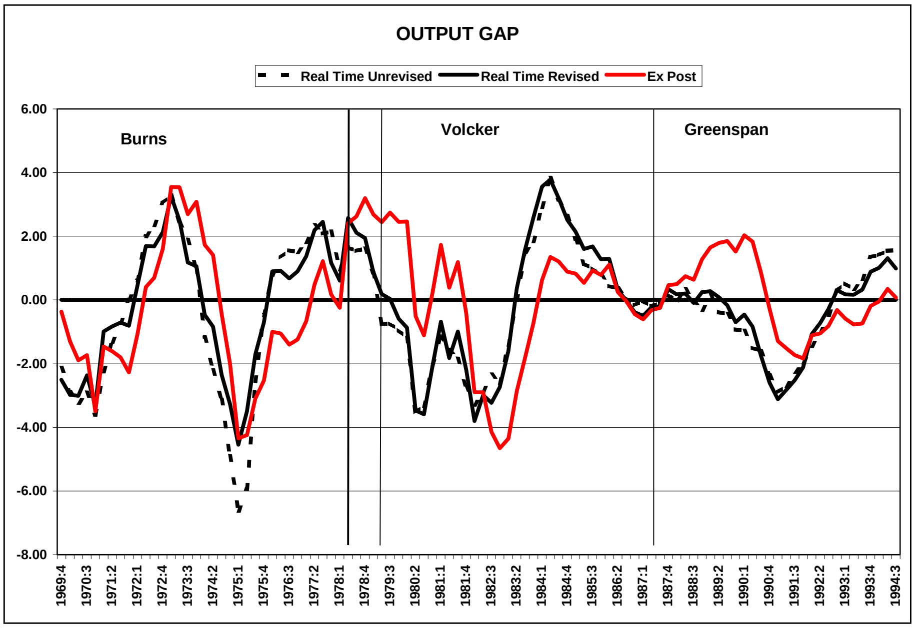

Figure 5: Output Gaps: Lags Only Unrevised, Lags Only Revised, Lags and Leads Revised

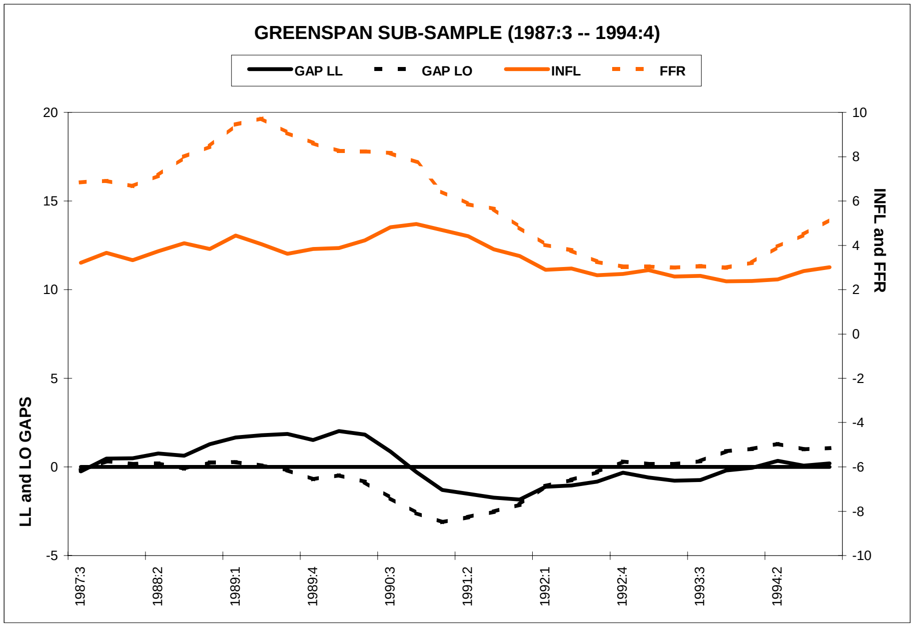

Figure 6: Greenspan Sub-sample