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An Inflation Goal with Multiple Reference Measures

William Whitesell

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Abstract

Most inflation-targeting central banks express their inflation objective in terms of a range for a single official inflation measure but generally have not clarified the meaning of the ranges and their implications for policy responses. In formulating policy, all central banks monitor multiple inflation indicators. This paper suggests an alternative approach to communicating an inflation goal: announcing point-values, rather than ranges, for a few key reference measures of inflation that are used in making policy. After reviewing and extending relevant theoretical and empirical studies, the paper argues that the alternative approach could more accurately reflect the concerns of policymakers and provide a better accountability structure for monetary policy performance.

Keywords: inflation targeting, monetary policy regime

JEL classifications: E52, E58, E42

* Board of Governors of the Federal Reserve System (wwhitesell@frb.gov, 202-452-2967). I have appreciated the comments of D. Cohen, D. Henderson, J. Kim, B. Madigan, A. Orphanides, S. Struckmeyer, E. Swanson and other participants at a Board staff seminar. The views expressed are those of the author and not necessarily those of the Board of Governors of the Federal Reserve System or others of its staff.

An Inflation Goal with Multiple Reference Measures

I. Introduction

Central banks have adopted inflation goals or more complete inflation targeting frameworks in order to improve the performance of monetary policy. Improvements are expected because of better behaved inflation expectations arising from the greater transparency and credibility of the regime and because of the disciplining of monetary policy through an enhanced accountability framework.

Central banks with explicit inflation goals have almost universally selected unique official price measures to represent their objective. However, no central bank would be satisfied by looking at only one price index when formulating monetary policy. Because inflation measures differ in methodology, sector coverage, inherent biases, and idiosyncratic noise, examination of a variety of these indicators has been needed to gain insight into the underlying inflation process. Why then do central banks generally set aside this richness of analysis and choose to represent an inflation goal in terms of a single reference measure? Evidently, they view the simplicity of a unique measure as essential to facilitate communication with the public and thus to achieve the credibility and accountability advantages of an inflation-targeting framework.

But central banks and observers recognize that inflation accountability can in some circumstances be oversimplified or misplaced. One example would be an "inflation nutter's" excessive focus on inflation control to the exclusion of other important policy objectives, such as output, employment, and financial stability. Another would be rigid adherence to an announced point-goal at a time when transitory special factors are distorting the inflation signal in the chosen measure. Such considerations have induced many central banks to allow some wiggle room in accountability discipline by announcing inflation ranges rather than point-goals and, in some cases, by articulating "escape clauses," or reasons to ignore a miss of their inflation range.

This paper considers whether the above typical structure of an inflation-goal regime will prove to be best practice. It assesses whether selection of a single official inflation measure and use of a range, with occasional escape clauses, is the best accountability framework for disciplining a central bank and for fostering transparency and credibility objectives. While a unique official inflation measure may ease communication challenges at the time of implementation of an inflation goal, the long-run transparency and credibility benefits of such a framework are less obvious. The analysis is relevant not only for inflation-targeters, but also for central banks that choose to announce a long-run inflation goal without the other trappings of an inflation-targeting framework, as advocated for the United States by Bernanke (2004), among others.

After summarizing key aspects of existing inflation-goal regimes, the paper investigates the role of inflation ranges in monetary policy frameworks. It then reviews theoretical research on an accountability standard for central banks and on optimal inflation indexes. It develops a version of the Mankiw/Reis (2003) model in order to depict how measurement uncertainties could affect the specification of an optimal price measure. Empirical evaluations are conducted on whether the choice of an inflation index really matters and, using factor analysis, whether a unique "underlying inflation process" can be said to exist. The paper then assesses the implications for central bank accountability of a range for a single indicator versus point-values for multiple reference measures. A summary concludes.

II. Characteristics of Inflation-Goal Regimes

Over the last decade and a half, the practice of announcing specific targets for monetary policy has become more widespread among central banks. For instance, in a survey of 91 central banks around the world, Sterne (1999) reported that 87 had an explicit announced policy target of some kind in 1998 versus only 50 in 1990. The survey also found that more than half of the central banks had explicit inflation objectives, although in most cases these goals were combined with target values for other economic indicators as well, such as money growth or the exchange rate.

Currently, 21 central banks are generally classified as inflation targeters (see Table 1), based on their priority commitment to an inflation goal and their use of inflation forecasts as intermediate targets for policy (see IMF, 2005). All but one of these inflation-targeting central banks use a unique official price measure and all but three employ an inflation range rather than a point-goal by itself.[1] Most of the central banks with ranges emphasize the center of the range as their point-goal. Ten of the 18 central banks with ranges have described the ranges as reflecting limits on their ability to control inflation. Nine use the boundaries of the range as a trigger for a formal communication by the central bank regarding the behavior of inflation, suggesting a key accountability role. Three central banks have described their ranges as zones of indifference regarding inflation outcomes.

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[1] These include a few cases of point-goals associated with "ranges" that are loosely defined or that have "soft edges," such as the Bank of England, which now faces only a reporting requirement if it misses its point inflation target by 1 percentage point or more.

Table 1: Inflation-Targeting Countries

Country	**Target Specification***	**Rationales for range** (Table 2)
Australia	2-3%, CPI	3, 5
Brazil	3¾ ± 2½%, CPI	10
Canada	1-3%, CPI, 6-8 quarter horizon, also emphasize CPIx	4, 10
Chile	2-4%, CPI, 8 quarter horizon, also emphasize CPIx	4
Colombia	3%, CPI	n.a.
Czech Republic	1-3% CPIx, 2-4% CPI	4
Hungary	3½±1%	4
Iceland	2½±1%	10
Israel	1-3%, CPI	10
Korea	2½-3½%, CPIx, medium term horizon	4, 9
Mexico	3±1%, CPI	4
New Zealand	1-3%, CPI, medium term horizon	3, 4, 10
Norway	2.5%, CPIx	n.a.
Peru	2½±1%, CPI, Dec.–Dec.	4
Philippines	2½±1%, CPI	10
Poland	2½±1%, CPI	4
South Africa	3-6%, CPIx	3, 4
Sweden	1-3%, CPI, 4-8 quarter horizon	10
Switzerland	Less than 2%, CPI, 3 year horizon	n.a.
Thailand	0-3½%, CPIx	10
United Kingdom	2±1%, HICP	10

* Sources: Truman (2003), Ayales (2002), and central bank websites.
Notes: CPIx implies the deletion of some component(s) from headline consumer prices, such as energy, food, indirect taxes, or mortgage interest in different cases. HICP is the harmonized index of consumer prices.

As noted in Table 2 and discussed further below, a variety of other interpretations of an inflation range are possible but have not generally been embraced by central banks. The alternative rationales imply differences in the appropriate width of an inflation range, in the variation in that width over time, and in associated monetary policy reaction functions. However, despite the absence of supportive quantitative analyses, most central banks with ranges have settled on a fixed range width of 2 percentage points.

As regards inflation indicators, most central banks with explicit inflation goals use headline consumer prices as a reference measure. This can create problems when transitory factors make it inappropriate for a central bank to respond to movements in the official measure. At such times, a central bank may put a substantial weight on core inflation indicators, which exclude volatile energy and food components, in formulating policy. Inflation reports generally include discussions of a variety of price indexes, often as a way of explaining why the deviation of headline inflation from the target is being tolerated and the extent to which other indicators may be giving a more policy-relevant inflation signal.

For example, the Bank of Canada officially targets headline CPI inflation, but at times has placed more emphasis on unofficial "operational" targets for measures of core inflation. It has devoted considerable effort to refining such core measures (Knight *et al*, 2002).[2] The Bank of England's official target, until December 2001, was the retail price

[2] The Bank of Canada cut interest rates in early 2001 to address slowing economic growth despite the fact that headline CPI inflation was around the top of the target range. It argued that headline inflation was only temporarily high while pointing out that core inflation was near the midpoint of the range (Knight *et al*, 2002). The core inflation measure excluded energy, food, and indirect taxes until May 2001 when it was redefined to exclude fruit, vegetables, gasoline, fuel oil, natural gas, intercity transportation, tobacco, mortgage-interest, and indirect taxes.

Table 2

RATIONALES FOR A RANGE	MIDPOINT EMPHASIS	IMPLIED RANGE WIDTH
Diffuse Goal:		
1. Uncertainty about numerical point-goal.	In some dynamic specifications	Time-varying
2. Facilitate compromise among policymakers with differing views of appropriate inflation goals.	No	Time-varying
3. Flat social welfare function.	In some dynamic specifications	Narrow, fixed
Expected Volatility in Inflation:		
4. Indicate limits on predictability and control of inflation.	Yes	Wide, varying
5. Indicate normal cyclical variation in inflation.	Yes	Narrow, fixed
6. Indicate an optimal trade-off between inflation stability and output/employment stability.	Yes	Wide, fixed
Policy Reaction Function:		
7. Outside range only, respond to inflation.	No	Narrow
8. Outside range, nonlinear response to inflation.	Yes	Narrow
9. Inside range only, respond to real economy.	Yes	Wide
Accountability Device:		
10. Outside range only, explanations required or penalties imposed.	No*	

* While not inherent in this rationale, a midpoint emphasis could nevertheless be communicated by other means, as is currently the case at the Bank of England.

index excluding mortgage payments.[3] However, as noted by Bowen (1995), "in the Bank, RPIY [retail price index excluding mortgage payments and indirect and local taxes] is preferred as a measure of underlying inflation." Also, the Reserve Bank of New Zealand officially targets the CPI excluding interest costs, but has operational targets for a measure of underlying inflation that adjusts for indirect taxes as well as terms of trade and other shocks (Sherwin, 2000). The Riksbank has an official inflation target based on the headline CPI, but regularly discusses and forecasts several other inflation measures in its quarterly inflation reports because "various measures of 'core' or 'underlying' inflation ... have at times been more decisive for monetary policy than CPI forecasts [and] ... the idea that a certain price index would invariably yield an unambiguous signal about the optimal policy seems ill-founded" (Heikensten and Vredin, 2002).

III. Uses of Inflation Ranges

A variety of possible competing or overlapping interpretations of inflation ranges are indicated in Table 2 and grouped for discussion purposes into four categories: a diffuse goal, expected inflation volatility, a policy response structure, and/or an accountability device.

A range may indicate a **diffuse goal** owing to *uncertainty* about the optimal point-value, *compromises* among policy makers, or a *flat social welfare function*. The *uncertainties* could be related to the measurement of inflation or to the optimal cushion above true price stability. For instance, the optimal cushion would vary over time owing to evolution in the inherent stability of the economy or in the pace of structural productivity

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[3] It was then changed to the geometric-means-based Harmonized Index of Consumer Prices (HICP), similar to that used by the ECB.

growth,[4] and a range would obviate the necessity of frequent associated adjustments in the point-goal. The *compromise* rationale could arise if members of a policy committee could not agree on a point-goal but could agree on a range encompassing their point-goal preferences (Santomero, 2004). Along these lines, Tetlow (2000) models an implicit point-target that drifts in a random walk owing to evolving compromises among policymakers. At the boundaries of the range, policymakers agree on the need to take action to bring inflation back in line. Orphanides and Wieland (2000) model a range as reflecting a *flat single-period welfare function*. They point out, however, that preferences based on discounted future welfare would not be indifferent when shocks are persistent, because approaching the boundaries would then increase the chance of breaching the range in a subsequent period. Except for such dynamic specifications with persistent shocks, these diffuse-goal rationales would tend to be associated with ranges as indifference zones and no emphasis on the midpoint. Ranges of that type have been criticized for failing to provide enough guidance for the long-run inflation expectations of the public (Bernanke *et al*, 1999, Faust and Henderson, 2004, Gavin, 2004).

Ranges more typically have been used to signal **expected volatility in inflation** outcomes around a midpoint-goal. In these cases, a range could indicate a confidence interval for *inflation control*, movements in inflation over the *business cycle* that the central bank will allow, or an *optimal trade-off* with output or employment volatility.

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[4] Faster trend productivity growth would diminish the need for an inflation cushion to facilitate labor market adjustments in the presence of downward wage rigidity because declining industries could then more easily shrink with slower but still positive wage growth. It would also imply a higher equilibrium real interest rate and thereby reduce the need for an inflation cushion to cope with the risk that the central bank would hit the zero lower bound on nominal interest rates when trying to stimulate the economy.

The appropriate width of an inflation range in these cases would depend importantly on the type of volatility that it is intended to signal. The control and trade-off rationales would likely imply wider ranges than cyclical drift, and the control rationale would probably be more time-varying. Numerous authors have commented that a typical range width of 2 percentage points is too narrow to signal the limits of inflation control unless inflation stability improves dramatically (e.g., Debelle and Stevens, 1995, and Haldane and Salmane, 1995). Cyclical movements in inflation have also been more pronounced in the past than envisioned in this rationale for a range. Estimates of range widths needed in optimal trade-offs of stabilization goals (Taylor, 1979, Erceg, 2002, Faust and Henderson, 2004) have differed widely.[5]

An alternative to using an inflation range to indicate expected inflation volatility is the "fan chart," or confidence interval that expands with forecast horizon, commonly used in inflation reports. Fan charts have an advantage over ranges in this role because they allow for time-varying uncertainty and can be accompanied by situation-specific simulations and explanations.

A third category of rationales for inflation ranges is as an indicator of the **monetary policy reaction function**. For instance, if a range signified an indifference zone, policy might be expected to respond to inflation only when the range was breached, or perhaps shift nonlinearly to a stronger response to inflation at that time. Orphanides and Wieland (2000)

[5] Reifschneider *et al* (1999) estimated inflation/output volatility trade-offs for a variety of Taylor-type policy rules using the FRB/US model and found that, on the policy frontier, pushing the standard deviation of four-quarter PCE inflation below 1½ percentage point resulted in the standard deviation of the output gap rising notably above 2 percentage points. Using the same model, Williams (2003) found a slightly better trade-off using a three-year average measure for inflation. Neither study developed a social welfare function to identify the optimal trade-off.

suggested that such a nonlinear reaction function could be optimal if the Phillips curve were flat near full output. Alternatively, with a hierarchical mandate, a central bank might be authorized to pursue output and employment objectives only if inflation remained in the range (see Stern and Miller, 2004, and Faust and Henderson, 2004). If the range were breached, inflation control would take precedence.

Finally, an inflation range may also be used, explicitly or implicitly, as an **accountability device.** The range may signify a "safe harbor" within which the central bank would be excused for small deviations from the midpoint goal (Goodfriend, 2005, Lacker, 2005). Mishkin and Westelius (2005) formalize this idea in a model with a fixed penalty on the central bank for every period that a range is breached. They advocate such a disciplinary structure as a means of countering political pressures that would over-emphasize employment objectives. Before evaluating the accountability role of an inflation range, some theoretical results on optimal accountability standards are reviewed next.

IV. An Optimal Unique Accountability Standard?

Theoretical Considerations

Micro-founded macroeconomic studies have shown that maximizing the welfare of a representative agent implies a unique targeting criterion for a central bank, the specification of which depends on the model. These criteria involve relationships among the central bank's objectives rather than reaction functions for the policy instrument. In general, as pointed out by Woodford (2004) and references therein, "the target criterion should involve more than inflation" and, in particular, central banks should "commit themselves to the pursuit of explicit target criteria that involve real variables as well as inflation." The optimal target criterion typically involves weighted averages of discounted forecast values for inflation and output. Even aside from the complications associated with different specifications across economic models, the implications of these targeting criteria for the setting of the policy instrument are complex and controversial. It would be a challenge to communicate them to the public.

In the face of such challenges, some researchers have assumed that a central bank will be explicitly accountable only for a single measure of inflation; they then investigate the theoretical case for determining the optimal measure. For instance, Aoki (2001) explored the issue of optimal price indexes in a two-sector model. He found that a central bank should target prices only in the sticky-price sector when prices in the other sector are perfectly flexible. The idea is that real economic distortions are caused by the deviation of prices from long-run values, which occurs only in the sticky price sector. Mankiw and Reis (2003) showed that the optimal weight on the flex-price sector need not be zero if there are sector-specific markup shocks, in addition to the productivity shocks assumed by Aoki, and if the sectors also differ in the variance of the shocks, expenditure shares, or responsiveness to the business cycle. A sticky-price model by Huang and Liu (2005) indicates that policy should respond to producer prices as well as consumer prices in order to reduce allocative distortions in the intermediate goods sector. Erceg *et al* (2000) and Levin *et al* (2005) find that a central bank should also place some weight on stabilizing wage inflation to avoid distortions in labor/leisure choices that could propagate widely in the economy.

Appropriate subsector weights could also depend on differences in the costs of adjustment to inflation. For instance, consumers may have more costs of compiling accurate information about inflation developments than firms, so the costs of inflation may be higher in the consumer sector. Institutionalized indexing arrangements, such as the use of the CPI to index Treasury inflation-protected securities and social security retirement benefits, reduce the cost to insured agents of adjusting to that measure of inflation, suggesting a lower weight, but may also increase the visibility of the measure and the concern of those who are not protected, arguing for a higher weight.

Differences in measurement uncertainty could also affect the choice of a price index. Indeed, some have even argued against announcing an explicit inflation goal partly because of "conceptual uncertainties and measurement problems" in the indexes (Greenspan, 2004). Appendix 1 explores one aspect of this issue: the effect of transitory measurement uncertainties, differing by economic sector, on the choice of an optimal price index in a Mankiw/Reis type of model. The analysis indicates that the presence of measurement uncertainty of this nature does not disqualify a sector from an optimal price index, but a sector's weight in the optimal index depends inversely on the extent of its measurement uncertainty. In addition, as a caveat to Aoki (2001), the optimal price index entails a positive weight on a flex-price sector if there is any measurement uncertainty in sticky-price sectors. This analysis suggests that establishing an inflation target based on a unique official measure may be suboptimal if that indicator is subject to measurement uncertainties.

This brief review indicates that, just as there is no clear consensus welfare function, macroeconomic model, or targeting criterion for monetary policy, there is also no theoretical consensus on specification of an optimal price index. In these circumstances, the typical practice has been to set aside the search for an optimal index and instead announce a goal based on a well-known inflation measure. A commonly used indicator is thought likely to better achieve transparency, credibility, and accountability objectives than a more obscure, specially constructed measure based on debatable claims to optimality. Some observers have gone further to suggest that, in practice, the choice of particular index may not be that important (see, e.g., Meyer, 2004). This issue is addressed next.

If You've Seen One Price Index, Have You Seen Them All?

Previous studies have documented differences among well-known price indexes in scope and coverage, subsector weights, estimation procedures, and persistent biases (see, e.g., Clark, 1999, and Lebow and Rudd, 2003). Despite such differences, however, are the behaviors of major inflation measures similar enough that stabilizing one of them would effectively stabilize them all? In particular, suppose the Federal Reserve held inflation as measured by the core PCE index perfectly constant at some low value.[6] How much volatility would then likely occur in other key inflation measures?

An answer to this question is suggested by the standard deviations of differences in inflation rates shown in Table 3. Inflation is measured quarterly but based on alternative averaging periods of one quarter, four quarters, and twenty quarters. The analysis uses the current definitions of price indexes consistently over time on the assumption that a central bank would explain and make appropriate adjustments for methodological breaks in series. Results are given for the period since 1964 and for the two decades of greater inflation stability since 1983. They suggest that, if core PCE inflation were held perfectly constant, quarterly inflation as measured by the core CPI index would typically vary from its mean by close to a percentage point.[7] Five-year average core CPI inflation would typically vary from its mean by one-fourth to one-third of a percentage point. Another way of interpreting this result is as an indication of how much core PCE inflation would vary if the Fed instead

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[6] Since June 2004, the Federal Reserve has used the core PCE measure in reporting semi-annual forecasts to Congress.

[7] The actual standard deviation of quarterly core CPI inflation has been 2.3 percentage points since 1964 and 1.2 percentage points since 1983.

stabilized core CPI inflation. Headline inflation measures and GDP chain-weight inflation (except at the quarterly frequency) would be more volatile.[8] Of course, these results are only suggestive, and they abstract from behavioral responses that could potentially lower volatility in alternative inflation measures after stabilization of one of the indicators. Nevertheless, they strengthen the presumption that the choice of inflation indicator does matter; indeed, the path of a central bank's policy instrument might look quite different depending on which measure it chooses to stabilize.

Table 3:
Standard Deviation of Difference of Indicated Inflation Rate from Core PCE Inflation

	1964:Q2 to 2005:Q3			1983:Q2 to 2005:Q3		
Quarters in Averaging Period →	*1*	*4*	*20*	*1*	*4*	*20*
Inflation Measure:	(percentage points)					
PCE	1.07	.83	.54	.88	.56	.38
CPI	1.57	1.04	.65	1.53	.91	.62
Core CPI	.99	.47	.33	.86	.37	.25
Chain-weight GDP	.98	.77	.70	.82	.63	.51

Is There a Unique Underlying Inflation Process?

But perhaps the well-known inflation indicators all suffer from some idiosyncratic tendencies that are tangential to what should be the true concern about inflation in the economy. Perhaps various indexes should be combined in some manner to construct an indicator of underlying inflation, and the central bank should stabilize that measure.

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8 Measures of producer prices (not shown on the table) would be even more volatile.

This line of thinking presumes that there is a unique underlying inflation process, which is investigated in Appendix 2, using factor analysis. Empirical tests are conducted to identify the minimum number of common factors needed to characterize the behavior of inflation in the United States. The measures include monthly price indexes for total and core CPI, PCE, and PPI (for finished and intermediate goods), as well as quarterly price indexes for GDP, nonfarm business output, producers' durable equipment, and imports. In all of the tests, a single factor was unable to represent the co-movements in these indicators. With monthly or quarterly data from 1959 on, a single factor was rejected in favor of two factors. With inclusion of core PPI indexes, available in the period since 1974, additional factors were needed to account for the co-movements among these inflation indicators. Even when restricting the analysis to the four core inflation measures or to the four consumer price measures, a single common factor was insufficient. This analysis suggests that the inflationary process may be inherently multi-faceted; no improvements in measurement may ever enable us to derive a unique index that captures even the underlying forces that are driving inflation. It supports the practice among central banks of making careful evaluation of a wide variety of inflation indicators, rather than focusing exclusively on any single measure.

V. Accountability Issues

Inflation Accountability in Principle

In light of the above discussion, would a range for a single inflation measure be a better accountability structure for a central bank than point-goals for a few reference measures? Before tackling this question, consider first the role of an accountability structure when inflation, by one measure, deviates from its goal value. Given lags, that inflation miss could have been prevented by a different setting for the monetary policy instrument a year or so previously. However, if the miss reflected a transitory supply shock, special factor, or measurement noise that did not affect inflation expectations, the central bank should not have tried to offset it. Nor should it have countered the miss if it represented an appropriate trade-off among the central bank's objectives of stabilizing inflation and stabilizing output, employment, and the financial sector. If instead the miss should have been offset, it would represent a policy error, at least *ex post*. Even in this case, though, if the cause was an unforeseeable shock, an *ex ante* policy error would not have occurred. But if the inflation miss was an *ex ante* error, it presumably could have been avoided with better forecasting by the central bank or a higher relative weight on inflation in the formulation of policy.

The role of an accountability structure should be to help align a central bank's incentives to appropriate objectives, which here involves helping to distinguish among the above cases so that discipline is applied when *ex ante* policy errors occur and not otherwise. A poorly constructed accountability framework could misalign incentives in various ways. For instance, knee-jerk responses of policy instruments to past inflation misses would be inappropriate, as a change in the current setting of policy would be called for only if an inflation miss had implications for the inflation forecast. Moreover, an accountability framework should avoid biasing incentives in favor of stabilizing inflation to the neglect of other important central bank objectives (Kohn, 2004). In light of these considerations, how does a single-indicator range compare with multiple inflation indicators as an accountability structure?

Accountability with a Range

An inflation range would seem well suited to align incentives to appropriate objectives if small deviations of inflation from target generally reflected appropriate trade-offs with other goals or transitory factors that the central bank should have ignored or could not have foreseen, while large deviations resulting in range breaches were typically attributable to poor forecasting or an inappropriate weight on inflation. However, the parsing of inflation misses by size does not always correspond to its parsing by type. Small misses may be caused by policy errors and may become persistent. Perhaps more importantly, range breaches are sometimes caused by temporary special factors, generating the use of "escape clauses" for inflation-targeting central banks and a regular discussion of factors affecting recent and forecast price developments in inflation reports. The presumption that a range breach calls for some explanation has itself been challenged by Faust and Henderson (2004). They claim that, if a range reflects an optimal trade-off between inflation and output stability, a central bank should be criticized if inflation breaches the range too seldom as well as too frequently.

Aside from ambiguities regarding the use of a range to identify policy mistakes, problems arise in devising appropriate penalties for range breaches, and enforcing them. For instance, the common practice of requiring central banks to offer public explanations when inflation breaches the range may not represent much of a penalty, as central banks are often called upon to discuss inflation outcomes and prospects, even when there is no range breach. On the other hand, if an enforcement device is severe, such as dismissal of a central bank Governor (as is possible in New Zealand following a range breach), it may almost never be used.

Accountability with Point-Values for Several Inflation Indicators

Suppose a central bank announced a goal of low, stable inflation that it would pursue, given measurement uncertainties, through reference values for a few key inflation measures used in the formulation of monetary policy. For example, instead of the usual practice of announcing a goal for headline consumer price inflation, suppose reference values were announced for total and core consumer prices, and for overall GDP prices. Would accountability with three reference values of this nature be impaired relative to accountability under a range for total consumer price inflation?

At first glance, a single inflation measure would seem to have the advantage of simplicity. Explaining a multiple indicator framework could be more of communication challenge at the time of announcement of the regime. However, the simplicity of a range would likely be undermined over time because of the uncertain meaning of the boundaries of the range. Complexity would also be increased by the need for escape clauses to explain range breaches.

Over time, transparency and credibility advantages may well accrue to central banks that announce several inflation reference measures, if those measures are in fact used in formulating policy. When faced with range breaches caused by special factors, inflation targeters often point to other, better-behaved inflation indicators in their inflation reports. Dennis (1997) noted that the hit to credibility from appeals to special factors would be limited if those factors were identified in advance. Pre-announcing the key inflation indicators used in formulating policy would also avoid the appearance of making after-the-fact excuses in such circumstances. Indeed, the use of multiple inflation reference values provides a natural framework to facilitate discussion of special factors that beset some measures but not others.

Multiple indicators and ranges can each be misused, however. On one hand, a range can be set too wide or escape clauses used too frequently. On the other hand, a central bank could announce too many official reference measures for inflation and try to avoid responsibility for any of them. In either case, and especially if the central bank appeared to be excusing an inflation miss after the fact, credibility could be impaired.

Finally, for a central bank that announces a long-run inflation goal without adopting other aspects of inflation-targeting, a multiple indicator framework may have a particular advantage over a single-indicator range. As noted above, an accountability structure risks making policy subject to backward-looking pressures. Inflation-targeting central banks can resist such tendencies by drawing attention to forecasts in regular inflation reports and even making the forecast an intermediate target for policy (Svensson, 1997). However, a central bank with an inflation goal but without regular inflation reports and forecasts could find itself subject to greater pressures to respond to recent inflation data, especially if a unique inflation measure was used. The "discipline" of an over-simplified accountability framework might then ironically be partly responsible for policy errors.

Experience with Monetary Aggregates

Multiple reference values for inflation might call to mind previous experiences involving targets for multiple monetary aggregates. Because of the instability of money demand, monetary aggregates proved unsatisfactory as intermediate targets for many central banks. Inflation benchmarks represent fundamental objectives for monetary policy, however, rather than intermediate targets, and for that reason inflation measures could never be discarded as an entire class as has often been the case with monetary aggregates. Nevertheless, individual price indexes are subject to measurement errors and may fall in or out of favor over time. Thus, some lessons from the experience with monetary aggregates may apply.

In the case of the Federal Reserve, three key experiences from the monetary targeting era seem relevant. First, announcing too many official measures may undermine the credibility of a targeting framework. This may have been the case in the 1970s, when the Federal Reserve published alternative measures of the monetary base and up to five broader monetary aggregates at one time (though official targets were only set for up to four measures). Secondly, frequent introduction of new official measures is also likely to impair the credibility of a targeting framework, as may have been the case for monetary targeting in the U.S. in the early 1980s. Thirdly, on the positive side, having more than one official measure did prove useful to the Federal Reserve in at least one instance: When deregulation of deposit interest rates undermined the indicator properties of the favored M1 aggregate in the early 1980s, the presence of previously announced targets for M2 may have helped facilitate a transition that preserved, at least for a while, the monetary targeting framework.

VI. Conclusion

Central banks with inflation goals have generally used a single measure of inflation as their official target. A unique reference measure has been seen as advantageous, relative to a multiple-indicator approach, because of its simplicity. However, unique-indicator regimes have not been able to maintain that simplicity in practice. Most such regimes employ a range, rather than a point-value, for their inflation goal. The boundaries of the ranges could reflect a wide variety of meanings, including those related to a diffuse goal, expected volatility in inflation, alternative policy reaction functions, and accountability structures. However, inflation-targeting central banks have not typically clarified the meaning of their inflation ranges, or what should be expected following a range breach. Often, escape clauses are used to explain that range breaches can be ignored because of special factors. These departures from simplicity generally seem to be concessions to the inherent complexities of monetary policy rather than pervasive failures to adhere to an appropriate standard.

More importantly, perhaps, a unique inflation indicator seems an over-simplification of the way central banks actually go about formulating monetary policy. Indeed, because of the idiosyncratic effects of special factors across inflation indicators, careful inspection of multiple indicators seems likely to deliver a better understanding of underlying inflationary developments. In these circumstances, a case can be made for central banks to announce that their goal of low, stable inflation will be achieved through the use of point-values for a few key reference measures of inflation that are important in the formulation of monetary policy. This approach would not lend itself to expectations of a mechanical policy response to inflation data, but single-indicator inflation targeters have also found it advisable to retain elements of discretion, or "flexibility," in implementing their policy frameworks.

The paper found support for a multiple-indicator approach in two types of analyses. First, in a theoretical model with sticky and flexible price sectors, optimal monetary policy needed to consider inflation in only one price measure (that for the sticky price sector), if there was no measurement uncertainty, as in Aoki (2001). However, when measurement uncertainty was added to the model, price measures for both the flexible and sticky price sectors had to be taken into account in formulating policy. Secondly, an empirical investigation of a factor model for U.S. inflation measures suggested that there may be no unique price measure that can capture underlying inflation processes. Thus, understanding inflationary developments may inherently require monitoring multiple indicators, as is the current central bank practice, rather than attempting to devise a unique optimal indicator. Finally, empirical evidence suggested that stabilizing one inflation indicator was not equivalent in practice to stabilizing other major inflation measures; indeed, strict targeting of one measure, to the exclusion of others, could imply quite different paths for policy, depending on the chosen indicator.

The paper also compared accountability frameworks in regimes with a single-indicator range to those with multiple inflation indicators. The single-indicator-range approach seemed preferable only if the official measure rarely gave false signals and if range breaches were indeed appropriate to avoid. In practice, however, these conditions often do not hold. Announcing more than one reference measure for inflation would address the criticism of false precision in inflation goal-setting and likely be more transparent about the genuine concerns of central bankers in the formulation of policy. Moreover, pre-announcing alternative inflation reference values, like the pre-announcement of "escape clauses" under inflation targeting frameworks, may avoid an over-simplified accountability structure and actually improve the credibility of a central bank's anti-inflationary resolve over time.

Accountability structures can put pressures on the formulation of monetary policy that are inherently backward-looking and are sometimes misdirected. These pressures would likely be more intense for a central bank that does not issue regular inflation reports discussing alternative inflation indicators and providing forecasts as contextual frameworks for the current setting of policy. For such central banks, a multiple-indicator approach could have a particular advantage over the implementation of an inflation goal through a unique official inflation measure.

This paper also suggests the desirability of further research on the welfare effects of maladaptive accountability structures, on the expectations of financial markets and of policy makers about policy responses at range boundaries for those central banks with inflation ranges, and on likely economic performance under single- versus multiple-indicator approaches to inflation targeting.

Appendix 1

Optimal Inflation Target with Sector Price Measurement Errors

This appendix depicts a modification of a model developed by Mankiw and Reis (2003) to allow for measurement error in the sectoral prices observed by the central bank. Mankiw and Reis show microfoundations for a model whose reduced form version involves the following price setting behavior by the private sector:

$$P_k^* = P + \alpha_k x + \varepsilon_k$$

$$P_k = \lambda_k P_k^* + (1-\lambda_k) E\left(P_k^*\right)$$

$$P = \sum_{k=1}^{K} \theta_k P_k \quad where \quad \sum_{k=1}^{K} \theta_k = 1$$

The first equation gives the equilibrium price for sector *k* as a function of aggregate prices, *P*, the output gap, *x*, and a sector productivity and markup shock, ε. The second equation reflects sluggish price setting, where some firms respond only to expected values of equilibrium prices, rather than fully updated values. The third equation gives the aggregate price measure based on expenditure weights, θ. The model is closed by adding a central bank that chooses sector weights, *w*, to form an aggregate price index that it holds constant while also trying to minimize the variance of the output gap. The central bank's problem is:

$$\min_{(w_k)} Var(x) \quad s.t. \quad \sum_{k=1}^{K} w_k P_k = 0 \quad and \quad \sum_{k=1}^{K} w_k = 1.$$

In a two-sector implementation of the model, Mankiw and Reis find that a sector with more sluggish prices should have a larger weight in the central bank's price index (as long as the weight is less than unity). They caveat Aoki (2001) by finding that sectors with fully flexible prices may get a nonzero weight in an optimal index because of sectoral differences in expenditure shares, shock variances, and responsiveness to the business cycle. In particular, they show that a sector should get a larger weight if it is more responsive to the business cycle (larger α) or if its productivity and markups are less volatile (smaller *Var(ε)*).

The Mankiw/Reis model is now modified by assuming that the central bank observes sector prices with transitory errors uncorrelated across sectors. Private sector agents are not subject to significant measurement error because of special knowledge of their own and closely related sectors and because aggregate measurement error is damped by convergence to the mean value of zero. The central bank's nominal anchor is then given by:

$$\sum_{k=1}^{K} w_k \left(P_k + \mu_k\right) = 0 \, ,$$

where μ_k is an i.i.d. measurement error in sector *k*. As in Mankiw and Reis, the distributions of shock variables are known. Using the constraint equations, the output gap can be expressed as a function of the true sector shocks and the central bank's measurement errors, where each variable is expressed as a deviation from its expected value. For a model with two sectors, A and B:

$$x = -\frac{[w_A + \lambda_B(\theta_A - w_A)]\lambda_A\varepsilon_A + [1 - w_A - \lambda_A(\theta_A - w_A)]\lambda_B\varepsilon_B + [\lambda_A\theta_A - 1 + \lambda_B(1-\theta_A)][\mu_B(w_A - 1) - \mu_A w_A]}{\alpha_A\lambda_B + w_A(\alpha_A\lambda_A - \alpha_B\lambda_B) + \lambda_A\lambda_B(w_A - \theta_A)(\alpha_A - \alpha_B)} \, .$$

Taking the variance of *x* under the assumption of zero covariance among the shocks, the first order condition for the weight in sector *A* is:

$$w_A = \frac{\lambda_B[\alpha_A V_B^{\varepsilon} - \theta_A\lambda_A(\alpha_A V_B^{\varepsilon} + \alpha_B V_A^{\varepsilon})] + R V_B^{\mu}}{\alpha_B\lambda_A(1-\lambda_B)V_A^{\varepsilon} + \alpha_A\lambda_B(1-\lambda_A)V_B^{\varepsilon} + \left[\dfrac{\alpha_B}{\lambda_A} + \theta_A(\alpha_A - \alpha_B)\right] Q V_A^{\mu} + R V_B^{\mu}}$$

$$\textit{where} \quad Q = 1 - \lambda_B + \theta_A(\lambda_B - \lambda_A) \quad \textit{and} \quad R = \left[\frac{\alpha_A}{\lambda_B} + (1-\theta_A)(\alpha_B - \alpha_A)\right] Q$$

and V_j^i = $Var(i_j)$. The signs of the comparative statics depend in a complex way on the shock variances and other parameters. However, if we focus on the issues of measurement error and speed of price adjustment, with other parameters equal across sectors, the optimal weight is:

$$w_A = \frac{\lambda_B(1-\lambda_A)V^{\varepsilon} + \frac{S}{\lambda_B}V_B^{\mu}}{\left[\lambda_B(1-\lambda_A)+\lambda_A(1-\lambda_B)\right]V^{\varepsilon} + \frac{S}{\lambda_A}V_A^{\mu} + \frac{S}{\lambda_B}V_B^{\mu}} \quad where \quad S = 1 - \frac{1}{2}(\lambda_A + \lambda_B) > 0$$

In this case, it is readily seen that $0 < w_A < 1$. Increased uncertainty about a sector price measure implies a smaller weight for the sector in the optimal price index:

$$\frac{\partial w_A}{\partial V_A^{\mu}} = -\frac{\lambda_B(1-\lambda_A)V^{\varepsilon} + \frac{S}{\lambda_B}V_B^{\mu}}{\left[(\lambda_A + \lambda_B - 2\lambda_A\lambda_B)V^{\varepsilon} + \frac{S}{\lambda_A}V_A^{\mu} + \frac{S}{\lambda_B}V_B^{\mu}\right]^2}\frac{S}{\lambda_A} < 0.$$

Interestingly, even if there is no measurement uncertainty in other sectors, $V_B^{\mu} = 0$, the optimal price index does not exclude a sector that is subject to measurement error, but rather gives it a lower weight depending on the degree of measurement uncertainty.

If prices are perfectly flexible in sector *B* ($\lambda_B = 1$) but sluggish in sector A, the optimal weight in sector A is:

$$w_A = \frac{2V^{\varepsilon} + V_B^{\mu}}{2V^{\varepsilon} + V_B^{\mu} + \frac{V_A^{\mu}}{\lambda_A}} \leq 1.$$

If there is no measurement uncertainty, $w_A = 1$, as in Aoki (2001). However, in the presence of measurement uncertainty regarding prices in the sluggish price sector ($V_A^{\mu} > 0$), that sector should not get all the weight in an optimal inflation index.

Appendix 2

Factor Model of U.S. Inflation Measures

This appendix reports on tests of the number of factors needed to encompass major U.S. inflation measures, using the matrix rank test of Cragg and Donald (1997), as implemented by Swanson (see Gurkaynak, Sack, and Swanson, 2005). If X is a matrix with n columns, each a time series of a different inflation measure, a factor model for X takes the form:

$$X = F \cdot L + \varepsilon,$$

where F is a matrix with m columns, each representing a factor, with $m < n$, while L is an m-by-n matrix of factor loadings, and ε is a matrix of white noise errors. Under the null hypothesis that X can be represented by m common factors, rather than $M > m$, the minimum normalized distance between Cov(X) and the model covariance of $L'L + \Sigma_\varepsilon$ has a χ^2 distribution with $\frac{n(n-1)+m(m-1)}{2} - nm$ degrees of freedom.

The tests are run on monthly and quarterly data. Monthly series include the total and core indexes for current methods consumer prices, personal consumption expenditure prices, and producers' prices for finished goods and intermediate materials. For the quarterly series, chain-weight price indexes for GDP, nonfarm business output, producers' durable equipment, and imports are included. A sample period from 1959 through September 2005 is used, as well as a second period beginning in 1974, which allows inclusion of the core PPI measures.[9]

The test results are given in Table 4. A p-value greater than 5 percent indicates that the null hypothesis cannot be rejected, and thus the indicated number of factors can represent

[9] Augmented Dickey-Fuller tests rejected a unit root in each of these inflation series over the indicated period.

the common movements of the variables. As shown in the table, the tests indicate that the co-movements among these inflation measures cannot be represented by a single factor. For monthly data and for quarterly data beginning in 1959, two factors appear to be sufficient. Additional factors are needed to explain common movements since 1974 in data sets that include core PPI series.

Table 4 also reports on the "communalities," or proportion of the variance of a variable explained by the common factors. While loadings on the factors (not shown) may vary depending on the particular "rotation" chosen for the model, the proportion of the variance of each price series that is explained by the factors does not change with alternative rotations. The communalities therefore may be a more useful guide to interpreting the factors.

The first column of Table 4 indicates that a two-factor monthly model does a good job of accounting for movements in total and core PCE prices and the total CPI series since 1959, but it explains only 50 to 60 percent of the variance of the core CPI and PPI measures. The four factors needed to represent co-movements in monthly data since 1974 explain a high proportion of the variance of most series, though total and core measures of the PPI for finished goods are less well explained. Separate tests (not shown) indicated rejection at the one percent level of the null hypothesis that one factor could represent co-movements in the four monthly *core* price measures since 1974 or in the four consumer price measures since 1959.

With the smoothing of data in quarterly series, two factors explain large fractions of the variance of most individual series since 1959, with prices for intermediate goods, producers' durable equipment, and imports somewhat less well represented. With the three factors called for in quarterly data since 1973, three-fourths or more of the variance of each price series was explained by common factors. A third factor called for in the period since 1974 considerably boosted the explanatory power for intermediate goods prices.

Table 4

	1959:2–2005:9	1974:2–2005:9	1959:Q2–2005:Q3	1974:Q2–2005:Q3
	Monthly	Monthly	Quarterly	Quarterly
Factors	*2*	*4*	*2*	*3*
p-value on null of # of factors	.240	.057	.135	.100
p-value on null of 1 less factor	.004	.007	.007	.000
INFLATION MEASURES:	Communalities:			
CPI (current methods)	0.818	0.959	0.915	0.914
Core CPI (current methods)	0.514	0.901	0.823	0.840
PCE	0.954	0.999	0.985	1.000
Core PCE	1.000	0.971	0.971	0.962
PPI (finished goods)	0.625	0.683	0.851	0.829
Core PPI (finished goods)		0.579		0.885
PPI (intermediate goods)	0.554	0.966	0.756	0.999
Core PPI (intermediate goods)		0.804		0.911
GDP			0.926	0.948
Non-Farm Business Sector			0.885	0.907
Producers Durable Equipment			0.683	0.798
Imports			0.719	0.739

References

Aoki, K., 2001, "Optimal Monetary Policy Responses to Relative-price Changes," *Journal of Monetary Economics* 48, 55-80.

Ayales, E., R. Merris and A. Torrez, 2002, "Inflation Targeting: Statistical Issues Suggested by the Experience of Six Emerging Market Countries," in Statistical Implications of Inflation Targeting, ed. by C. Carson, C. Enoch, and C. Dziobek, International Monetary Fund.

Bernanke, B., 2004, "Inflation Targeting," in *Review*, Federal Reserve Bank of St. Louis, July/August.

Bernanke, B., T. Laubach, R. Mishkin, and A. Posen, 1999, Inflation Targeting, Princeton University Press.

Bowen, A., 1995, "Inflation Targetry in the United Kingdom," in Targeting Inflation, ed. by A. Haldane, Bank of England, pp. 59-74.

Clark, T.E., 1999, "A Comparison of the CPI and the PCE Price Index," Economic Review, Federal Reserve Bank of Kansas City, Third Quarter, 15-29.

Cragg, J. G., and S. G. Donald, 1997, "Inferring the Rank of a Matrix," Journal of Econometrics 76, 223-250.

Debelle, G. and G. Stevens, 1995, "Uncertainties in Inflation Forecasting," in Targeting Inflation, A. Haldane, ed., Bank of England, pp. 81-112.

Dennis, R., 1997, "Bandwidth, Bandlength, and Inflation Targeting," Reserve Bank of New Zealand Bulletin 60:1, pp. 22-26.

Erceg, C., 2002, "The Choice of an Inflation Target Range in a Small Open Economy," *American Economic Review* 92(2), pp. 85-89.

Erceg, C., D. Henderson, and A. Levin, 2000, “Optimal Monetary Policy with Staggered Wage and Price Contracts,” *Journal of Monetary Economics* 46, 281-313.

Faust, J. and D. Henderson, 2004, "Is Inflation Targeting Best Practice Monetary Policy?" *Review*, Federal Reserve Bank of St. Louis, July/August.

Gavin, W., 2004, "Inflation Targeting: Why It Works and How To Make It Work Better," *Business Economics*, April, 39, pp. 30-37.

Goodfriend, M., 2005, "Inflation Targeting in the United States?" in The Inflation-Targeting Debate, B. Bernanke and M. Woodford, ed., University of Chicago Press.

Greenspan, A., 2002, "Transparency in Monetary Policy," *Review*, Federal Reserve Bank of St. Louis, July/August.

Gurkaynak, R., B. Sack, and E. Swanson, 2005, "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, May, pp. 55-93.

Haldane, A. and C. Salmon, 1995 "Three Issues on Inflation Targets," in Targeting Inflation, A. Haldane, ed., Bank of England, pp. 170-201.

Heikensten, L. and A. Vredin, 2002, "The Art of Targeting Inflation," *Sveriges Riksbank Quarterly Review* 4, pp. 5-34.

Huang, K.X.D., and Z. Liu, 2005, “Inflation Targeting: What Inflation Rate to Target,” *Journal of Monetary Economics* 52(8), pp. 1435-1462.

International Monetary Fund, 2005, "Does Inflation Targeting Work in Emerging Markets," World Economic Outlook, Chapter IV.

Knight, M., R. Fay and B. O'Reilly, 2002, "The Bank of Canada's Approach to Inflation Targeting," in Statistical Implications of Inflation Targeting, ed. by C. Carson, C. Enoch, and C. Dziobek, International Monetary Fund.

Kohn, D., 2004, "Inflation Targeting," *Review*, Federal Reserve Bank of St. Louis 86(4), pp. 179-183.

Lacker, J., 2005, "Inflation Targeting and the Conduct of Monetary Policy," remarks at the University of Richmond, March 1.

Lebow, D. and J. Rudd, 2003, "Measurement Error in the Consumer Price Index: Where Do We Stand?", Journal of Economic Literature 41, pp. 159-201.

Levin, A., A. Onatski, J. Williams, and N. Williams, 2005, "Monetary Policy under Uncertainty in Micro-Founded Macroeconometric Models," NBER working paper # 11523.

Mankiw, N.G., and R. Reis, 2003, "What Measure of Inflation should a Central Bank Target?" *Journal of the European Economic Association* 1(5), pp. 1058-1086.

Meyer, L. H., 2004, "Practical Problems and Obstacles to Inflation Targeting," *Review*, Federal Reserve Bank of St. Louis 86(4), pp. 151-160.

Mishkin, F., and N. Westelius, 2005, "Inflation Band Targeting and Optimal Inflation Contracts," working paper.

Orphanides, A. and V. Wieland, 2000, "Inflation Zone Targeting," *European Economic Review* 44, pp. 1351-1387.

Reifschneider, D., R. Tetlow, and J. Williams, 1999, "Aggregate Disturbances, Monetary Policy, and the Macroeconomy: The FRB/US Perspective," *Federal Reserve Bulletin*, January, pgs. 1-19.

Santomero, A., 2004, "Monetary Policy and Inflation Targeting in the United States," remarks before the NABE/GIC Conference, October 4.

Sherwin, M., 2000, "Strategic Choices in Inflation Targeting: The New Zealand Experience," in Inflation Targeting in Practice, ed. by M. Blejer, A. Ize, A. Leone, and S. Werlang, International Monetary Fund.

Sterne, G., 1999, "The Use of Explicit Targets for Monetary Policy: Practical Experiences of 91 Economies in the 1990s," *Quarterly Bulletin*, Bank of England, August.

Stern, G. and P. Miller, 2004, "Avoiding Significant Monetary Policy Mistakes," *Quarterly Review*, Federal Reserve Bank of Minneapolis, December, 2-9.

Svensson, L., 1997, "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets," *European Economic Review* 41, pp. 1111-1146.

Taylor, J., 1979, "Estimation and Control of a Macroeconomic Model with Rational Expectations," *Econometrica* 47, 1267-1286.

Tetlow, R., 2000, "Inflation Targeting and Target Instability," *Finance and Economics Discussion Series* 2000-1. Board of Governors of the Federal Reserve System.

Truman, E., 2003, Inflation Targeting in the World Economy, Washington D.C., Institute for International Economics.

Williams, J., 2003, "Simple Rules for Monetary Policy," *Economic Review*, Federal Reserve Bank of San Francisco, pgs. 1-12.

Woodford, M., 2004, "Inflation Targeting and Optimal Monetary Policy," *Review*, Federal Reserve Bank of St. Louis 86(4), pp. 15-41.