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William T. Gavin
Editor
July 31, 2005

Understanding the Term Structure of Interest Rates

William Poole

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A topic much discussed in recent months is the relationship over the past year or so between long-term and short-term interest rates. Some observers have argued that the failure of long rates to trend up as the Fed has increased its target federal funds rate is a puzzle. Others have argued that Fed policy is ineffective because increasing the rising short rate is not affecting the long rate. I'll not say much about the policy issue, but I do want to address the puzzle.

However, I'm going to define the puzzle somewhat narrowly. I'll not address the current low level of the real rate of interest on long-term bonds. That same puzzle existed a year ago, although it may not have been so obvious at the time. What I'll discuss is the issue of why the long rate has not increased as the Fed has raised the target federal funds rate.

I thank my colleagues at the Federal Reserve Bank of St. Louis—especially Ed Nelson—for their assistance and comments.

THE RECENT TERM STRUCTURE PUZZLE

Since June 2004, the Federal Open Market Committee (FOMC) has increased the target federal funds rate by 25 basis points every time they have met, including the recent meeting on May 3. Moreover, the federal funds futures market predicted that the Committee would raise the target funds rate by another 25 basis points at its June meeting. On the other hand, a key long-term interest rate, the yield on 10-year U.S. Treasury securities, has shown little persistent tendency to change, either up or down, over the same period. I refer to this discrepancy in interest rate patterns as the recent *term structure puzzle*.

The eight increases in the target funds rate took it from 1 percent to 3 percent as of May 3, 2005. The 10-year Treasury bond rate, however, has exhibited a different pattern. If we look at monthly average data, which I'll use throughout unless indicated otherwise, we can see that the rate has not had a persistent trend since mid-2002, when the rate was about $4^1/_2$ percent (a rate that also prevailed at the end of 2003 and again this spring). The monthly average level of the bond rate increased by about 90 basis points from March to June 2004, mostly in response to evidence of stronger economic growth and the beginning of Fed tightening. The June 2004 level of 4.73 percent on the bond rate was the highest since June 2002 and has not been exceeded since.

Some observers like to emphasize that the long rate has declined since the Fed first started

William Poole is the president of the Federal Reserve Bank of St. Louis. The author appreciates comments provided by colleagues at the Federal Reserve Bank of St. Louis. Edward Nelson provided special assistance. The views expressed are the author's and do not necessarily reflect official positions of the Federal Reserve System.

raising rates in June 2004, but I think the right observation, given the variability of the rate, is to say that the long rate has fluctuated around roughly $4^1/_2$ percent since mid-2002. June 2004 is not the best month to begin the analysis because the Fed's rate increases were foreseen some months in advance. Based on the July 2004 federal funds futures contract, in late 2003 the market anticipated a funds rate of 1.25 percent or above, but then the expected rate for July fell to nearly 1 percent (i) as the FOMC maintained its 1 percent target funds rate at its January and March 2004 meetings and (ii) as a consequence of somewhat weak economic data. When the FOMC introduced the "measured pace" language at its meeting of May 4, 2004, the market priced-in a policy target of 1.25 percent for the June 2004 FOMC meeting. In any event, I'll frame this puzzle as the *failure of long-term interest rates to increase* as short-term interest rates have risen since the late winter and spring of 2004.

Two phenomena deserve to be distinguished: the *level* of long-term rates and the change in long rates as short rates have risen. Low long-term rates were already in place before the recent term structure puzzle, and some major factors behind low long-term rates do not necessarily help in explaining the term structure puzzle, which concerns changes in rates. Most notably, Fed Governor Ben Bernanke (2005) has convincingly argued that the "global saving glut" has been a depressing factor on U.S. real and nominal interest rates since 2000. Yet this factor does not solve the term structure puzzle, for two important reasons. First, as noted, the glut has been in force throughout this decade, whereas the term-structure puzzle refers to the period since early 2004. Second, the glut is a source of downward pressure on real interest rates at all maturities since 2001, whereas the term structure puzzle instead refers to the recent flat trend of the long rate despite a significant increase in the short rate.

AVERAGE HISTORICAL BEHAVIOR

That there is a puzzle is a consequence of just how atypical the recent behavior of the term structure is. The funds rate and bond rate do typically move in the same direction. A linear regression of the first difference of the bond rate on the first difference of the federal funds rate provides a simple description of the average relationship between the bond rate and funds rate. The regressions indicate that the contemporaneous relationship between the two series is positive and statistically significant. For the entire period from May 1954 to March 2005, the regression coefficient is a bit below 0.2; for the period from January 1984 to March 2005, the coefficient is a bit above 0.3. Using the period from 1984, what the coefficient means is that on average a 100-basis-point change in the funds rate has been associated with a 32-basis-point change in the bond rate in the same direction. Thus, over the past year, as the funds rate rose by 200 basis points, we should have seen an increase of the bond rate of about 65 basis points. Depending on how you eyeball your favorite chart of the 10-year bond rate, instead of increasing, the bond rate has been about flat, or down somewhat, over the past year.

THE EXPECTATIONS THEORY OF THE TERM STRUCTURE

To decide whether there really is a puzzle, or to make sense of the puzzle, we'll need to call on economic theory. According to economic theory, a key reason why the contemporaneous relationship between the funds rate and the bond rate is far from one-for-one is that changes in the bond rate should be closely linked not to today's change in the funds rate but to revisions in expectations of the future path of the funds rate. The theory will provide a framework for an analysis of the recent term structure puzzle.

The essential message of the expectations theory of the term structure is that market forces should make longer-term interest rates a weighted average of the short-term interest rates expected to prevail over the life of the bond. The investor should be indifferent between making N consecutive investments in 1-period securities and investing in an N-period bond. Or at least enough investors should be indifferent to force the N-period bond to trade in the market at the weighted average of the next N 1-period bonds. To take a simple example, letting time be quarters, the expectations theory says that the 2-quarter interest rate should be equal to the average of today's 1-quarter interest rate and the expected 1-quarter rate next quarter. We assume that today's expectation of next quarter's 1-quarter rate is based rationally on all information available today.

The argument applies to bond rates of any maturity. The simple expectations theory implies that the 10-year bond rate reflects the expected path over the next ten years of the short-term rate. The 10-year bond rate at the beginning of June 2004 incorporated the 1-year rate and the next nine expected 1-year rates, the last of which was a 1-year rate on a security that would be issued in June 2013 and mature in June 2014.

Similarly, the 10-year rate prevailing at the beginning of June this year incorporated the current 1-year rate and the next nine expected 1-year rates, the last of which was a 1-year rate on a security that would be issued in June 2014 and mature in June 2015. After comparing the 10-year bond from a year ago with the one today, we see that nine of the ten 1-year periods are the same. Today's 10-year bond does not include the 1-year rate prevailing in June 2004—that security has matured. Today's 10-year bond does include the expected 1-year rate on a security maturing in June 2015. Thus, the difference in the yields on the two 10-year bonds—last June's and this June's—reflects substitution of (i) the expected 1-year rate for a security to be issued in June 2014 for (ii) the 1-year rate in the market in June 2004 for the security that has just matured in June 2005, *plus revisions* in the expected 1-year rates to prevail every year from 2005 through 2013. The key to understanding changes in the 10-year rate is to understand revisions in those nine expected 1-year rates.

To understand the process by which expected future 1-year rates are revised, it is useful to partition the 1-year rate into a real rate and an inflation premium. How might we anticipate far-off expected real short rates to behave? This variable should respond to new information about the real shocks likely to be facing the economy several years in the future. It would be tempting to think that such new information arises so infrequently that the distant short-term real rate could be treated as constant.

There is considerable evidence against this presumption, however. For example, Laubach (2003) finds that expectations of short-term nominal interest rates beyond five years in the future fluctuate in response to the changes in multiyear budget deficit projections, and some of this fluctuation may reflect revisions to expected real rates. It is not hard to imagine other information that might rationally affect investor expectations about distant real rates. Ultimately, the issue is an empirical one and it does appear that the expected real short rate fluctuates considerably in practice.

Historically, expected future nominal short rates have often fluctuated in response to changes in inflation expectations. Over the past year, distant inflation expectations, as measured by the spread between conventional and inflation-protected bonds, have not changed markedly. Thus, we can proceed by assuming that long-term expectations of inflation have remained roughly constant in the past year because of confidence in Federal Reserve policies and, in the absence of information to the contrary, that there is no new information about far-off real rates. With these assumptions, the change in the long rate is driven by new information about the medium-term path of short-term real interest rates.

For example, if newly published data suggest greater pressure on aggregate demand in the years immediately ahead, agents will expect a greater degree of offsetting pressure from the Federal Reserve in the form of higher real interest rates, and the expectation of future real rates will be higher than the expectation based on the prior period's information set. My emphasis in this discussion is that new information about the state of the economy drives changes in long-term interest rates.

A DETAILED LOOK AT JANUARY 2004–MAY 2005

Consider the behavior of bond rates since the beginning of 2004 from the perspective of the expectations theory of the term structure. In January 2004, the 10-year bond rate was 4.15 percent; in January 2005, it was 4.22 percent. I'll concentrate on information that has created revisions to future expected short rates.

Consider revisions to expected real short rates in immediately coming years. In past tightenings, such as in 1994, policy-induced increases in real rates led to sharp contemporaneous increases in bond rates. The past year has not repeated this phenomenon because the Federal Reserve indicated its tightening intentions well in advance and because the economy has performed about as expected.

An indication of what markets were expecting as of January 2004 is given by the Blue Chip Consensus forecast for real gross domestic product (GDP) growth in 2004 of 4.6 percent. In the event, U.S. real GDP growth in 2004 was 4.4 percent. In 2004, the economy performed as close to expected as we will find in the historical record. Events have not much changed the outlook for 2005 either. In January 2004, the Blue Chip Consensus forecast for 2005 real growth was 3.7 percent; the latest (June 10, 2005) Blue Chip forecast is for real growth of 3.5 percent, an extremely small downward revision from the expectation prevailing in January 2004.

To study this matter more carefully, I've examined large daily movements of the 10-year bond rate since January 2004. These are listed in Table 1. The criterion for determining a "large" movement is a change of 10 basis points or more in the bond rate.

See the table for details; I will provide here the flavor of major financial news that occurred on some of the "large change" days. The sluggish recovery of employment during this expansion was reflected in weak payroll data that surprised the market on January 9, 2004, and March 5, 2004, leading to declines in the bond rate of 16 basis points and 19 basis points, respectively. These employment reports led to revisions of market expectations toward a slower expected withdrawal by the Fed of its accommodative policy stance, and, accordingly, expectations of real short rates over the next few years declined.

As another example, the oil price spike on March 9, 2005, was associated with an increase in the bond rate of 14 basis points. Such bond rate increases can be interpreted two ways. One interpretation is that markets did not revise upward their expectations of future inflation but did revise upward their expectations of the Fed monetary policy required to keep inflation stable. Alternatively, the bond rate increase may have reflected expectations that the Fed would accommodate a temporary increase in inflation in the wake of the oil shock.

Expectations of future monetary policy have affected the bond rate significantly from time to time. A recent study by Gürkaynak, Sack, and Swanson (2005), covering a period earlier than that considered here, finds that news about likely future FOMC actions on the funds rate has an important effect on the bond rate, distinct from FOMC actions on the current funds rate. This finding is, of course, in line with the expectations theory. In the period considered here, news about future policy increased bond rates by 11 basis points on January 28, 2004, when the FOMC dropped from its press release the phrase that it expected policy accommodation to prevail "for a considerable period." Once this phrase was dropped, markets revised their expectations of short rates to a higher path than previously, and bond rates accordingly were immediately revised upward.

Although certain data releases did surprise the market, over the period as a whole the data came in about as expected, contributing to the absence of a trend in the bond rate over the period at issue. Likely policy responses to economic data were also known in advance; and, in the absence of economic surprises, FOMC decisions on the funds rate were much as expected. Thus, there was no particular reason over this period for the market to revise its expectations of future interest rates continuously in one direction; the bond rate fluctuated in response to arriving information, but ended up about where it started.

The argument I am making is not a new one. There is a huge literature on the expectations theory of the term structure of interest rates, and policymakers have long been aware of the basic ideas. For example, the Radcliffe Committee, a

Table 1

Selected Changes in the 10-Year Treasury Bond Rate, January 2004–May 2005

Date	Bond-yield change, basis points	Main news item	Source
1/6/2004	–12	Weaker-than-expected growth in services sector	Reuters
1/9/2004	–16	Weaker-than-expected payroll data	*DJNW*
1/28/2004	+11	Federal Reserve drops "for a considerable period" language from FOMC statement	*NYT*
3/5/2004	–19	Weaker-than-expected payroll data	*WSJ*
4/2/2004	+24	Higher payroll data	*WSJ*
4/13/2004	+10	Weaker-than-expected retail sales for March 2004	*DJNW*
5/7/2004	+16	Better-than-expected payroll data	*WSJ*
6/15/2004	–20	Better-than-expected May inflation; reaction to Greenspan Senate testimony	*FT*
7/16/2004	–12	Better-than-expected June inflation	*DJNW*
7/27/2004	+13	Better-than-expected July consumer confidence	*DJNW*
8/6/2004	–19	Lower-than-expected payroll data	*WSJ*
10/8/2004	–11	Weaker-than-expected payroll data	*DJNW*
10/27/2004	+10	Higher oil prices	*DJNW*
11/5/2004	+11	Better-than-expected payroll data	*WSJ*
12/3/2004	–13	Weaker-than-expected payroll data	*DJNW*
12/16/2004	+10	Continuing reaction to FOMC statement	*DJNW*
3/9/2005	+14	Concern about spike in oil prices	*NYT*
4/15/2005	–10	Continued rise in energy prices. Disappointing reports from Ford and GM	Bloomberg
4/21/2005	+10	Better-than-expected manufacturing report and jobless claims data	Bloomberg

NOTE: *DJNW, Dow Jones News Wire*; *FT, Financial Times*; *NYT, New York Times*; *WSJ, Wall Street Journal*. Dates refer to the date of the interest rate change; sources refer to same-day wire reports and next-day newspaper reports on the principal economic news accompanying the bond rate movement.

U.K. inquiry into monetary policy in the late 1950s, noted that "It is generally agreed that the more temporary a rise in short rates is expected to be, the less it will cause long rates to rise; correspondingly, the more temporary a drop is expected to be, the less will long rates fall."[1] Arthur Burns, then Federal Reserve Chairman, observed in 1977 that "Long-term interest rates, of course, are of much larger significance to the economy than short-term rates; but the long-term rates are also especially sensitive to inflationary expectations."[2] In a 1976 paper, I studied the implications for monetary policy of the expectations theory and concluded that the "implications of the rational expectations hypothesis for macro modeling are profound... This point is of greatest importance for the auction markets in financial assets" because the expectations theory tells us that "long-term interest rates adjust immediately and fully in response to new information."[3]

The expectations theory of the term structure

[1] Radcliffe Committee (1959, paragraph 447).

[2] Burns (1977, p. 724).

[3] Poole (1976, pp. 471, 503).

has been severely criticized on a number of grounds, but for the problem at hand I believe that the theory tells the basic story correctly. In sum, economic surprises have been minimal over the past year and there has been no reason for significant revision in expected future short-term interest rates. Thus, there has been no reason for a significant trend in long-term interest rates.

FULL CIRCLE

I began by discussing the average term structure relationship, in which long rates change by about 30 basis points for every 100-basis-point change in short rates. Now I'll circle back to that topic.

The average relationship reflects average business cycle experience in which information surprises change expectations about future short rates. But a casual glance at the data will show how variable these periods have been. In some cases, long rates rose by much more than 30 basis points for every 100-basis-point increase in short rates, and in some cases much less. For example, over the 12 months ending July 1987, the bond rate rose by 115 basis points while the federal funds rate was rising by only 2 basis points. In contrast, over the 24 months ending in July 1963, the 10-year bond rate rose by only 10 basis points while the federal funds rate was rising by 185 basis points. Clearly, I've picked out particular cases to serve as examples; but I can assure you that, if you look at the data systematically, you will find that the average term structure relationship of about 30 basis points on the bond rate for every 100 basis points on the funds rate is the average of very diverse experience. If I were writing a Ph.D. thesis, I could explore in great detail the flow of information and how both short and long rates responded as new information changed expectations about inflation, real growth, and Fed policy.

Because the role of changes in inflation expectations has been so important historically, but not very important over the past decade or so, consider an example from the 1980s. The 10-year bond rate declined sharply over 1984-86, from 11.67 percent in January 1984 to 7.11 percent in December 1986. Kozicki and Tinsley (2005, p. 427) suggest that this decline reflected continued adjustment of 10-year-ahead expectations of inflation in the wake of the Volcker disinflation. They argue that the decline in consumer price index (CPI) inflation to about 4 percent in 1983 was not accepted as a lasting change until the mid-1980s, whereupon it became more fully reflected in long-term bond yields.

An episode that more closely resembles the 2004 experience is the period 1987-89. Here the FOMC raised the target federal funds rate sharply, but the long rate was fairly trendless. Kozicki and Tinsley (2005, Figure 1) show that the late 1980s was a period where 10-year-ahead expectations of inflation continued to decline, even though 1-year-ahead expectations rose. The rise in 1-year-ahead expectations probably reflected inflation already in the pipeline. Actual Fed policy over this period was, by contrast, disinflationary. It seems that this episode corresponds to one where the Fed adjusted down its long-run inflation objective. The long-term bond market understood this change and discounted the rise in CPI inflation as not reflecting the long-term direction of monetary policy.

FINAL THOUGHTS

It should be clear by now that I do not believe that there is a term structure puzzle reflected in interest rate behavior over the past year or so. Recent experience is unusual but far from unprecedented. The real economy has performed very close to expectation at the beginning of 2004. The major surprise has been the large increase in energy prices. The market has interpreted this increase as a relative price change and not a sign of higher long-run inflation. The spread between conventional and inflation-protected bonds has increased over the near-term horizon but not over the period 5 to 10 years out.

The fact that the 10-year bond has not exhibited a persistent trend over the past 18 months or so while the Fed has been increasing the target federal funds rate by 200 basis points is not evidence that something is awry with monetary policy. Think of the issue this way. At the beginning of a planning period the Fed has in mind a probable course for the economy and expectations about the policy adjustments that will be consistent with long-run policy objectives. Suppose the market has the same understanding as the Fed. Suppose also that events turn out largely as expected. Then, everything goes according to plan, including policy adjustments and the course of bond rates. In fact, in January 2004 the eurodollar futures contract for June 2005 traded at an average rate of 2.81 percent, which was not far off the target federal funds rate of 3.0 percent set by the FOMC on May 3, 2004.

I am not claiming that the Fed had a firm plan in mind in January 2004 to reach a target federal funds rate of 3 percent in May 2005, but rather that events have simply worked out that way, corresponding rather closely to the market's best guess as to how events would unfold. In any event, the fact that everything goes about as expected is certainly not evidence of a policy problem.

I would be delighted, as would professional forecasters, for the string of accurate forecasts to continue. But we would be well advised not to forget those forecast standard errors. They have not vanished. With respect to forecast errors, the future is more likely to be like the past several decades than like the past year. If real growth and/or inflation depart significantly from current expectations, then we will see a persistent trend in the bond rate. I hope we do not see such an outcome, for I believe that the current outlook for the economy is quite favorable. I hope that current expectations are realized.

REFERENCES

Bernanke, Ben S. "The Global Saving Glut and the U.S. Current Account Deficit." Homer Jones Lecture, Federal Reserve Bank of St. Louis, St. Louis, Missouri, April 14, 2005; http://www.federalreserve.gov/boarddocs/speeches/2005/20050414/default.htm.

Burns, Arthur F. Statement before the Committee on Banking, Finance and Urban Affairs, U.S. House of Representatives. *Federal Reserve Bulletin*, August 1977, *63*, pp. 721-28.

Gürkaynak, Refet S.; Sack, Brian and Swanson, Eric. "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking*, May 2005, *1*(1), pp. 55-93.

Kozicki, Sharon and Tinsley, P.A. "What Do You Expect? Imperfect Policy Credibility and Tests of the Expectations Hypothesis." *Journal of Monetary Economics*, March 2005, *52*(2), pp. 421-47.

Laubach, Thomas. "New Evidence on the Interest Rate Effects of Budget Deficits and Debt." Finance and Economics Discussion Series Paper No. 2003-12, Federal Reserve Board, April 2003.

Poole, William. "Rational Expectations in the Macro Model." *Brookings Papers on Economic Activity*, April 1976, *2*(76), pp. 463-505.

Radcliffe Committee. *Report: Committee on the Working of the Monetary System*. London: Her Majesty's Stationery Office. Command Paper No. 827, August 1959.

Targeting versus Instrument Rules for Monetary Policy

Bennett T. McCallum and Edward Nelson

Svensson (2003) argues strongly that specific targeting rules—first-order optimality conditions for a specific objective function and model—are normatively superior to instrument rules for the conduct of monetary policy. That argument is based largely on four main objections to the latter, plus a claim concerning the relative interest-instrument variability entailed by the two approaches. The present paper considers the four objections in turn and advances arguments that contradict all of them. Then, in the paper's analytical sections, it is demonstrated that the variability claim is incorrect, for a neo-canonical model and also for a variant with one-period-ahead plans used by Svensson, providing that the same decisionmaking errors are relevant under the two alternative approaches. Arguments relating to general targeting rules and actual central bank practice are also included.

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1 INTRODUCTION

In the recent literature on monetary policy analysis, several writers have emphasized the distinction between instrument rules—i.e., formulae for setting controllable instrument variables in response to current conditions—and targeting rules, as proposed by Svensson (1997, 1999).[1] In a major contribution, Svensson (2003) has presented a sophisticated and comprehensive case for the use of targeting rules, arguing that "monetary-policy practice is better discussed in terms of targeting rules than instrument rules" (2003, p. 429).[2] The superiority of targeting rules is, moreover, claimed to pertain to both normative and positive perspectives (pp. 428-30). Svensson's paper is rich in both analytical and practical content and provides insights that can be usefully pondered by all students of monetary policy analysis.

It is our belief, nevertheless, that the paper seriously overstates the relative attractiveness of targeting rules, from both normative and positive perspectives, and describes inaccurately the properties of instrument rules. The purpose of the present paper is to develop this argument. As a major part of our argument, we study in detail one concrete and important claim of Svensson's regarding interest rate variability induced by instrument rules with strong feedback. In the wide variety of cases considered, we find all results to be inconsistent with the claim.

The outline of the present paper is as follows. Section 2 presents explanations of the basic concepts and an introduction to the issues. Section 3

1 See, for example, Svensson (1997, 1999, 2003), Svensson and Woodford (2005), Rudebusch and Svensson (1999), Clarida, Galí, and Gertler (1999), Cecchetti (2000), Giannoni and Woodford (2003a,b), Jensen (2002), Walsh (2003), and Woodford (2003).

2 In what follows, quotations with page-number citations but no author or year indication, refer to that paper, i.e., Svensson (2003).

Bennett T. McCallum is a professor of economics at Carnegie Mellon University and a research associate of the National Bureau of Economic Research. Edward Nelson is a research officer at the Federal Reserve Bank of St. Louis and a research affiliate of the Centre for Economic Policy Research. An earlier version of this paper was presented at a conference at the Board of Governors of the Federal Reserve System, Washington, D.C., in March 2004 and will also be published in a Federal Reserve Board volume, *Models and Monetary Policy: Research in the Tradition of Dale Henderson, Richard Porter and Peter Tinsley* (J. Faust, A. Orphanides, D.L. Reifschneider, eds.). The authors thank Lars Svensson, James Bullard, Mark Gertler, Ricardo Rovelli, and Javier Vallés for comments on earlier drafts.

then takes up, and disputes, four particular criticisms of instrument rules that are central to the argument in Svensson (2003), after which Section 4 does the same for two additional criticisms. In Sections 5 and 6, the paper turns to the precise analytical claim mentioned above and develops results in a number of settings that show it to be incorrect. Finally, Section 7 provides a brief recapitulation.

2 BASIC IDEAS AND TERMINOLOGY

What is the distinction between instrument and targeting rules? A rule of the former type refers, quite simply, to some formula prescribing settings for the monetary policymaker's instrument as a function of currently observed variables. Well-known examples include the Taylor rule (1993), several interest rate rules studied by Henderson and McKibbin (1993a,b), and the activist monetary base rules of McCallum (1988) and Meltzer (1987). Precisely which variables are observable is, of course, a matter that can be debated in practical analyses, but is one on which the analyst has to take some explicit position. Note that expectations (based on current information) of present or future variables may be among the variables that the instrument in the rule responds to.[3]

The definition of targeting rules is somewhat more complex. There has been some evolution since Svensson's (1997, 1999) introduction of the concept,[4] but his current terminology recognizes both general and specific variants. Basically, a general targeting rule is the specification of a central bank objective function,[5] whereas a specific targeting rule is an optimality condition implied by an objective function together with a specified model of the economy (pp. 448-60).[6] Initially, optimization was presumed to be of the discretionary type, with period-by-period reoptimization based on prevailing initial conditions, but in Svensson (2003) the possibility of optimization from a "timeless perspective" (see Woodford, 1999) is also considered.

It is not our intention to argue that analysis with instrument rules is in all respects preferable to the use of targeting rules. Even if we held that belief, moreover, we would not think it socially desirable for all researchers to employ the same approach. Nevertheless, we are more attracted to analysis with instrument rules than with targeting rules and believe that a few words should be included to indicate why—especially since Svensson's numerous writings argue so strongly in favor of the targeting rule position.

As a matter of terminology, it seems inappropriate to refer to the specification of the policymaker's objective function as a *rule*. Obviously, for a given objective function, desirable instrument settings—i.e., policy actions—can be very different under the same prevailing conditions, depending on the policymaker's preferred model or models of the economy. There are words available to describe policymakers' objectives—for example, "policymakers' objectives"—so there is nothing analytical to be gained by referring to them as "general targeting rules." It is terminologically useful, rather, for objectives and rules to be clearly distinguished. Also, from the substantive perspective, the adoption of an objective function is innocuous if the function accurately represents the central bank's true preferences. But if it does not represent the true preferences and is made public, as in the scheme suggested in Svensson's Section 5.3.3, then the central bank will be describing its objectives dishonestly to the public, a

3 In cases in which expectations are based on current-period information, however, Svensson refers to this type of policy rule as an "implicit instrument rule."

4 In particular, only specific (not general) targeting rules were considered in Svensson (1997) and they were called "target rules."

5 Svensson (2003, p. 430) further requires that these be "*operational objectives*" (italics in original), i.e., numeric targets for particular variables, rather than a general concept such as "price stability."

6 Svensson has explained to us that he does not require that a specific targeting rule necessarily expresses an optimality condition, as he has in the past (1997, p. 1136), and his definition on p. 429 conforms to that explanation. On p. 430, however, he states that "specific targeting rules essentially specify operational Euler equations." Also, on p. 455 Svensson states that "a specific targeting rule specifies a condition…[that] may be an optimal first-order condition, or an approximate first-order condition." In the remainder of this paper, accordingly, we shall follow Svensson's practice by typically treating specific targeting rules as first-order optimality conditions.

practice that seems inconsistent with Svensson's emphasis on transparency.[7]

The most critical problem with specific targeting rules—i.e., first-order optimality conditions—is that they are obviously model-dependent.[8] By construction, the coefficients and variables that appear in these rules are always closely related to the precise specification of private sector behavior in the associated model—and thus to the assumptions made regarding the parameters and dynamics of the model's IS, Phillips curve, and any other key structural equations. It is unclear which portion of today's macroeconomic models are most questionable, but it is entirely clear that there is much dispute among leading scholars concerning the proper specification of several of the crucial relationships. Yet a condition that implies policy optimality in one model may be highly inappropriate under other specifications. Consequently, an attractive approach to policy design, promoted, for example, by McCallum (1988, 1999), is to search for an instrument rule that performs at least moderately well—avoiding disasters—in a variety of plausible models. In other words, it is our belief that it is unwise to restrict policy analysis to optimal-policy exercises, which will typically be optimal only for the single model being used. Yet such analysis is precisely what is contemplated by focus on specific targeting rules.

A good illustration of the model-dependence of optimality conditions is provided in a recent paper by Levin and Williams (2003), which is a follow-up to the robustness study of Levin, Wieland, and Williams (1999). The initial experiments of Levin and Williams (2003) calculate the consequences of using a policy rule, designed to be optimal in *one* model, in *other* models. The three models in their introductory example are (i) a "New Keynesian" baseline model (NKB) that is highly prominent in recent theoretical research, (ii) an alternative specification (denoted FHP) with more sources of inertia used by Fuhrer (2000), and the empirically oriented model of Rudebusch and Svensson (1999, RS hereafter). Suppose a specific targeting rule is optimal in a calibrated version of the NKB model, with a loss function that assigns output gap variability a weight of λ (as in Section 5) and also gives interest rate variability a weight of 0.1, both in relation to inflation variability relative to target. If that optimality condition is used instead in the FHP model, the loss values are 95 or 150 percent higher (for λ values of 0.0 and 0.5, respectively) than the minimum loss in that model. Even more strikingly, if this NKB optimality condition is transferred to the RS model, the combination generates explosive oscillations—an "infinite" percentage deterioration. Next, a specific targeting rule that is optimal in the FHP model produces losses that are 173 percent or 130 percent greater than the minimum loss in the NKB model and explosive oscillations in the RS model. Finally, a rule that is optimal in the RS model generates analogous loss increases of 219 percent or 254 percent in the NKB model and 146 percent or 128 percent in the FHP model.

As an extension of our position, we would suggest that it is not desirable *always* to limit analysis to cases in which an explicit objective function has been specified. Explicitness is itself a virtue, of course, other things equal. But it is unclear what terms actually appear in central banks' objective functions and what weights each term receives. It is also unclear what weights and terms *should* appear, since there is professional disagreement over proper model specification.[9] Accordingly, it can be useful to explore the way in which different properties of a modeled economy (e.g., variances of key endogenous variables) are related to policy rule parameters, leaving it to actual policymakers to assign the relevant weights. Examples of this approach appear in some of our previous papers (e.g., McCallum and Nelson, 1999a,b), as well as in Bryant, Hooper, and Mann (1993).

[7] Svensson has informed us that he would have the central bank explain the discrepancy between its objective function and preferences to the public. We consider that such a need reflects a substantial degree of nontransparency.

[8] The existence of model dependency is recognized by Svensson (p. 450).

[9] Our position does not deny the attractiveness in principle of basing policymaker objective functions on the preferences of individual agents.

3 FOUR MAIN OBJECTIONS

After some preliminary discussion, Svensson considers the case of central bank commitment to an optimal instrument rule (which he terms an implicit reaction function when the rule includes any current endogenous variables) and concludes that the implied approach is "completely impractical." Indeed, Svensson states that "commitment to an optimal instrument rule has no advocates, as far as I know" (p. 439). With this particular judgment we have no serious disagreement; see McCallum (1999, pp. 1490-95), for example. Consequently, Svensson moves on to consideration of simple instrument rules (pp. 439-41), with one subsection entitled "Problems of Commitment to a Simple Instrument Rule" (pp. 441-44). We now examine that subsection's arguments in some detail, since they evidently constitute the most important ingredients of Svensson's position.

In the subsection in question, there are four main objections to instrument rules that are identified and discussed. The first is "(1) the simple instrument rule may be far from optimal in some circumstances" (p. 441). In particular, "[a] *first* obvious problem for a Taylor-style rule…is that, if there are other important state variables than inflation and the output gap, it will not be optimal…For a smaller and more open economy [than the U.S.], the real exchange rate, the terms of trade, foreign output, and the foreign interest rate seem to be the minimal essential state variables that have to be added" [for the rule to be optimal] (p. 442). But Taylor rules do not comprise the entire class of simple instrument rules; nominal income growth rules provide just one obvious counterexample. Thus, the foregoing is not actually an argument against simple instrument rules, but merely an objection to one particular class. Furthermore, it is not clear that the supposed departure from optimality resulting from the absence of the other state variables, pertaining to open economies, is quantitatively or even qualitatively important. Indeed, in Clarida, Galí, and Gertler's (2001) small open-economy model there are no additional terms in the welfare function beyond the two Taylor-rule state variables—inflation and the output gap—provided that the former is defined in terms of domestic-goods price inflation. Similarly, the McCallum-Nelson (1999a, 2000b) open-economy model can be formulated entirely in terms of consumer price index (CPI) inflation, output, and the real interest rate, with openness changing only the interpretation of the model parameters.

"A *second* problem," Svensson states, "is that a commitment to an instrument rule does not leave any room for judgmental adjustments and extra-model information…" (p. 442). This claim is difficult for us to understand, since there seem to be various ways in which judgmental adjustments to instrument rule prescriptions could be made. For example, the interest rate instrument could be set above (or below) the rule-indicated value when policymaker judgments indicate that conditions, not adequately reflected in the central bank's formal quantitative models, imply different forecasts and consequently call for additional policy tightening (or loosening). This way of incorporating judgment is not the same as the one proposed by Svensson, which he represents by the inclusion in the structural equations of the central bank's macroeconomic model of an unobservable exogenous stochastic variable that is not generated by a simple process, such as "an exogenous autoregressive process" (p. 433). These exogenous deviations appear in the model's structural equations. "Judgment" is then the central bank's estimate of these deviation variables. But it is unclear that this approach reflects the only, or even the best, way of representing the role of judgment in policymaking.[10] Thus the fact that the above-mentioned way of incorporating judgment is different from Svensson's seems to be beside the point—that is, it does not justify his quoted statement.[11] What is crucial is that judgment can be incorporated into instrument rules as well as targeting rules.

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[10] Svensson also states that "a commitment to a simple instrument rule does not provide any rules for when discretionary departures from the simple instrument rule are warranted" (p. 442). But a procedure that did do this would hardly seem to reflect what most analysts would think of as "judgment." It would be, rather, a complex rule.

[11] We do not mean to deny that Svensson has insightful and constructive observations to make regarding incorporation of judgment; our objection is to the asymmetry that he paints with respect to such incorporation by means of targeting and instrument rules.

Svensson suggests that "a *third* problem with simple instrument rules would seem to be that a once-and-for-all commitment to an instrument rule would not allow any improvement of the… rule when new information about the transmission mechanism, the variability of shocks, or the source of shocks arrives" (p. 442). But the words "would seem" appear in the foregoing quotation because Svensson does not actually make the foregoing argument. After mentioning it, he goes on to recognize that Woodford's (1999) "timeless perspective" type of commitment does permit modification of rules when new information is developed.[12] Such rules can, in a manner that is indicated below, be implemented by means of an instrument rule. Furthermore, the implied type of commitment—to a procedure rather than a formula—could also be applied to other types of instrument rules.

Finally, switching from a normative to a positive point of view, Svensson states that "an obvious *fourth* problem is that commitment to a simple instrument rule is far from an accurate description of current monetary policy" as practiced by inflation-targeting or other central banks. He continues: "No central bank has (to my knowledge) announced and committed itself to an explicit instrument rule" (p. 444). But, as we have argued previously (McCallum and Nelson, 2000a, p. 15), no actual central bank has announced or committed itself to an explicit objective function, which is a necessary condition for either the general or specific type of targeting rule promoted by Svensson.[13] Indeed, commitment to an optimal specific targeting rule would in addition entail commitment to be bound by the output of a new optimal control exercise, conducted with a particular quantitative macroeconomic model, each decision period (e.g., each month). Such exercises could, Svensson says, be modified by judgment. But are they actually conducted by the central banks that he identifies as the world's leaders in this regard, those of the United Kingdom, New Zealand, and Sweden? If so, what is the value of the weight λ on output gap variability announced and used by each of these central banks? What is the specification of the model used?

In short, it seems appropriate to conclude that all four of the objections to instrument rules emphasized by Svensson are equally applicable—or equally inapplicable—to targeting rules.

4 ADDITIONAL OBJECTIONS

Two other debatable points deserve some brief attention before we turn to a major analytical issue in Sections 5 and 6. One of these concerns Svensson's argument against the view that "simple instrument rules fit actual central-bank behavior well" (p. 444). In opposition to this idea, Svensson states that "even the best empirical fits leave one third or more of the variance of changes in the [interest instrument] rate unexplained." In this regard it is important to note that the statement pertains to the variability of *first differences* of the interest rate, as found in the study by Judd and Rudebusch (1998). In terms of *levels*, the fraction of the variance that is unexplained is approximately 0.02 (i.e., about 2 percent).[14] Neither of these measures is conceptually "correct" or "incorrect," of course, but to put matters in perspective, we note that 33 percent would be a comparatively *small* unexplained variance fraction for the first difference of most important variables in typical quarterly macroeconometric models. In the well-known Rudebusch and Svensson (1999) model, for example, the unexplained variance fractions for changes in inflation and the output gap are about 71 percent and 87 percent, respectively.[15]

[12] For discussions, see Woodford (1999) and Svensson and Woodford (2005).

[13] Note that at a minimum it would be necessary for the central bank to state explicitly its value for the objective function parameter labeled λ below and in Svensson's equation (2.2).

[14] Judd and Rudebusch (1998, p. 14) report a residual standard deviation of 0.27 for the Greenspan period 1987:Q3–1997:Q4. Over that span, the standard deviation of the quarterly average funds rate is 1.93 (annual percentage units). Thus, the unexplained fraction of variability is $(0.27/1.93)^2 = 0.0196$.

[15] These figures pertain to the model's "inflation equation" and "output [gap] equation," for which the reported residual standard errors are, respectively, 1.009 and 0.819 (Rudebusch and Svensson, 1999, p. 208). The sample standard deviations for first differences of the relevant inflation and output gap series over the 1961:Q1–1996:Q2 sample period are, respectively, 1.197 and 0.877, so we have $(1.009/1.197)^2 = 0.711$ and $(0.819/0.877)^2 = 0.872$.

Our second point concerns Svensson's contention that actual central banks noted for their inflation-targeting regimes, including the Reserve Bank of New Zealand, the Bank of Canada, and the Bank of England, use in practice procedures that are more reasonably characterized by the notion of a targeting rule rather than an instrument rule. We have already mentioned that none of these central banks has publicly adopted an explicit objective function. But, furthermore, we find that descriptions of their policy procedures provided by officials and economists of these central banks read more like instrument rules than specific targeting rules.

As a first example, there are several short articles describing the policy procedures of the Bank of Canada that appear in the Summer 2002 issue of the *Bank of Canada Review*. These do not refer to targeting rules or optimal control exercises, but discuss instrument rules quite explicitly—see, e.g., Cote et al. (2002). Another relevant reference to the use of instrument rules in Canadian policy is provided by Longworth and O'Reilly (2002). At the risk of being excessively repetitive, let it be said explicitly that we do not claim that the Bank of Canada—or any actual central bank—strictly follows an instrument rule, but rather that its practices are closer to the analytical representation of an instrument rule than to the analytical representation of a targeting rule.

For the Bank of England, a natural starting place is a publication by Bean and Jenkinson (2001) entitled "The Formulation of Monetary Policy at the Bank of England," which describes the role of forecasts in policy decisions of the Bank's Monetary Policy Committee. Their paper's discussion explains that a variety of models and techniques are used in the process, but recognizes the special status of the "MM" quarterly macroeconometric model. In the publication *Economic Models at the Bank of England: September 2000 Update*, there are several examples of policy experiments with MM involving alternative instrument rules (Bank of England, 2000, pp. 13-20). The more recent discussion by Allsopp (2002, p. 489) suggests that "the broad features of the reaction function in place in the United Kingdom increasingly seem to be publicly-understood and built into expectations."

A still more recent discussion of the U.K. policy framework is that in a document prepared by the U.K. Treasury (2003). This study uses a comparison of "interest rate decisions [with] those that a Taylor rule would suggest" as one measure of whether "the current frameworks…have allowed monetary policy to perform a stabilizing role" (pp. 33, 35). By contrast, there is no attempt to evaluate policy using a numerically specified loss function or Euler equation. The study does note criticisms of the instrument rule approach, citing Svensson (2003) in that regard. But it characterizes the deviation of actual policy from the Taylor rule as reflecting discretionary adjustments: "[Prescriptions from] Taylor rules…are typically different from the actual rates chosen by central banks, which use discretion to determine rates based on a wider range of information" (2003, p. 36). In addition, in a speech accompanying the release of this study, the Chancellor of the Exchequer (who sets the target for monetary policy in the United Kingdom and appoints several of the members of the Monetary Policy Committee) was explicit in characterizing actual policy in a Taylor-rule-like manner: "For a 1 per cent rise in British inflation, the British interest rate would, other things being equal, tend to rise by 1.5 per cent" (Brown, 2003, p. 410).

In the case of New Zealand, descriptions of the Reserve Bank's policy procedures (e.g., Hampton, 2002) make no mention of optimal control exercises, but clearly refer to a role for an instrument rule in their Forecasting and Policy System. In addition, it is interesting to note that Svensson's own extensive and authoritative independent review of New Zealand monetary policy (2001, p. 66) suggests that "the Reserve Bank may want to consider some further developments of its Forecasting and Policy System. Alternative interest rate reaction functions and alternative interest rate paths could be used and presented systematically to the MPC [Monetary Policy Committee] to provide a larger menu of policy choices for discussions and consideration."

5 VOLATILITY FROM INSTRUMENT RULES?

We now turn to our main analytical discussion. Svensson's subsection 5.5 expresses sharp and specific disagreement with a crucial argument made by McCallum (1999, p. 1493) and McCallum and Nelson (2000a) concerning the relationship between targeting and instrument rules. In particular, these two papers argue that an instrument rule can be written so as to entail instrument responses that would tend to bring about the satisfaction of any specific target rule (which usually amounts to a first-order condition for the maximization of the central bank's objective function). By increasing the response coefficient attached to the discrepancy between the relevant prevailing conditions and the desired first-order condition, the average discrepancy can be made arbitrarily small.[16] Thus, in a sense, one can accomplish with an instrument rule anything that can be accomplished with a specific targeting rule, according to our argument. Svensson (p. 461) has objected to this argument, however, on the grounds that "this is a dangerous and completely impracticable idea. It is completely inconceivable in practical monetary policy to have reaction functions with very large response coefficients, since the slightest mistake in calculating the argument of the reaction function would have grave consequences and result in extreme instrument-rate volatility." A similar objection is expressed by Svensson and Woodford (2005).

Our intuition was that embedding a first-order condition in an instrument rule with a large but finite reaction coefficient (such as μ_1 below) would typically entail less-severe instrument movements than would imposition of the relevant specific targeting rule, because the latter is equivalent to use of an "infinite" reaction coefficient. In other cases, large μ_1 values might entail somewhat greater interest volatility, but in such cases the magnitude of this volatility would approach that obtained with the targeting rule as μ_1 grows without bound. It is important to note that—in contrast to Svensson's suggestion on p. 461—we actually do not recommend the adoption of a large reaction coefficient; see McCallum and Nelson (2000a, pp. 20-24). Our point, instead, is that an instrument rule with a large reaction coefficient is less open to Svensson's objection than is its associated specific targeting rule. In our paper (2000a) we did not, however, explore the effects of *mistakes* in calculating the argument of the reaction function. In the following paragraphs we shall, accordingly, investigate the validity of Svensson's conjecture.

For this exercise, suppose initially that the economy is represented by the following model, which is a version of the neo-canonical specification used by Bullard and Mitra (2002), Clarida, Galí, and Gertler (1999), Jensen (2002), Woodford (1999, 2003), McCallum and Nelson (1999b, 2000a), and many others:

(1) $$x_t = \mathrm{E}_t x_{t+1} + \beta_r \left(i_t - \mathrm{E}_t \pi_{t+1}\right) + \eta_t, \qquad \beta_r < 0$$

(2) $$\pi_t = \alpha_x x_t + \delta \mathrm{E}_t \pi_{t+1} + \varepsilon_t. \qquad \alpha_x > 0,\ 0 < \delta < 1$$

Here, x_t is the output gap, π_t is the inflation rate, δ is a discount factor, and i_t is the one-period nominal interest rate. Equation (1) is the now-familiar expectational IS function and (2) is the Calvo price-adjustment relation—both consistent under well-known assumptions with optimizing behavior by individuals in the economy (e.g., Woodford, 2003).

Supposing that the central bank wishes at t to minimize the loss function[17]

$$\mathrm{E}_t \Sigma_{j=0}^{\infty} \delta^j \left(\pi_{t+j}^{\ 2} + \lambda x_{t+j}^{\ 2}\right),$$

the optimum first-order condition in the absence of commitment is $\pi_t = -(\lambda/\alpha_x)x_t$, or

(3) $$\pi_t + \left(\lambda/\alpha_x\right) x_t = 0.$$ [18]

This is the specific targeting rule that is implied for this model, assuming the absence of commitment, by Svensson's approach. The corresponding

[16] The sign of the response coefficient must, of course, be appropriate—so that policy is tightened when aggregate demand needs to be reduced, etc.

[17] Up to a scaling term, this is the same objective function as in Svensson (2003), whose notation we follow.

[18] See the papers cited in the previous paragraph.

instrument rule proposed in McCallum and Nelson (2000a) is

$$(4)\ i_t = (1-\mu_2)\left\{\bar{r} + \pi_t + \mu_1\left[\pi_t + (\lambda/\alpha_x)x_t\right]\right\} + \mu_2 i_{t-1},$$

where $\bar{r}$ is the average long-run real rate of interest. The term $\bar{r}$, which is included along with π_t so as to express (4) in a Taylor-style form, is normalized to zero by expressions (1) and (2). For present purposes the interest-rate-smoothing coefficient, μ_2, may also be set equal to zero, yielding $i_t = \pi_t + \mu_1[\pi_t + (\lambda/\alpha_x)x_t]$.

To incorporate mistakes of the type contemplated by Svensson, we modify (3) and (4) to become

$$(3')\qquad \pi_t + (\lambda/\alpha_x)x_t + e_t = 0$$

and

$$(4')\qquad i_t = (1-\mu_2)\left\{\bar{r} + \pi_t + \mu_1\left[\pi_t + (\lambda/\alpha_x)x_t + e_t\right]\right\} + \mu_2 i_{t-1},$$

where e_t represents a stochastic mistake term. We have included the same mistake term, e_t, in both the targeting and instrument rules, a step that seems necessary to provide a reasonable basis for comparison. Because the issue is whether use of an instrument rule (with a large μ_1 parameter) leads to excessive variability (when there are policy errors) *in comparison with the corresponding targeting rule*, it would make no sense to omit the errors from the targeting rule.

In our experiments, we shall treat e_t as a first-order autoregressive (AR(1)) process—usually as white noise—with AR parameter ρ_e and innovation ω_t (standard deviation σ_ω). Various values for σ_ω and ρ_e are considered. Behavioral parameter values for the model are taken to be $\beta_r = -0.5$, $\alpha_x = 0.03$, and $\delta = 0.99$. Also, the stochastic shock term, η_t, in (1) includes a term, $\bar{y}_t - E_t\bar{y}_{t+1}$, where $\bar{y}_t$ is log potential output. This term forms part of η_t—in addition to a white noise preference shock, v_t—because (1) and (2) are expressed in terms of the output gap rather than output. The natural rate value, $\bar{y}_t$, is assumed to follow a first-order autoregressive process with AR parameter 0.95 and innovation standard deviation 0.007. The white noise preference shock has standard deviation 0.02, and the shock term, ε_t, in the price adjustment equation (2) is taken to be white noise with standard deviation 0.005. For the results given hereafter, the value of the central bank preference parameter, λ, is set at 0.1.

We begin by reporting in Table 1 results of using different values for the feedback parameter μ_1 (setting $\mu_2 = 0$ here and in subsequent cases). The first column of results pertains to the μ_1 value of 0.5, as suggested by Taylor (1993). Successive columns then use values of 5.0 and 50.0. Finally, the last column includes results for "$\mu_1 = \infty$," that is, for the targeting rule (3′). In each cell, two values are reported. The first is the unconditional expected value of the loss function, which is (with $\delta = 0.99$) 100 times the unconditional expectation of the single-period loss. The second is the standard deviation of i_t, the interest rate instrument. These values are based on analytical expressions for the unconditional variances of π_t, x_t, and i_t implied by the model-plus-rule systems.

The first row of cells in Table 1 gives results for the reference case in which there is no e_t mistake term. The pattern is similar to those in McCallum and Nelson (2000a, Table 4) in that the value of the loss function with the instrument rule (4′) approaches the value with the target-rule first-order condition (3′). Here, however, the i_t standard deviation values are also reported. Not surprisingly, they also show the instrument rule values approaching the targeting rule value smoothly as μ_1 grows without bound. In the second row, the mistake or error term, e_t, is included as white noise with a standard deviation of 0.002. With this small variability, the results are not much affected. Then, in the third row, the standard deviation of e_t is increased to a magnitude that is similar to that of the other model shocks. Nevertheless, there is again no tendency in this case for the large μ_1 values to generate poor performance. Indeed, the variability of i_t is slightly smaller, with $\mu_1 = 50$, than with the targeting rule holding exactly. (The same remains true if we set $\mu_1 = 500$.) For more-stringent tests, we increase the standard deviation of the error term by a factor of ten in the fourth row and then, in the fifth row, revert to 0.02 for the innovation standard deviation but with an autoregressive parameter of $\rho_e = 0.8$. In both cases, the standard deviation of the interest rate increases slightly as we switch from a large μ_1 coefficient

Table 1

Results with Model (1)-(2), Discretionary Policy, λ = 0.1

	Instrument rule (4′) μ_1 = 0.5	Instrument rule (4′) μ_1 = 5.0	Instrument rule (4′) μ_1 = 50	Target rule (3′) $\mu_1 = \infty$
σ_ω = 0.0	3.70	2.52	2.48	2.48
ρ_e = 0.0	0.0191	0.0360	0.0397	0.0402
σ_ω = 0.002	3.70	2.53	2.48	2.48
ρ_e = 0.0	0.0191	0.0360	0.0397	0.0402
σ_ω = 0.02	3.77	2.81	2.83	2.83
ρ_e = 0.0	0.0198	0.0375	0.0414	0.0419
σ_ω = 0.20	11.02	30.93	37.31	38.16
ρ_e = 0.0	0.0572	0.1121	0.1240	0.1255
σ_ω = 0.02	4.42	3.58	3.58	3.59
ρ_e = 0.80	0.0192	0.0361	0.0398	0.0403

NOTE: Entries are loss times 10^3 and standard deviation of i_t.

Table 2

Results with Model (1)-(2), Timeless Perspective Policy, λ = 0.1

	Instrument rule (6) μ_1 = 0.5	Instrument rule (6) μ_1 = 5.0	Instrument rule (6) μ_1 = 50	Target rule (5) $\mu_1 = \infty$
σ_ω = 0.0	11.26	2.83	2.30	2.31
ρ_e = 0.0	0.0336	0.0403	0.0401	0.0401
σ_ω = 0.002	11.27	2.86	2.34	2.33
ρ_e = 0.0	0.0336	0.0403	0.0401	0.0401
σ_ω = 0.02	11.71	5.99	5.88	5.92
ρ_e = 0.0	0.0337	0.0403	0.0401	0.0401
σ_ω = 0.20	55.62	319.47	359.99	364.75
ρ_e = 0.0	0.0449	0.0417	0.0428	0.0430
σ_ω = 0.02	54.37	60.70	59.17	59.05
ρ_e = 0.80	0.0396	0.0463	0.0460	0.0460

NOTE: Entries are loss times 10^3 and standard deviation of i_t.

value of 50 in the instrument rule to the analogous targeting rule.

Table 2 repeats the same experiments as in Table 1, but with the first-order targeting rule and its analogous instrument rule pertaining to policy behavior of the "timeless perspective" type of commitment, rather than discretion.[19] In this case, the optimality condition is

$$\pi_t + (\lambda/\alpha_x)(x_t - x_{t-1}) + e_t = 0 \tag{5}$$

and the analogous instrument rule (with $\mu_2 = 0$) is

$$i_t = r + \pi_t + \mu_1\left[\pi_t + (\lambda/\alpha_x)(x_t - x_{t-1}) + e_t\right] \tag{6}$$

when the mistake terms, e_t, are included. Here the values and patterns are quite different from those in Table 1, but the same finding vis-à-vis Svensson's conjecture is obtained. There is, in other words, no tendency for large μ_1 values in

[19] This is the type of rule recommended by Woodford (1999, 2003) and by Svensson and Woodford (2005).

(5) to lead to high i_t volatility or to poor performance, in comparison with the specific targeting rule results of condition (6).

Thus, there appears to be little to choose from between targeting rules and instrument rules on the criteria of interest rate volatility and welfare performance; consistently, the results obtained from targeting rules emerge as a limiting case of those obtained from instrument rules. Two other criteria that we have not considered here for discriminating between policy rules are whether the rule produces a determinate and learnable rational expectations equilibrium. Other work, however, suggests that these criteria do not appear to provide grounds for favoring targeting rules over instrument rules. Studying these issues with a basic canonical model and no policy mistakes, Evans and Honkapohja (2004, p. 19) find that instrument rules of the kind studied in this section "lead to both determinacy and stability under learning."

6 MODEL WITH PREDETERMINED OUTPUT AND INFLATION

There are various modifications to the model (1)-(2) that could be examined[20] to determine whether the foregoing results obtain generally, but one in particular is of special relevance. This modification stems from recognition that the examples in Svensson's (2003) paper are worked out in terms of models (pp. 432-35) in which agents' actions in period t have no effect on output or inflation until period t+1. Accordingly, we now modify our model (1)-(2) so as to possess that property. Thus, consider the following specification, in which symbols are the same as previously noted[21]:

(7)
$$x_t = E_{t-1}x_{t+1} + \beta_r\left(E_{t-1}i_t - E_{t-1}\pi_{t+1}\right) + \eta_t, \qquad \beta_r < 0$$

(8)
$$\pi_t = \alpha_x E_{t-1}x_t + \delta E_{t-1}\pi_{t+1} + \varepsilon_t. \qquad \alpha_x > 0,\ 0 < \delta < 1$$

[20] We have verified that inclusion of serial correlation in the ε_t shock process does not alter our basic result.

[21] Our specification is equivalent to Svensson's, in which t+1 is used wherever we use t, etc.

Here we have used the law of iterated expectations, for example, $E_{t-1}(E_t X_{t+1}) = E_{t-1}X_{t+1}$. With this modification, the optimal discretionary first-order condition imposed in period t—that is, the specific targeting rule—becomes

(9)
$$E_t\pi_{t+1} + \left(\lambda/\alpha_x\right)E_t x_{t+1} = 0$$

instead of (3). (See Svensson, p. 452.) Accordingly, the implied instrument rule with $\mu_2 = 0$ and $\overline{r} = 0$ is

(10)
$$i_t = E_{t-1}\pi_t + \mu_1\left[E_{t-1}\pi_t + \left(\lambda/\alpha_x\right)E_{t-1}x_t\right].$$

Again the relevant experiment, designed to compare these two approaches in the presence of policy mistakes, entails specifications with random error terms included in both rules. The model to be solved, then, consists of equations (7), (8), and either

(11)
$$E_{t-1}\pi_t + \left(\lambda/\alpha_x\right)E_{t-1}x_t + e_{t-1} = 0$$

or

(12)
$$i_t = E_{t-1}\pi_t + \mu_1\left[E_{t-1}\pi_t + \left(\lambda/\alpha_x\right)E_{t-1}x_t + e_{t-1}\right].$$

Here the random mistake terms are dated t–1 so as to respect the notion that output and inflation in t are predetermined.

Before turning to more-complex cases, we consider an analytical solution for the simple special case in which discretion obtains and the three disturbance terms are all white noise. Then the minimum state variable solution to the system (7), (8), and (11) is of the form

(13a)
$$\pi_t = \phi_{11}\varepsilon_t + \phi_{12}\eta_t + \phi_{13}e_{t-1}$$

(13b)
$$x_t = \phi_{21}\varepsilon_t + \phi_{22}\eta_t + \phi_{23}e_{t-1}$$

(13c)
$$i_t = \phi_{31}\varepsilon_t + \phi_{32}\eta_t + \phi_{33}e_{t-1}.$$

With this specification, we have $E_{t-1}\pi_t = \phi_{13}e_{t-1}$, $E_{t-1}\pi_{t+1} = 0$, $E_{t-1}x_t = \phi_{23}e_{t-1}$, and $E_{t-1}x_{t+1} = 0$. Undetermined coefficient calculations then yield $\phi_{11} = 1$, $\phi_{12} = 0$, $\phi_{13} = -\alpha_x/[\alpha_x + (\lambda/\alpha_x)]$, $\phi_{21} = 0$, $\phi_{22} = 1$, $\phi_{23} = -1/[\alpha_x + (\lambda/\alpha_x)]$, $\phi_{31} = 0$, $\phi_{32} = 0$, and $\phi_{33} = -1/\beta_r[\alpha_x + (\lambda/\alpha_x)]$.

For comparison, we need to solve with the instrument rule (12) in place of the targeting rule (11). The solution is again of the form (13), and

Table 3

Results with Model (7)-(8), Discretionary Policy, λ = 0.1

	Instrument rule (12) $\mu_1 = 0.5$	Instrument rule (12) $\mu_1 = 5.0$	Instrument rule (12) $\mu_1 = 50$	Target rule (11) $\mu_1 = \infty$
$\sigma_\omega = 0.0$, $\rho_e = 0.0$	7.03	6.99	6.99	6.99
$\rho_\varepsilon = 0.0$	0.0025	0.0022	0.0021	0.0021
$\sigma_\omega = 0.02$, $\rho_e = 0.0$	7.10	7.27	7.34	7.35
$\rho_\varepsilon = 0.0$	0.0060	0.0108	0.0119	0.0121
$\sigma_\omega = 0.2$, $\rho_e = 0.0$	14.4	35.4	41.8	42.7
$\rho_\varepsilon = 0.0$	0.0539	0.1061	0.1175	0.1189
$\sigma_\omega = 0.02$, $\rho_e = 0.0$	772	779	780	780
$\rho_\varepsilon = 0.9$	0.0841	0.0847	0.0848	0.0849
$\sigma_\omega = 0.02$, $\rho_e = 0.8$	773	780	780	780
$\rho_\varepsilon = 0.9$	0.0840	0.0841	0.0841	0.0841

NOTE: Entries are loss times 10^3 and standard deviation of i_t.

Table 4

Results with Model (7)-(8), Timeless Perspective Policy, λ = 0.1

	Instrument rule (15) $\mu_1 = 0.5$	Instrument rule (15) $\mu_1 = 5.0$	Instrument rule (15) $\mu_1 = 50$	Target rule (14) $\mu_1 = \infty$
$\sigma_\omega = 0.0$, $\rho_e = 0.0$	8.58	7.01	6.99	6.99
$\rho_\varepsilon = 0.0$	0.0058	0.0025	0.0022	0.0021
$\sigma_\omega = 0.02$, $\rho_e = 0.0$	9.02	10.2	10.6	10.6
$\rho_\varepsilon = 0.0$	0.0065	0.0027	0.0026	0.0026
$\sigma_\omega = 0.2$, $\rho_e = 0.0$	52.9	324	365	369
$\rho_\varepsilon = 0.0$	0.0304	0.0113	0.0152	0.0156
$\sigma_\omega = 0.02$, $\rho_e = 0.0$	446	308	306	306
$\rho_\varepsilon = 0.9$	0.0392	0.0098	0.0128	0.0131
$\sigma_\omega = 0.02$, $\rho_e = 0.8$	488	362	360	360
$\rho_\varepsilon = 0.9$	0.0444	0.0249	0.0260	0.0261

NOTE: Entries are loss times 10^3 and standard deviation of i_t.

now the undetermined coefficient calculations yield $\phi_{11} = 1$, $\phi_{12} = 0$, $\phi_{13} = \alpha_x\beta_r\mu_1/[1 - (1 + \mu_1)\alpha_x\beta_r - (\lambda/\alpha_x)\mu_1\beta_r]$, $\phi_{21} = 0$, $\phi_{22} = 1$, $\phi_{23} = \beta_r\mu_1/[1 - (1 + \mu_1)\alpha_x\beta_r - (\lambda/\alpha_x)\mu_1\beta_r]$, $\phi_{31} = 0$, $\phi_{32} = 0$, and $\phi_{33} = \mu_1/[1 - (1 + \mu_1)\alpha_x\beta_r - (\lambda/\alpha_x)\mu_1\beta_r] > 0$. Then to compare the variability of i_t under the two types of policy behavior, we need only to calculate the magnitude of ϕ_{33} for the two cases, since $\text{Var}(i_t) = \phi_{33}^2\,\sigma_e^2$ in both cases (where σ_e denotes the standard deviation of e_t). But with $\mu_1 > 0$, it is just a matter of algebra to verify that ϕ_{33} is smaller in the second case (i.e., the instrument rule). So again we find that mistakes involving the first-order optimality condition are less serious (in terms of interest rate variability) when the instrument rule, rather than the corresponding targeting rule, is used. Also, it is straightforward to verify that, as $\mu_1 \to \infty$, the instrument rule expression for ϕ_{33} approaches the targeting rule expression.

The case just examined is, however, excessively special. Indeed, inspection of the solutions given above shows that, for the discretionary case with all white noise shocks, there is no effect of different μ_1 values on the mean value (unconditional expectation) of the objective function. In other words, with no source of serial correlation in the model, and with the existence of an information lag, the discretionary policy rule has no stabilizing properties for π_t and x_t in the model (7)-(8). Thus we need to consider cases with autocorrelated disturbances and/or with timeless perspective optimization. For the latter case we find, from Svensson's equation (5.28), that the relevant targeting and instrument rules are, respectively,

$$\text{(14)} \quad E_{t-1}\pi_t + (\lambda/\alpha_x)\left[E_{t-1}x_t - E_{t-2}x_{t-1}\right] + e_{t-1} = 0$$

and

$$\text{(15)} \quad i_t = E_{t-1}\pi_t + \mu_1\left[E_{t-1}\pi_t + (\lambda/\alpha_x)(E_{t-1}x_t - E_{t-2}x_{t-1}) + e_{t-1}\right].$$

In Tables 3 and 4 we report numerical results with the model (7)-(8). Again we report standard deviations based on analytical covariances. In most of the cases, the standard deviation of the innovations to the policy errors is kept at $\sigma_\omega = 0.02$. In Table 3, which pertains to discretionary behavior, the policy specifications are (11) and (12) for the targeting and instrument rules, whereas, in Table 4, with timeless perspective behavior, the relevant rules are (14) and (15). In both tables the first three rows apply to cases with white noise shocks, so we see that, as in the analytical solution just given, policy activism is not helpful in achieving policy objectives. Indeed, when policy errors are included, as in rows 2 and 3, the activist rules tend to be harmful. This should not be greatly surprising, because there are no general optimality results pertaining to the formulations being considered. In the final two rows of each table, serially correlated shocks are present, however, so policy activism can potentially be helpful.[22] Indeed, in Table 4 we see that larger values of μ_1 lead to reduced values of the loss function.

[22] Where autocorrelation is included in the ε_t process, the innovation variance is kept at 0.005^2.

Be that as it may, with regard to the issue at hand the results are clear-cut: There is no tendency for the variability of i_t to grow alarmingly with large values of μ_1. Indeed, in most cases the variability of i_t is *smaller* with large values of μ_1 used in the instrument rule than it is with the associated specific targeting rule. In addition, the results provided by the targeting rules (11) and (14) are, as before, very closely approximated by those of the instrument rules (12) and (15) for large values of μ_1.

7 CONCLUSION

Svensson (2003) argues strongly that general and specific targeting rules, which amount to commitments to specified objective functions and first-order conditions (respectively), are normatively superior to instrument rules for the conduct of monetary policy. By contrast, we suggest that it is unhelpful, terminologically, to refer to "general targeting rules" as policy rules and that, substantively, their adoption is either innocuous or else represents a departure from transparency. Most of the present paper's discussion is focused, accordingly, on specific targeting rules—i.e., the first-order optimality conditions implied by the combination of a specific objective function and a specific model. We argue in Section 2 of this paper that a key problem with targeting rules is that they are inevitably fine-tuned to the model chosen to describe private sector behavior; so, they may perform poorly in the event that the chosen model is misspecified. In that respect, instrument rules, which may rely on more-generic properties of models used for monetary policy analysis, may be preferable.

Svensson's argument that, instead, specific targeting rules are superior to instrument rules is based largely on four main objections to the latter plus a claim concerning the relative interest-instrument variability entailed by the two approaches. Our Section 3 considers the four objections in turn and advances arguments that contradict all of them. Then, in the paper's analytical sections (5 and 6), we demonstrate that the variability claim is incorrect for a neo-canonical model and also for a variant with one-period-ahead plans used by Svensson, providing that the same decisionmaking errors are relevant under the two alternative approaches.

We suggest, then, that despite its large quantity of meticulous analysis, Svensson (2003) does not develop any compelling reasons for preferring targeting rules over instrument rules, from a normative perspective. We also suggest, regarding the positive perspective, that no actual central bank has expressed explicitly the magnitude of objective function parameters that are essential for the utilization of a targeting rule.

REFERENCES

Allsopp, Christopher. "Macroeconomic Policy Rules in Theory and in Practice." Bank of England *Quarterly Bulletin*, Winter 2002, *42*(4), pp. 485-504.

Bank of England. *Economic Models at the Bank of England: September 2000 Update*. London: Bank of England, 2000.

Bean, Charles and Jenkinson, Nigel. "The Formulation of Monetary Policy at the Bank of England." Bank of England *Quarterly Bulletin*, Winter 2001, *41*(4), pp. 434-41.

Brown, Gordon. "Economic and Monetary Union: Statement by the Chancellor of the Exchequer on U.K. Membership of the Single Currency." *House of Commons Debates*, London, June 9, 2003, pp. 407-15.

Bryant, Ralph C.; Hooper, Peter and Mann, Catherine L., eds. *Evaluating Policy Regimes: New Research in Empirical Macroeconomics.* Washington, DC: Brookings Institution, 1993.

Bullard, James and Mitra, Kaushik. "Learning About Monetary Policy Rules." *Journal of Monetary Economics*, September 2002, *49*(6), pp. 1105-29.

Cecchetti, Stephen G. "Making Monetary Policy: Objectives and Rules." *Oxford Review of Economic Policy*, Winter 2000, *16*(4), pp. 43-59.

Clarida, Richard; Galí, Jordi and Gertler, Mark. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature*, December 1999, *37*(4), pp. 1661-707.

Clarida, Richard; Galí, Jordi and Gertler, Mark. "Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach." *American Economic Review (Papers and Proceedings)*, May 2001, *91*(2), pp. 248-52.

Cote, Denise; Lam, Jean-Paul; Liu, Ying and St-Armant, Pierre. "The Role of Simple Rules in the Conduct of Canadian Monetary Policy." *Bank of Canada Review*, Summer 2002, pp. 27-35.

Evans, George W. and Honkapohja, Seppo. "Monetary Policy, Expectations and Commitment." Unpublished manuscript, University of Oregon, February 2004.

Fuhrer, Jeffrey C. "Habit Formation in Consumption and Its Implications for Monetary-Policy Models." *American Economic Review*, June 2000, *90*(3), pp. 367-90.

Giannoni, Marc P. and Woodford, Michael. "Optimal Interest-Rate Rules: I. General Theory." NBER Working Paper No. 9419, National Bureau of Economic Research, January 2003a.

Giannoni, Marc P. and Woodford, Michael. "Optimal Interest-Rate Rules: II. Applications." NBER Working Paper No. 9420, National Bureau of Economic Research, January 2003b.

Hampton, Tim. "The Role of the Reserve Bank's Macro-Model in the Formation of Interest Rate Projections." Reserve Bank of New Zealand *Bulletin*, June 2002, *65*(2), pp. 5-11.

Henderson, Dale W. and McKibbin, Warwick J. "A Comparison of Some Basic Monetary Policy Regimes for Open Economies: Implications of Different Degrees of Instrument Adjustment and Wage Persistence." *Carnegie-Rochester Conference Series on Public Policy*, 1993a, *39*, pp. 221-317.

Henderson, Dale W. and McKibbin, Warwick J. "An Assessment of Some Basic Monetary-Policy Regime Pairs: Analytical and Simulation Results from Simple Multiregion Macroeconomic Models," in Ralph C. Bryant, Peter Hooper, and Catherine L.

Mann, eds., *Evaluating Policy Regimes: New Research in Empirical Macroeconomics*. Washington, DC: Brookings Institution, 1993b, pp. 45-218.

Jensen, Henrik. "Targeting Nominal Income Growth or Inflation?" *American Economic Review*, September 2002, *92*(4), pp. 928-56.

Judd, John P. and Rudebusch, Glenn D. "Taylor's Rule and the Fed: 1970-1997." Federal Reserve Bank of San Francisco *Economic Review*, 1998, *24*(3), pp. 3-16.

Levin, Andrew T.; Wieland, Volker and Williams, John C. "Robustness of Simple Monetary Policy Rules under Model Uncertainty," in John B. Taylor, ed., *Monetary Policy Rules*. Chicago: University of Chicago Press, 1999, pp. 263-99.

Levin, Andrew T. and Williams, John C. "Robust Monetary Policy with Competing Reference Models." *Journal of Monetary Economics*, July 2003, *50*(5), pp. 945-75.

Longworth, David, and O'Reilly, Brian. "The Monetary Policy Transmission Mechanism and Policy Rules in Canada," in Norman Loayza and Klaus Schmidt-Hebbel, eds., *Monetary Policy: Rules and Transmission Mechanisms*. Santiago: Central Bank of Chile, 2002, pp. 357-92.

McCallum, Bennett T. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy*, Autumn 1988, *29*, pp. 173-203.

McCallum, Bennett T. "Issues in the Design of Monetary Policy Rules," in John B. Taylor and Michael Woodford, eds., *Handbook of Macroeconomics.* Volume 1C. Amsterdam: North Holland, 1999, pp. 1483-530.

McCallum, Bennett T. and Nelson, Edward. "Nominal Income Targeting in an Open-Economy Optimizing Model." *Journal of Monetary Economics*, June 1999a, *43*(3), pp. 553-78.

McCallum, Bennett T. and Nelson, Edward. "Performance of Operational Policy Rules in an Estimated Semi-Classical Structural Model," in John B. Taylor, ed., *Monetary Policy Rules*. Chicago: University of Chicago Press, 1999b, pp. 15-45.

McCallum, Bennett T. and Nelson, Edward. "Timeless Perspective vs. Discretionary Monetary Policy in Forward-Looking Models." NBER Working Paper No. 7915, National Bureau of Economic Research, September 2000a. (Revised version published in Federal Reserve Bank of St. Louis *Review*, March/April 2004, *86*(2), pp. 43-56.)

McCallum, Bennett T. and Nelson, Edward. "Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices." *Oxford Review of Economic Policy*, Winter 2000b, *16*(4), pp. 74-91.

Meltzer, Allan H. "Limits of Short-Run Stabilization Policy." Presidential address to the Western Economic Association, July 3, 1986. *Economic Inquiry*, January 1987, *25*(1), pp. 1-13.

Rudebusch, Glenn D. and Svensson, Lars E.O. "Policy Rules for Inflation Targeting," in John B. Taylor, ed., *Monetary Policy Rules*. Chicago: University of Chicago Press, 1999, pp. 203-46.

Svensson, Lars E.O. "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review*, June 1997, *41*(6), pp. 1111-46.

Svensson, Lars E.O. "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics*, June 1999, *43*(4), pp. 607-54.

Svensson, Lars E.O. *Independent Review of the Operation of Monetary Policy in New Zealand: Report to the Minister of Finance.* Wellington, New Zealand, February 2001.

Svensson, Lars E.O. "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules." *Journal of Economic Literature*, June 2003, *41*(2), pp. 426-77.

Svensson, Lars E.O. and Michael Woodford. "Implementing Optimal Policy through Inflation-Forecast Targeting," in Ben S. Bernanke and

Michael Woodford, eds., *The Inflation Targeting Debate*. Chicago: University of Chicago Press, 2005, pp. 19-83.

Taylor, John B. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy*, 1993, *39*, pp. 195-214.

U.K. Treasury. *Policy Frameworks in the U.K. and EMU*. London: HM Treasury, June 2003.

Walsh, Carl E. "Speed Limit Policies: The Output Gap and Optimal Monetary Policy," *American Economic Review*, March 2003, *93*(1), pp. 265-78.

Woodford, Michael. "Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?" in *New Challenges for Monetary Policy: A Symposium Sponsored by the Federal Reserve Bank of Kansas City*. Kansas City, MO: Federal Reserve Bank of Kansas City, 1999, pp. 277-316.

Woodford, Michael. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, NJ: Princeton University Press, 2003.

Targeting versus Instrument Rules for Monetary Policy: What Is Wrong with McCallum and Nelson?

Lars E.O. Svensson

In their paper "Targeting versus Instrument Rules for Monetary Policy," McCallum and Nelson critique targeting rules for the analysis of monetary policy. Their arguments are rebutted here. First, McCallum and Nelson's preference to study the robustness of simple monetary policy rules is no reason at all to limit attention to simple *instrument* rules; simple *targeting* rules may have more desirable properties. Second, optimal targeting rules are a compact, robust, and structural description of goal-directed monetary policy, analogous to the compact, robust, and structural consumption Euler conditions in the theory of consumption. They express the very robust condition of equality of the marginal rates of substitution and transformation between the central bank's target variables. Indeed, they provide desirable micro foundations of monetary policy. Third, under realistic information assumptions, the instrument rule analog to any targeting rule that McCallum and Nelson have proposed results in very large instrument rate volatility and is also, for other reasons, inferior to a targeting rule.

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1 INTRODUCTION

My good friends Ben McCallum and Ed Nelson have written a paper, McCallum and Nelson (2005), with arguably a somewhat destructive purpose. They attempt to contradict the arguments in favor of targeting rules, rather than instrument rules, in positive and normative analysis of monetary policy that I have presented in Svensson (2003b) and previous papers (for instance, Svensson, 1997 and 1999). In their concluding section, they suggest that Svensson (2003b) "does not develop any compelling reasons for preferring targeting rules over instrument rules." They seem to believe that the concept of targeting rules is unnecessary and that instrument rules are all that is needed in monetary policy analysis.

In their struggle against targeting rules, however, McCallum and Nelson seem to face an uphill battle. There is now a rapidly growing literature by many authors that successfully applies targeting rules to monetary policy analysis. This literature includes recent contributions by Benigno and Benigno (2003), Benigno and Woodford (2004a,b), Cecchetti (1998, 2000), Cecchetti and Kim (2004), Evans and Honkapohja (2004), Giannoni and Woodford (2003a,b and 2004), Kuttner (2004), Mishkin (2002), Onatski and Williams (2004), Preston (2004), Walsh (2003 and 2004a,b), Woodford (2004), and others. In the first drafts of Woodford's (2003) book, there were no targeting rules; in the final, published version, targeting rules are prominent. In 1998, at a distinguished National Bureau of Economic Research (NBER)

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conference on monetary policy rules (Taylor, 1999), Rudebusch and Svensson (1999) was the only paper to use targeting rules; in 2003, at an equally distinguished NBER conference on inflation targeting (Bernanke and Woodford, 2004), several papers used targeting rules and no paper used a simple instrument rule as a model of inflation targeting. A Google search with the string '"targeting rules" AND monetary' gave about 1,700 results in April 2004, about 2,100 in August 2004, and about 5,700 in June 2005. There are, hence, more papers than mine—indeed, some books—that McCallum and Nelson may want to take issue with.[1]

To be clear: An *instrument rule* is a formula for setting the central bank's instrument rate as a given function of observable variables. A *simple* instrument rule makes the instrument rate a simple function of a few observable variables. The best-known example of a simple instrument rule is the Taylor rule, where the instrument rate is a linear function of the inflation gap (between inflation and an inflation target) and the output gap (between output and potential output). Another example is a formula for adjusting the monetary base proposed by McCallum (1988) and Meltzer (1987).[2]

A (specific) *targeting rule* specifies a condition to be fulfilled by the central bank's target variables (or forecasts thereof). A real-world example of a *simple* targeting rule is the one that has been applied by the Bank of England, Sweden's Riksbank, and the Bank of Norway (Goodhart, 2001; Svensson, 2003a; Svensson et al., 2002): The two-year-ahead inflation forecast shall equal the inflation target. More precisely, the instrument rate shall be set such that the two-year-ahead inflation forecast equals the inflation target.[3] An *optimal* targeting rule is a first-order condition for optimal monetary policy. But, importantly, not all targeting rules are optimal targeting rules.[4]

McCallum and Nelson explain that "we are more attracted to analysis with instrument rules than with targeting rules" (p. 598). They imply that the main reason is that "an attractive approach to policy design...is to search for an instrument rule that performs at least moderately well—avoiding disasters—in a variety of plausible models" (p. 599). Thus, McCallum and Nelson are attracted to simple and robust instrument rules; they agree with Svensson (2003b) that a complex optimal instrument rule is not practical. The idea of a robust and simple instrument rule is further developed in McCallum (1988 and 1999).

A simple and robust monetary policy rule is indeed an attractive idea. There is always some uncertainty about the true model of the transmission mechanism of monetary policy, and monetary policy is always conducted under considerable uncertainty of different kinds. A simple and robust monetary policy rule gives the central bank an option that it can fall back on in difficult times. A central bank that knows nothing except current inflation and some estimate of the current output gap can always fall back on a Taylor rule. If the bank does not trust its information about inflation and the output gap, but data on monetary aggregates are more easily accessible or more reliable, the central bank can fall back further on Friedman's rule of *k*-percent money growth.

But several facts stand in the way of McCallum and Nelson's attraction to simple instrument rules. First, the fact is that nothing says that a simple and robust monetary policy rule must be an *instrument* rule. For instance, Friedman's *k*-percent rule is a *targeting* rule! The *k* percent refers to a broad monetary aggregate, such as M2 or M3.

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1 Sims (1980) and Aizenman and Frenkel (1986) provide early discussions of targeting rules (the former without using the term).

2 Svensson (2005) provides a compact and general definition of targeting rules and instrument rules. An *explicit* instrument rule is an instrument rule where the instrument is a function of predetermined variables only. An *implicit* instrument rule is an instrument rule where the instrument is related to a non-predetermined variable. An implicit instrument rule is an equilibrium condition, where several variables are simultaneously determined. This makes the practical implementation of implicit instrument rules more complicated than that of explicit instrument rules (see footnote 12). Any given equilibrium is consistent with a continuum of implicit instrument rules.

3 Strangely, McCallum and Nelson seem to believe that no central bank is using a targeting rule and that a central bank needs to announce an explicit loss function to use a targeting rule. Obviously, neither of these beliefs is correct, as this paragraph shows.

4 Although McCallum and Nelson seem to want to restrict the discussion of targeting rules to optimal targeting rules, that makes no more sense than to restrict the discussion of instrument rules to optimal instrument rules.

This is an (intermediate) target variable, not an instrument. It reacts with a lag of a quarter or so to changes in the central bank's instrument (the instrument rate or the monetary base). The way to implement Friedman's *k*-percent rule, then, is to make forecasts of broad money growth for the next quarter and set the instrument such that the one-quarter-ahead money-growth forecast equals *k* percent (Svensson, 1999). Thus, the targeting rule: "Set the instrument such that the forecast of money growth equals *k* percent."[5] The simple monetary policy rule used by the Bank of England, the Riksbank, and the Bank of Norway—already mentioned above—is also a targeting rule. Walsh (2004b) has recently demonstrated an equivalence between the robust-control policies of Hansen and Sargent (2003 and 2005) and the optimal targeting rules derived by Giannoni and Woodford (2003a,b).[6]

Second, the fact is that central banks normally do not use the fallback options of the simple instrument rules of Taylor or McCallum and Meltzer or even the simple targeting rule of Friedman's *k* percent. With improved understanding of the transmission mechanism of monetary policy, increased experience, and better-designed objectives for monetary policy, central banks believe that they can do better than follow these mechanical simple rules. They have developed complex decision processes, where huge amounts of data are collected, processed, and analyzed (see Brash, 2001, and Svensson, 2001). They construct forecasts of their target variables, typically inflation and the output gap, conditional on their view of the transmission mechanism, their estimate of the current state of the economy and the development of a number of exogenous economic variables, and alternative instrument rate paths. They select and implement an instrument rate or an instrument rate path such that the corresponding forecasts of the targeting variables "look good" relative to the objectives of the central bank. I have called this monetary policy process "forecast targeting." It is a decision process and implementation of monetary policy that is very different from the mechanical application of the simple instrument rules that McCallum and Nelson favor. Advanced central banks attempt to do better, to fulfill their objectives as well as possible, to optimize. I am advocating targeting rules as a better way to describe and prescribe this kind of monetary policy than the simple instrument rules. Targeting rules are one way to make the "look good" concept precise. Bernanke (2004) endorses this view of practical monetary policy, although he uses the term "forecast-based policies" rather than "forecast targeting."[7]

Third, since central banks in a number of countries have developed this approach of forecast targeting to monetary policy (essentially the implementation of inflation targeting that started in a few countries in the early 1990s and has since spread to a large number of countries), the mon-

[5] A broad monetary aggregate such as M2 or M3 is to a large extent endogenously determined by demand and supply of broad money and an endogenous multiplier between broad money and the monetary base. It reacts with a lag of a quarter or so to central bank adjustments of the instrument rate or the monetary base and is subject to various intervening shocks during that lag. Hence, the central bank does not have complete control over broad money; therefore, it is not an instrument of monetary policy. Even if the money growth forecast is on target, actual money growth will ex post deviate from *k* percent due to unanticipated shocks and imperfections in the forecasts.

[6] In some of the literature mentioned above, the instrument rate is also a target variable (that is, an argument of the loss function). In such cases, the instrument rate appears in the targeting rule, and the targeting rule is also an implicit instrument rule. Some of the literature, for instance, Walsh (2004b), follows Giannoni and Woodford (2003a,b) and frequently refers to such targeting rules as instrument rules, which is a source of some confusion. A good test of whether a rule is fundamentally a targeting rule or an instrument rule is to let the weight on the instrument rate in the loss function go to zero. If the instrument rate then vanishes from the rule, it is better to call it a targeting rule.

[7] McCallum and Nelson note (in Section 4) that many central bank publications refer to simple instrument rules. But this merely demonstrates how the concept of simple instrument rules has previously dominated the monetary policy debate (for instance, as noted, in Taylor, 1999). It does not imply that central banks conduct monetary policy by implementing simple instrument rules. They also note that the Reserve Bank of New Zealand (RBNZ) has used a particular instrument rule in generating forecasts in the so-called Forecasting and Policy System (Black et al., 1997). But, as far as I know, the instrument path generated by the instrument rule is subject to considerable judgmental adjustment, especially for the first few quarters. Furthermore, the instrument rate path and the inflation and output gap forecasts generated can be seen as *reference* paths and forecasts, used as an input in the policy decision, in the same way other central banks use forecasts conditional on a constant interest rate. They are not necessarily the central bank's optimal instrument rate plan and optimal inflation and output gap forecasts (although I am advocating improvements in that direction; see Svensson, 2001, 2003a). Thus, the RBNZ's use of an instrument rule in generating its forecasts does not imply that the RBNZ is actually following that instrument rule in setting its instrument rate.

etary policy outcome in those countries has been extremely good. The past decade has seen unprecedented monetary and real stability with low inflation in a number of countries. This makes it even more important, I believe, to develop the tools and definitions through which this kind of monetary policy can be best understood.[8]

McCallum and Nelson have one somewhat constructive contribution in their paper. They provide further analysis of the proposition, previously put forward in McCallum (1999, p. 1493) and McCallum and Nelson (2000), that there is a useful instrument rule analog, with a very large response coefficient, to any targeting rule. In particular, they maintain that this large response coefficient, counter to what is argued in Svensson and Woodford (2005), Svensson (2003b), and, in a related case, in Bernanke and Woodford (1997), does not imply higher volatility of the instrument rate, even if the central bank makes some realistic errors in determining the arguments for the instrument rule. However, as we shall see, under reasonable information assumptions, McCallum and Nelson are wrong. A large response coefficient does indeed make the instrument rate very volatile. Only under very strange information assumptions is there no extra volatility. Even if they were right on this volatility issue, there still seems to be no point to their proposed instrument rule analog. As we shall see, it simply adds unnecessary complexity to the monetary policy rule for no apparent gain. It is conceptually and numerically inferior to the targeting rule, and it is not neutral from a determinacy point of view. In summary, the idea of instrument rules with very large response coefficients is both impractical and pointless.

Section 2 shows a useful analogy between the development of Euler conditions as structural descriptions of consumption choice in the theory of consumption and the development of targeting rules as a structural description of monetary policy in the theory of monetary policy. Section 3 gives an example of an optimal targeting rule and discusses some of its properties, including its robustness. Section 4 shows that the instrument rule analog proposed by McCallum and Nelson indeed brings high instrument rate volatility under reasonable information assumptions. Section 5 discusses McCallum and Nelson's criticism of my definition of "general" targeting rules. I concede that another term, Walsh's (2003) "targeting regimes," may be preferable. Consequently, in future work, I am inclined to use the term "targeting regime" rather than "general targeting rule" and to let "targeting rules," as in this introduction, refer to what I have also called "specific" targeting rules.

2 AN ANALOGY WITH CONSUMPTION THEORY

To view the issue of targeting rules versus instrument rules from a broader descriptive perspective, it is useful to compare this issue with the modeling of consumption in macroeconomics. Several decades ago, it was common to model consumption in period t, C_t, as a given function of income, Y_t, the real rate of interest, R_t, and possibly other variables,

$$C_t = f\left(R_t, Y_t, \ldots\right). \tag{1}$$

In the past 25 years, especially after Hall (1978), it has become common to model consumption as fulfilling an Euler condition—a first-order condition for optimal consumption choice, which, for an additively separable utility function of a representative consumer, has the simple form,

$$\mathrm{E}_t \frac{\delta U_C\left(C_{t+1}\right)}{U_C\left(C_t\right)} = \frac{1}{1+R_t}. \tag{2}$$

Here, the left side of (2) is the representative consumer's expected marginal rate of substitution of period-t consumption for period-$t+1$ consump-

[8] McCallum and Nelson disagree with my statement that one of the problems with a commitment to an instrument rule as a description and prescription of monetary policy "is that a commitment to an instrument rule does not leave any room for judgmental adjustments and extra-model information" (Svensson, 2003b, p. 442). They state (on p. 600): "This claim is difficult for us to understand, since there seem to be various ways in which judgmental adjustments to instrument rule prescriptions could be made. For example, the interest rate instrument could be set above (or below) the rule-indicated value when policymaker judgments indicate that conditions, not adequately reflected in the central bank's formal quantitative models, imply different forecasts and consequently call for additional policy tightening (or loosening)." McCallum and Nelson seem to believe that a commitment is consistent with discretionary adjustments, an obvious contradiction.

tion ($0 < \delta < 1$ is a discount factor and $U_C(C_t)$ denotes the marginal utility of consumption). The right side is the consumer's marginal rate of transformation of period-$t+1$ consumption into period-t consumption, when the consumer can borrow or lend; that is, the period-t consumption value of consumption in period $t+1$. A loglinear approximation to (2) is

$$c_t = c_{t+1|t} - \sigma\left(r_t - \rho\right), \tag{3}$$

where $c_t \equiv \ln C_t$, $c_{t+1|t} \equiv \mathrm{E}_t c_{t+1}$, σ is the intertemporal elasticity of substitution, $r_t \equiv \ln(1 + R_t)$ is the continuously compounded real interest rate, and $\rho \equiv -\ln\delta > 0$ is the rate of time preference.

As is well known, a serious problem with modeling consumption as a given consumption function is that this function is not a structural relation but a reduced form. Its properties and parameters depend on the whole model of the economy, including the existing shocks and their stochastic properties, the monetary and fiscal policy pursued, and so forth.

In contrast, the consumption Euler condition (2) or (3) is more structural, independent of the rest of the model, and independent of the monetary and fiscal policy pursued. It is a robust, compact, and therefore practical description of optimizing consumption behavior. Indeed, this development of a more microfounded modeling of consumption is an integral part of the rational expectations revolution in macroeconomics.

The consumption function can be seen as an instrument rule for consumption behavior, whereas the Euler condition (2) or (3) can be seen as a targeting rule for consumption. When I argue for the adoption of targeting rules rather than instrument rules in modeling monetary policy, I am arguing for a development in the theory of monetary policy that already happened, a long time ago, in the theory of consumption.

McCallum and Nelson are attracted to modeling monetary policy with instrument rules rather than targeting rules also for descriptive purposes (see Section 4). If they were consistent, they should also prefer to model consumption with consumption functions rather than Euler conditions. But they are not consistent. Indeed, it is a great irony that one of McCallum and Nelson's important contributions to macroeconomics is precisely the introduction of Euler conditions in modeling aggregate demand (for instance, in McCallum and Nelson, 1999) and, with other New Keynesian pioneers, the use of a condition such as (3) to derive the New Keynesian aggregate-demand relation.

Do McCallum and Nelson really believe that a modern central bank is less rational and goal-directed and a worse optimizer than the average consumer? At least they must admit that policymakers in modern central banks have the advantage above the average consumer of being advised by a staff with an increasing number of Ph.D. economists with training in modern macroeconomics and intertemporal optimization. Indeed, an increasing proportion of policymakers themselves are Ph.D. economists with such training!

A structural description of consumption choice is essential in estimating meaningful and robust empirical representations of consumption behavior. In the same way, a structural description of monetary policy is essential in estimating meaningful and robust representations of monetary policy—for instance, parameters of a monetary policy loss function. Furthermore, a structural description of consumption choice is essential in generating correct predictions in macro models of the consequences of changes in the policy regime. In the same way, a structural description of monetary policy is essential in generating correct predictions in macro models of consequences of changes in the monetary policy regime (in the form of changes in parameters of the monetary policy loss function), changes in the fiscal policy regime, changes in the policy regime of other countries, or other changes in the relevant economic or political environment.[9]

Indeed, microfoundations of policy are often as helpful as microfoundations of private sector behavior.

[9] See Benigno and Benigno (2003) and Svensson (2004) for examples of the use of targeting rules in discussing international monetary cooperation and transmission of shocks.

3 AN EXAMPLE OF AN OPTIMAL TARGETING RULE

To present an example of a targeting rule, let me consider a variant of the New Keynesian model, a variant used in Svensson and Woodford (2005) and Svensson (2003b), where inflation and the output gap are predetermined.[10] This variant will also be used in discussing McCallum and Nelson's instrument rule analog in Section 4.

Private sector "plans" made in period t for inflation and the output gap in period $t+1$, $\pi_{t+1|t}$ and $x_{t+1|t}$, are determined in period t by

(4)
$$\pi_{t+1|t} - \mathrm{E}[\pi_t] = \delta\left(\pi_{t+2|t} - \mathrm{E}[\pi_t]\right) + \alpha_x x_{t+1|t} + \alpha_z z_{t+1|t},$$

(5) $$x_{t+1|t} = x_{t+2|t} - \beta_r\left(i_{t+1|t} - \pi_{t+2|t} - r^*_{t+1|t}\right) + \beta_z z_{t+1|t}.$$

The aggregate-supply relation, (4), follows from the first-order condition for Calvo-style profit-maximizing price-setting firms. The firms are assumed to index prices to the long-run average inflation, $\mathrm{E}[\pi_t]$, between the times of optimal price-setting, which implies that the long-run Phillips curve is vertical. The parameter $\delta\,(0 < \delta < 1)$ is a discount factor, and $\alpha_x > 0$ is the slope of the short-run Phillips curve. The expression $\alpha_z z_{t+1}$ is the inner product of a vector of coefficients, α_z, and a vector of exogenous random variables, z_{t+1} (the "deviation" in period $t+1$), such that $\alpha_z z_{t+1}$ is a simple representation of the difference between this simple model and the true model of the transmission mechanism. The deviation may also include any "cost-push" and other shocks. Then, $z_{t+1|t} \equiv \mathrm{E}_t z_{t+1}$, where E_t denotes expectations conditional on information available in period t, is the private sector's estimate of the deviation—the private sector's "judgment" in period t. Thus, the one-period-ahead inflation plan depends on expected future inflation, $\pi_{t+2|t} \equiv \mathrm{E}_t\pi_{t+2}$, the output gap plan, $x_{t+1|t}$, and the private sector judgment, $z_{t+1|t}$.

The aggregate-demand relation, (5), follows from the first-order condition for optimal consumption choice by households. Here, i_{t+1} is the instrument rate set by the central bank in period $t+1$, r^*_{t+1} is an exogenous Wicksellian natural interest rate (the real interest rate in a hypothetical flexible-price economy with zero deviation), and β_r is a positive constant (in the simplest case, the intertemporal elasticity of substitution in consumption). Thus, the one-period-ahead output gap plan depends on the expected future output gap, $x_{t+2|t}$, the expected one-period-ahead real interest-rate gap, $i_{t+1|t} - \pi_{t+2|t} - r^*_{t+1|t}$, and the private sector judgment, $z_{t+1|t}$ (through the inner product $\beta_z z_{t+1|t}$).

Actual inflation and the output gap in period $t+1$ will then differ from the plans because of unanticipated shocks to the deviation and natural interest rate:

$$\pi_{t+1} - \pi_{t+1|t} = \alpha_z\left(z_{t+1} - z_{t+1|t}\right),$$
$$x_{t+1} - x_{t+1|t} = \beta_r\left(r^*_{t+1} - r^*_{t+1|t}\right) + \beta_z\left(z_{t+1} - z_{t+1|t}\right).$$

Suppose the central bank conducts flexible inflation targeting and has an intertemporal loss function in period t,

(6) $$\mathrm{E}_t \sum_{\tau=0}^{\infty} (1-\delta)\delta^\tau L_{t+\tau},$$

where the period loss is

(7) $$L_t = \frac{1}{2}\left[\left(\pi_t - \pi^*\right)^2 + \lambda x_t^2\right],$$

where π^* is the inflation target and $\lambda > 0$ is the weight on output gap stabilization relative to inflation stabilization.

An equilibrium that minimizes the central bank's intertemporal loss function (under commitment in a timeless perspective) will fulfill the first-order condition

(8) $$\pi_{t+1|t} - \pi^* + \frac{\lambda}{\alpha_x}\left(x_{t+1|t} - x_{t|t-1}\right) = 0$$

for all periods t (Svensson and Woodford, 2005, and Svensson, 2003b). This condition is the central bank's optimal targeting rule for private sector inflation and output gap plans.

Thus, optimal price-setting and consumption

[10] A predetermined variable depends on the current period's realizations of exogenous variables and previous periods' realizations of endogenous and exogenous variables. Equivalently, a predetermined variable has exogenous one-period-ahead forecast errors (cf. Klein, 2000).

choice by the private sector is described by the first-order conditions (4) and (5), and optimal monetary policy is characterized by the first-order condition (8), the central bank's targeting rule. The behavior of the agents of the model—the firms, the households, and the central bank—are each described by a first-order condition, an attractive symmetry. The central bank's targeting rule is a robust, compact, and, therefore, practical way to describe the optimal monetary policy. In particular, it is robust to the central bank's estimate of the deviation—the central bank's "judgment"—and any additive shocks and their stochastic properties, in the sense that neither the judgment nor any shocks enter into the targeting rule. The targeting rule (8) is a structural representation of monetary policy to the same extent that the aggregate-supply and aggregate-demand relations are structural representations of private sector behavior.

As discussed in some detail in Svensson (2003b), the optimal targeting rule is simply, and fundamentally, a restatement of the standard efficiency condition of *equality between the marginal rates of substitution and transformation between the target variables*. The target variables—the variables that enter into the loss function—are inflation and the output gap. The marginal rate of substitution between inflation and the output gap follows from the form of the loss function, including the relative weight, λ. The marginal rate of transformation between inflation and the output gap follows from the form of the aggregate-supply relation, including the slope of the short-run Phillips curve, α_x. Thus, these two parameters appear in the targeting rule. Because the marginal rate of transformation between inflation and the output gap is completely determined by the aggregate-supply relation, the aggregate-demand relation and its parameters do not affect the targeting rule; the targeting rule is, in this case, robust to the aggregate-demand relation.

Thus, fundamentally, the optimal targeting rule is simply the very robust and intuitive relation

$$\text{MRS} = \text{MRT},$$

where MRS and MRT refer, respectively, to the marginal rates of substitution and transformation between the target variables. This relation holds regardless of the particulars of the model and is, in this sense, model independent. Consider the following instruction: "From your loss function, find the marginal rate of substitution between your target variables. From your view of the transmission mechanism of monetary policy, find your marginal rate of transformation between the target variables. Find and implement an instrument rate, or instrument rate plan, that makes these marginal rates of substitution and transformation equal. Optimal monetary policy is, in principle, as easy as that." What more robust description of optimal monetary policy can you find?

The optimal equilibrium can be solved for by combining the targeting rule, (8), with the aggregate-supply relation, (4). This results in a second-order difference equation that can be solved for the optimal inflation and output gap plans. Substitution of these plans into the aggregate-demand relation, (5), gives the corresponding optimal instrument rate plan. Svensson and Woodford (2005) and Svensson (2003b) discuss in some detail how the central bank can implement (8) for private sector plans by "forecast targeting"—constructing and announcing inflation and output gap projections and a corresponding instrument rate plan that "look good" in the sense of fulfilling the analog of (8) for inflation and output gap projections. McCallum and Nelson do not go into those details.

4 VOLATILITY FROM INSTRUMENT RULES?

Instead, McCallum and Nelson provide a more precise analysis of their previous claim (in McCallum, 1999, p. 1493, and McCallum and Nelson, 2000) that there is a useful instrument rule analog of any targeting rule. They discuss two alternatives: The central bank implements a targeting rule, such as (8), directly; and the central bank replaces the targeting rule (8) with an instrument rule such as

(9)
$$i_{t+1} - r^* - \pi_{t+1|t} = \mu\left[\pi_{t+1|t} - \pi^* + \frac{\lambda}{\alpha_x}\left(x_{t+1|t} - x_{t|t-1}\right)\right],$$

where μ is a large positive number. The idea with (9) is that, for a large μ, there would be an equilibrium fulfilling (4), (5), and (9), where the term in the bracket on the right side of (9) is close to zero and the instrument rate on the left side is close to the optimal instrument rate. Therefore, this instrument rule would result in an equilibrium close to the optimal equilibrium.

This is indeed the case, under some circumstances. But what is the point with McCallum and Nelson's instrument rule? *First*, for any finite μ, the corresponding equilibrium is no longer optimal but only close to optimal. Everything else equal, optimal is better. *Second*, equation (9) is a more complex equilibrium condition than (8). Everything else equal, simplicity is better than complexity. *Third*, the targeting rule (8) has the attractive conceptual property of corresponding to a standard efficiency condition, the equality of the marginal rates of substitution and transformation between the target variables. The instrument rule (9) has no such intuitive interpretation. Hence, there is a conceptual disadvantage to (9). *Fourth*, it is no longer possible to solve for the optimal inflation and output gap plans by combining (9) only with the aggregate-supply relation, (4). Because the instrument rate enters, (9) must now be combined also with the aggregate-demand relation, (5), leading to a higher-order system of difference equations. Hence, there is a computational disadvantage to (9).[11] *Fifth*, as discussed in some detail in Svensson and Woodford (2005), modifying targeting or instrument rules in this way often affects the determinacy properties of forward-looking models and is therefore not innocuous.

Finally, as pointed out in Svensson and Woodford (2005) and Svensson (2003b), a high response coefficient, μ, can lead to instrument rate volatility under realistic information assumptions of some central bank mistakes or even just rounding errors. From a practical perspective, a very high response coefficient is a bizarre idea and would cause serious problems, except under very strange circumstances, as we shall see.

Thus, for several reasons, the instrument rule (9) is inferior to the targeting rule (8). I have not found any arguments by McCallum and Nelson in favor of (9). McCallum and Nelson might have thought that (9) would be easier to implement than (8). But a more precise discussion of the implementation reveals that this is not so: Aside from the issue of volatility, they are equally difficult or easy to implement.[12]

To examine the case of central bank mistakes, McCallum and Nelson consider the targeting rule with a random error, e_t,

$$\pi_{t+1|t} - \pi^* + \frac{\lambda}{\alpha_x}\left(x_{t+1|t} - x_{t|t-1}\right) + e_t = 0, \tag{10}$$

and the alternative instrument rule,

$$i_{t+1} = r^* + \pi_{t+1|t} + \mu\left[\pi_{t+1|t} - \pi^* + \frac{\lambda}{\alpha_x}\left(x_{t+1|t} - x_{t|t-1}\right) + e_t\right]. \tag{11}$$

We can (in a simpler discussion of implementation than in footnote 12) interpret the instrument rule as the central bank attempting to observe private sector plans $\pi_{t+1|t}$ and $x_{t+1|t}$ in period t, using its previous observation of $x_{t|t-1}$ in period t–1, to calculate the expression

[11] More precisely, (8) can be combined with *only* (4) to solve for the optimal inflation and output gap plans. These can then be substituted into (5) to find the optimal instrument rate. If (9) is used instead of (8), it has to be combined with *both* (4) and (5) to solve for the optimal inflation and output gap plans.

[12] The instrument rule (9) is an *implicit* instrument rule, meaning that it is an equilibrium condition, where the variables on the right side depend on the instrument rate; there is a simultaneity aspect that needs to be handled. In contrast, an *explicit* instrument rule makes the instrument a function of predetermined variables, which are hence independent of the instrument. Hence, the implementation of an explicit instrument rule is simply a matter of observing the predetermined variables and calculating and announcing the corresponding instrument value. Implicit instrument rules and targeting rules are both equilibrium conditions, with variables that are simultaneously determined. Hence, their implementation is different from, and more complicated than, that of an explicit instrument rule. As discussed in detail in Svensson and Woodford (2005) and Svensson (2003b), their implementation requires the central bank to use its model of the transmission mechanism, make projections of the variables included in the target rule or implicit instrument rule, and find the combination of instrument and target-variable projections that fulfill the target rule or implicit instrument rule. Announcing these projections and implementing the instrument rate path will then induce the private sector to behave according to the desired equilibrium.

$$\pi_{t+1|t} - \pi^* + \frac{\lambda}{\alpha_x}\left(x_{t+1|t} - x_{t|t-1}\right) \tag{12}$$

for use in (9). In doing this, the central bank introduces a random error, e_t.

McCallum and Nelson then actually calculate the rational expectations equilibrium under the implicit assumption that the error, e_t, is *immediately observed* and known to *both* the central bank and the private sector in period t, *before* the instrument rate i_{t+1} is announced. Suppose that the error is positive, $e_t > 0$. Everything else equal, it would raise the instrument rate by $\mu e_t > 0$, where μ is a large number. The private sector, realizing this, immediately responds by lowering their inflation and output gap plans, $\pi_{t+1|t}$ and $x_{t+1|t}$, according to (4) and (5). Indeed, the private sector is assumed to instantaneously adjust their plans so as to bring about the rational expectations equilibrium for a known error, e_t. Furthermore, the central bank is then assumed to observe the adjusted plans, and then calculate and implement the equilibrium instrument rate according to (11). The result is that the equilibrium instrument rate increases by much less than μe_t. Indeed, with a large μ, (10) is approximately fulfilled, so the equilibrium resulting from (11) ends up being similar to the equilibrium resulting from (10) (disregarding any determinacy issues). In particular, the error introduces no more volatility for the instrument rule (11) than for the targeting rule (10).

But the idea that the central bank and the private sector immediately observe the error in period t is strange, to say the least. If the central bank observes the error, why does it not immediately correct the sum (12) so as to eliminate the error and instead implement (9) without any error?

Assume, more realistically, that the error is not immediately observed by the central bank or the private sector. Instead, the private sector first forms its plans under the assumption of an expected central bank error equal to zero (assuming that the error is i.i.d. and has a zero mean). The central bank then imperfectly observes those plans, introduces the (measurement) error, and announces the corresponding instrument rate, i_{t+1}, for period $t+1$. Assume, realistically, that the instrument rate can be announced only once in each period. In this case, the error hits the instrument rate with the full force of μe_t. If the private sector knows its own plans and how the central bank calculates the instrument rate, the private sector will be able to infer the error when it learns i_{t+1}. If the announcement is early—in period t rather than in period $t+1$—the private sector may be able to adjust its plans after the announcement, and the error will have an impact on the plans. If the announcement is late—in period $t+1$—the private sector plans cannot be adjusted and the plans for inflation and the output gap are unaffected by the error. But, in either case, the error still affects the instrument rate with the full magnitude μe_t. Under this realistic information assumption of the error not being immediately observed by the central bank and the private sector, a large μ will indeed introduce high volatility of the instrument rate, precisely as argued in Svensson and Woodford (2005) and Svensson (2003b). Central bankers, beware of McCallum and Nelson's instrument rule!

Even something as trivial as a small rounding error could be problematic. Suppose that the central bank rounds off its calculation of (12) to one decimal percentage point—that is, 10 basis points. This would introduce a uniformly distributed absolute error with a mean of 2.5 basis points. With $\mu = 50$, the corresponding mean absolute error of the instrument rate is 125 basis points—a sizeable error, especially because instrument changes are seldom larger than 50 basis points. In real-world monetary policy, the error, e_t, could be substantially larger—say, a mean absolute error of 50 basis points (0.5 percent) or more. With $\mu = 50$, this would lead to a huge mean absolute instrument rate error of 2,500 basis points or more.

McCallum and Nelson (2005) defend their informational assumptions by pointing out, in their reply ("Commentary," pp. 627-31), that Svensson and Woodford (2005) and Svensson (2003b) make information assumptions that imply that any error would be immediately revealed. But Svensson and Woodford (2005) and Svensson (2003b) do not attempt to provide any detailed discussion of such central bank errors and related realistic information assumptions. This detail is provided here, instead. One might have wished that McCallum and Nelson would have considered more realistic information assumptions on their own, because these assumptions are so crucial to their proposition. Indeed, realistic assumptions completely contradict their proposition.

Thus, the criticism in Svensson and Woodford (2005) and Svensson (2003b) of McCallum and Nelson's proposed instrument rule stands up to scrutiny: An instrument rule such as (9) with a very large response coefficient is a purely academic construction and completely impractical for any real-world monetary policy. The first five items in the list in the beginning of this section provide additional reasons why such instrument rules are inferior to targeting rules.

5 GENERAL TARGETING RULES?

The discussion here has so far concerned "specific" targeting rules, in the terminology of Svensson and Woodford (2005) and Svensson (2003b). Those papers also define "general" targeting rules for monetary policy as an operational formulation of the objectives for monetary policy—for instance, in the form of listing the target variables and the corresponding target levels and specifying the loss function to be minimized. McCallum and Nelson clearly find this definition confusing and not useful. My idea behind the definition is that the instruction to "specify your loss function in an operational way, construct forecasts of the target variables, and select and implement an instrument rate or an instrument rate path such that the forecasts minimize the loss function" is such a specific instruction to a central bank that it deserves to be called a "rule," in the common (and dictionary, see Merriam-Webster, 1996) sense of a rule being "a prescribed guide for conduct or action."[13] Perhaps it would have been better, and caused less confusion, to refer to this as "general targeting" instead of a "general targeting rule."[14] Walsh (2003) uses the term "targeting regime," which arguably is better.[15]

The idea with a particular terminology and particular definitions is, of course, that it shall contribute to more useful and precise discussion and analysis. I am inclined to concede that the term "general targeting rule" has not been successful and that Walsh's term "targeting regime" is better. Consequently, I am inclined to use that terminology in the future and to let "targeting rules" refer only to what I have previously called "specific" targeting rules.[16]

6 CONCLUSION

Counter to what McCallum and Nelson seem to take as granted, there is no reason at all to limit a study of robust simple monetary policy rules to instrument rules; simple targeting rules may have more desirable properties. Furthermore, targeting rules are a compact, robust, structural and, therefore, practical representation of goal-directed monetary policy. From a descriptive

[13] This is the idea behind the word "rule" in the title of Svensson (1999), "Inflation Targeting as a Monetary Policy Rule."

[14] It should not be necessary to state that "targeting," in the sense of "achieving a target," is best seen as equivalent to minimizing a loss function that is increasing in the deviation between the target variables and the target levels. That is, targeting and target variables refer to a loss function to be minimized and the arguments in that loss function. Previously, the literature has, by "targeting variable *X*," sometimes meant putting variable *X* in the instrument rule. To avoid confusion, it is better to call this "responding to variable *X*." Generally, the best way to target variable *X*, in the sense of minimizing a loss function increasing in deviations of variable *X* from its target level, is to respond, in the explicit instrument rule, to *all* the *determinants* of variable *X*. Even if inflation and the output gap are the only target variables, there are usually many more variables determining future inflation and the output gap, and it is optimal to respond to all of those. Generally, the mapping from a loss function to the optimal reaction function, the optimal explicit instrument rule, is quite complex, and the response coefficients of the optimal explicit instrument rule are complicated and sometimes nonmonotonic functions of the parameters of the loss function and the whole model. The size of the response coefficient of a variable is not an indicator of the weight of the variable in the loss function.

[15] In any case, there is always a close relation between a (specific) targeting rule in the form of some scalar expression $T_t(\pi_t,x_t) = 0$ and a loss function of the form $L_t = [T_t(\pi_t,x_t)]^2$, because the former is a first-order condition for a minimum of the latter.

[16] For a situation when a commitment to an optimal (specific) targeting rule is not possible, Svensson and Woodford (2005) and Svensson (2003b) discuss a "commitment to continuity and predictability," which involves minimizing the central-bank loss function while taking into account the cost of deviating from previously announced forecasts. This will make optimization under discretion result in the optimal outcome under commitment. Strangely, McCallum and Nelson describe this mechanism that induces the central bank to keep previous promises as "the central bank describing its objectives dishonestly to the public" (p. 598).

point of view, they amount to the same development in the theory of monetary policy as the consumption Euler conditions in the theory of consumption. Optimal targeting rules express the intuitive optimality condition of equality between the marginal rates of substitution and transformation of the target variables. They provide microfounded monetary policy, in the same way Euler conditions provide microfounded private sector behavior. Regardless of McCallum and Nelson's skepticism in McCallum and Nelson (2005), targeting rules for the analysis of monetary policy have arrived and are, as indicated by the long list of papers and books mentioned in the introduction, likely to stay. In particular, McCallum and Nelson's proposed instrument rule analog to any targeting rule will, under realistic information assumptions, lead to very high instrument rate volatility; for other reasons, it is also inferior to the targeting rule.

REFERENCES

Aizenman, Joshua and Frenkel, Jacob A. "Targeting Rules for Monetary Policy." *Economics Letters*, 1986, *21*(2), pp. 183-87.

Benigno, Pierpaolo and Benigno, Gianluca. "Designing Targeting Rules for International Monetary Policy Cooperation." ECB Working Paper No. 279, European Central Bank, October 2003.

Benigno, Pierpaolo and Woodford, Michael. "Optimal Monetary and Fiscal Policy: A Linear-Quadratic Approach" in Mark Gertler and Kenneth Rogoff, eds., *NBER Macroeconomics Annual 2003*. Volume 18. Cambridge, MA: MIT Press, 2004a, pp. 271-333.

Benigno, Pierpaolo and Woodford, Michael. "Optimal Stabilization Policy When Wages and Prices are Sticky: The Case of a Distorted Steady State." Unpublished manuscript, 2004b (forthcoming in *Journal of the European Economic Association*).

Bernanke, Ben S. "The Logic of Monetary Policy." Speech given before the National Economists Club, Washington, DC, December 2, 2004; www.federalreserve.gov.

Bernanke, Ben S. and Woodford, Michael. "Inflation Forecasts and Monetary Policy." *Journal of Money, Credit, and Banking*, November 1997, *29*(4, Part 2), pp. 654-84.

Bernanke, Ben S. and Woodford, Michael. *The Inflation-Targeting Debate*. Chicago: Chicago University Press, 2004.

Black, Richard; Cassino, Vincenzo; Drew, Aaron; Hansen, Eric; Hunt, Benjamin; Rose, David and Scott, Alasdair. "The Forecasting and Policy System: The Core Model." Research Paper No. 43, Reserve Bank of New Zealand, 1997.

Brash, Donald T. "Making Monetary Policy: A Look behind the Curtains." Speech given before the Canterbury Employers' Chamber of Commerce, Christchurch, January 26, 2001.

Cecchetti, Stephen G. "Central Bank Policy Rules: Conceptual Issues and Practical Considerations," in Helmut Wagner, ed., *Current Issues in Monetary Economics*. Heidelberg: Physica-Verlag, 1998, pp. 121-40.

Cecchetti, Stephen G. "Making Monetary Policy: Objectives and Rules." *Oxford Review of Economic Policy*, 2000, *16*(4), pp. 43-59.

Cecchetti, Stephen G. and Kim, Junhan. "Inflation Targeting, Price-Path Targeting, and Output Variability," in Ben S. Bernanke and Michael Woodford, eds., *The Inflation-Targeting Debate*. Chicago: Chicago University Press, 2004, pp. 173-95.

Evans, George W. and Honkapohja, Seppo. "Monetary Policy, Expectations and Commitment." Unpublished manuscript, 2004a (forthcoming in *Scandanavian Journal of Economics*).

Giannoni, Marc P. and Woodford, Michael. "Optimal Interest-Rate Rules: I. General Theory." NBER Working Paper No. 9419, National Bureau of Economic Research, 2003a.

Giannoni, Marc P. and Woodford, Michael. "Optimal Interest-Rate Rules: II. Applications." NBER Working Paper No. 9420, National Bureau of Economic Research, 2003b.

Giannoni, Marc P. and Woodford, Michael. "Optimal Inflation Targeting Rules," in Ben S. Bernanke and Michael Woodford, eds., *The Inflation-Targeting Debate*. Chicago: Chicago University Press, 2004, pp. 93-171.

Goodhart, Charles A.E. "Monetary Transmission Lags and the Formulation of the Policy Decision on Interest Rates." Federal Reserve Bank of St. Louis *Review*, July/August 2001, *83*(4), pp. 165-81.

Hall, Robert E. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy*, December 1978, *86*(6), pp. 971-87.

Hansen, Lars Peter and Sargent, Thomas J. "Robust Control of Forward-Looking Models." *Journal of Monetary Economics*, April 2003, *50*, pp. 581-604.

Hansen, Lars Peter and Sargent, Thomas J. "Robust Control and Model Uncertainty." Unpublished manuscript, 2005; homepages.nyu.edu/~ts43/.

Klein, Paul. "Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model." *Journal of Economic Dynamics and Control*, September 2000, *24*, pp. 1405-23.

Kuttner, Kenneth N. "The Role of Policy Rules in Inflation Targeting." Federal Reserve Bank of St. Louis *Review*, July/August 2004, *86*(4), pp. 89-111.

McCallum, Bennett T. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy*, 1988, *29*, pp. 173-204.

McCallum, Bennett T. "Issues in the Design of Monetary Policy Rules," in John Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*. Volume 1C. New York: North-Holland, 1999, pp. 1483-530.

McCallum, Bennett T. and Nelson, Edward. "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis." *Journal of Money, Credit, and Banking*, August 1999, *31*(3), pp. 296-316.

McCallum, Bennett T. and Nelson, Edward. "Timeless Perspective vs. Discretionary Monetary Policy in Forward-Looking Models." Federal Reserve Bank of St. Louis *Review*, March/April 2000, *86*(2), pp. 43-56.

McCallum, Bennett T. and Nelson, Edward. "Targeting vs. Instrument Rules for Monetary Policy." Federal Reserve Bank of St. Louis *Review*, September/October 2005, *87*(5), pp. 597-611.

Meltzer, Allan H. "Limits of Short-Run Stabilization Policy." Presidential address to the Western Economic Association, July 3, 1986. *Economic Inquiry*, January 1987, *25*, pp. 1-13.

Merriam-Webster's Tenth New Collegiate Dictionary. Springfield, MA: Merriam-Webster, 1996.

Mishkin, Frederic S. "The Role of Output Stabilization in the Conduct of Monetary Policy." *International Finance*, Summer 2002, *5*(2), pp. 213-27.

Onatski, Alexei and Williams, Noah. "Empirical and Policy Performance of a Forward-Looking Monetary Model." Unpublished manuscript, 2004; www.princeton.edu/~noahw/forward15.pdf.

Preston, Bruce. "Adaptive Learning and the Use of Forecasts in Monetary Policy." Working paper, Columbia University, 2004.

Rudebusch, Glenn D. and Svensson, Lars E.O. "Policy Rules for Inflation Targeting," in John Taylor, ed., *Monetary Policy Rules*. Chicago: Chicago University Press, 1999, pp. 203-46.

Sims, Christopher A. "Macroeconomics and Reality." *Econometrica*, January 1980, *48*(1), pp. 1-48.

Svensson, Lars E.O. "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review*, June 1997, *41*(6), pp. 1111-46.

Svensson, Lars E.O. "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics*, 1999, *43*(3), pp. 607-54.

Svensson, Lars E.O. "Independent Review of the Operation of Monetary Policy in New Zealand:

Report to the Minister of Finance." Unpublished manuscript, 2001; www.princeton.edu/~svensson/NZ/RevNZMP.htm.

Svensson, Lars E.O. "The Inflation Forecast and the Loss Function," in Paul Mizen, ed., *Central Banking, Monetary Theory and Practice: Essays in Honour of Charles Goodhart*. Volume 1. New York: Edward Elgar, 2003a, pp. 135-52.

Svensson, Lars E.O. "What is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules." *Journal of Economic Literature*, 2003b, *41*(2), pp. 426-77.

Svensson, Lars E.O. "The Magic of the Exchange Rate: Optimal Escape from a Liquidity Trap in Small and Large Open Economies." Working paper, Princeton University, 2004; www.princeton.edu/~svensson.

Svensson, Lars E.O. "Optimization under Discretion and Commitment, and Targeting Rules and Instrument Rules." Lecture notes. Princeton University, 2005; www.princeton.edu/~svensson.

Svensson, Lars E.O; Houg, Kjetil; Solheim, Haakon and Steigum, Erling. "An Independent Review of Monetary Policy and Institutions in Norway." *Norges Bank Watch 2002*, Centre for Monetary Economics, Norwegian School of Management BI, 2002; www.princeton.edu/~svensson.

Svensson, Lars E.O. and Woodford, Michael. "Implementing Optimal Policy through Inflation-Forecast Targeting," in Ben S. Bernanke and Michael Woodford, eds., *The Inflation-Targeting Debate*. Chicago: Chicago University Press, 2004, pp. 19-83.

Taylor, John B., ed. *Monetary Policy Rules*. Chicago: Chicago University Press, 1999.

Walsh, Carl E. *Monetary Theory and Policy*. Second edition. Cambridge, MA: MIT Press, 2003.

Walsh, Carl E. "Parameter Misspecification and Robust Monetary Policy Rules." Working paper, University of California–Santa Cruz, 2004a; econ.ucsc.edu/~walshc.

Walsh, Carl E. "Robustly Optimal Instrument Rules and Robust Control: An Equivalence Result." *Journal of Money, Credit, and Banking*, December 2004b, *36*(6), pp. 1105-13; econ.ucsc.edu/~walshc.

Woodford, Michael. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, NJ: Princeton University Press, 2003.

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

Commentary

Bennett T. McCallum and Edward Nelson

The following are comments in response to Lars Svensson's "Targeting versus Instrument Rules for Monetary Policy: What Is Wrong with McCallum and Nelson?"

Federal Reserve Bank of St. Louis *Review*, September/October 2005, *87*(5), pp. 627-31.

We are very pleased that Lars Svensson refers to us as "good friends," for we certainly view him in that manner. We therefore regret that we have little agreement with the manner in which he has represented the arguments in our paper (McCallum and Nelson, 2005). To begin with, to characterize our paper as "destructive" is, we believe, not justified by the content of the paper. One of its main purposes is to recognize and emphasize that there is no single approach to policy rule analysis that is uniquely legitimate; targeting rules are appropriate and convenient for some problems, whereas instrument rules are for others. That this is our position should be clear from our previous writings, from the explicit passage on our page 598,[1] and from the fact that over half of our paper—Sections 5 and 6—is devoted to analysis showing that instrument rules can be used to approximate targeting rules as closely as desired. In what sense is any of this "destructive," rather than merely expressing a somewhat different, more eclectic, approach to policy rule analysis? Also, to suggest that we are engaged in a "struggle against targeting rules" is to suggest something that we could not imagine that Lars would believe, especially because we use targeting rules in our own work—e.g., McCallum and Nelson (2004) and Jensen and McCallum (2002).

On his p. 613, Svensson emphasizes that "there is now a rapidly growing literature by many authors that successfully applies targeting rules to monetary policy analysis" and hints that historical inevitability is on his side (page 613, paragraph 2). We agree that an increasing fraction of monetary policy rule analysis is based on targeting rules, but this fact does not settle any of the actual issues. In Svensson's passages, for example, there is a good bit of appealing rhetoric but no indication of how a study is judged to be "successful." Besides, there are many types of contemporary phenomena that seem inevitable yet highly undesirable.

In his footnote 3, Svensson says that we "seem to believe that no central bank is using a targeting rule and that a central bank needs to announce an explicit loss function to use a targeting rule," which he denies. But in this regard, it is important to note that our paper interprets a targeting rule as definitionally given by optimality conditions with respect to a particular objective function and particular model. Our justification for this stated limitation is based on Svensson's

[1] "It is not our intention to argue that analysis with instrument rules is in all respects preferable to the use of targeting rules. Even if we held that belief, moreover, we would not think it socially desirable for all researchers to employ the same approach."

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practice as well as his several writings on the subject prior to his *Journal of Economic Literature* paper (2003a). It is adopted explicitly in our paper—see footnote 6.

INVALID ANALOGY WITH CONSUMPTION THEORY

In his Section 2, Svensson makes the observation, with which we agree fully, that it is desirable to model consumption decisions—and, for that matter, all other private sector spending and pricing decisions—as reflecting optimizing behavior by private agents in the economy. But Svensson's conclusions about the implications of this observation for modeling central bank behavior constitute a non sequitur. Dynamic general equilibrium theory implies that valid policy analysis—for example, working out the implications for inflation or output gap variability of a particular monetary policy rule—*always* requires modeling the private sector as optimizing. By contrast, how central bank behavior should be modeled depends on the purpose of the analysis. If the intention is to work out the effects of a constant money growth rule, then the central bank should be modeled as following a constant money growth rule. If the intention is to work out the effects of a fixed exchange rate regime, the central bank should be modeled as pursuing a fixed exchange rate. And if the intention is to work out the effects of the regimes that we observe in practice, the analyst should strive to model central bank behavior realistically.

Svensson, of course, argues that the most realistic characterization of inflation targeting is as a targeting rule. We have presented evidence that casts doubt on this characterization and have argued that an instrument rule characterization of actual central bank behavior is preferable. To emphasize, we argued that this was a valid characterization of the manner in which some inflation-targeting central banks actually carried out their policy decisions. We rested our argument not on the "descriptive" grounds Svensson attributes to us—i.e., on the ex post reduced-form relationships between the monetary policy instrument and other variables—but on documentation produced by these inflation-targeting central banks of their practices and on the support that that evidence provides for an instrument rule interpretation of policy.[2] If our claim is valid, then the appropriate means of carrying out a structural analysis of inflation targeting is to use a model that combines the private sector's optimality conditions with an instrument rule (possibly including expectational terms) estimated over the period of inflation targeting. There is no internal inconsistency, or irony, in following this procedure. Rather, the procedure takes into account the necessary condition for a valid structural model (i.e., private sector optimizing behavior), while also using the policy rule specification that is the best approximation of actual practice.

FRIEDMAN'S *k*-PERCENT RULE

In his latest discussion, Svensson goes beyond his argument that targeting rules closely describe the practice of inflation-targeting central banks, to claim that even "Friedman's *k*-percent rule is a *targeting* rule!" (2005, p. 614). A more careful consideration of Friedman's own description of his proposed rule, however, rules out a targeting rule interpretation.

Svensson argues that, because Friedman's proposal involves targeting growth in a definition of the money supply that includes commercial bank deposits, the targeted variable is necessarily out of direct control of the central bank. Therefore, he contends, the effort of the central bank to target a monetary aggregate can be characterized as a targeting rule. But the specifics of Friedman's proposal clearly contradict targeting rule practice. Consider first the specific proposal for the *k*-percent money growth rule outlined in Friedman

[2] This documentation included evidence that inflation-targeting countries viewed discretionary adjustments to policy as adjustments to the settings implied by an instrument rule. The implication of this for our discussion of Svensson is that, contrary to the suggestions of Svensson (2003a), central banks' use of "judgment" is not evidence in favor of targeting rules over instrument rules as a characterization of inflation targeting. Svensson's (2005) footnote 8 muddies the waters by focusing on the discretion-vs.-commitment issue rather than the targeting-vs.-instrument rules issue that is at the heart of our debate.

(1960). The 1960 proposal included a list of reforms to be undertaken prior to implementing the rule, including the introduction of 100 percent reserve requirements on those commercial banks whose deposits were included in the proposed target aggregate. This reform would make the target identical to the monetary base—immediately making the *k*-percent rule an instrument rule.

More frequently, Friedman has set out a *k*-percent money growth proposal without suggesting the major overhaul of the financial system implied by a 100 percent reserve requirement. In that case, the definition of money targeted, if it includes commercial bank deposits, will not be subject to exact central bank control. Does this rule proposal correspond to a targeting rule? Clearly not. Consider the following specifics of the proposal as given by Friedman (1982, p.117):

> Set a target for several years ahead for a single aggregate—for example, M2 or the base…
>
> Estimate the change over an extended period, say three to six months, in the Fed's holdings of securities that would be necessary to approximate the target path over that period. Divide that estimate by 13 or 26. Let the Fed purchase precisely that amount every week…
>
> Finally, announce in advance and in full detail the proposed schedule of purchases and stick to it.

Friedman's proposal here refers to targeting either "M2 or the base." The latter again corresponds simply to a constant-growth instrument rule for the base. In the case of M2 targeting, denoting the log of the money multiplier by $mu = \log(\text{M2}) - h$, with h the log of the monetary base, this rule is given by $\Delta h_t = (k/400) - 1.0\, \text{E}_{t-1}\Delta mu_t$, that is, a simple instrument rule with an intercept term and one further argument, the expected change in the money multiplier.[3] Importantly, Friedman's proposal explicitly specifies the policy instrument (the monetary base) with which to pursue the target. A targeting rule, by contrast, generally does not explicitly refer to the policy instrument.

While we disagree with Svensson's characterization of Friedman's rule, his surrounding discussion does indicate that his perspective is coming closer to ours. Whereas Svensson once devoted considerable effort to arguing that "[i]nflation-targeting central banks should specify explicit loss functions…[including] a specific relative weight on output-gap stabilization" (Svensson, 2003b, p. 148), Svensson (2005) goes so far as to say that a "simple and robust monetary policy rule is indeed an attractive idea," especially if the central bank "does not trust its information about…the output gap" and in light of uncertainty about "the true model of the transmission mechanism of monetary policy." These are, of course, long-standing arguments of those who argue for instrument rules. A targeting rule is hardly an ideal way of treating these problems. The lack of information about the output gap that Svensson acknowledges would make it hard for central bank committee members to settle on a way of estimating the gap, let alone follow the Svensson (2003b) proposal of announcing a welfare function with an explicit output gap weight. Proceeding with such an announcement in the face of uncertainty about the output gap would hardly be the way to create a "robust" rule and so would be unattractive by Svensson's own standard. As we emphasized in McCallum and Nelson (2005), the more general dilemma for targeting rules is that they are especially vulnerable to robustness problems because of their model dependency. Levin and Williams's (2003) results graphically depict the bloodbath that can result from imposing targeting rules derived from one model specification on models that come from other areas of the specification space.

VOLATILITY ANALYSIS

Let us now consider Svensson's discussion of our analytical contribution concerning interest rate variability. We are, of course, quite pleased that he acknowledges that our claims regarding volatility are correct, under the information

[3] Note that Friedman (1982) explicitly disavows using period-t information in pursuing the monetary target. His proposal therefore cannot correspond to a targeting rule because an optimal-control approach to targeting M2 would utilize period-t information helpful in hitting the target. Friedman is clearly willing to forfeit possible extra precision in hitting the target in favor of making the target one that can be pursued by a fully predictable instrument rule for the monetary base.

assumptions utilized in Svensson (2003a) and Svensson and Woodford (2005). We had been under the impression that these assumptions reflected careful consideration, as is typically the case in the work of both Svensson and Woodford. But now Lars goes on to propose new assumptions as representing "realistic" information conditions. We find the particulars of his specification to be unclear—e.g., concerning "early" versus "late" in a given time period and especially the notion that the central bank would "observe" its own error; so, rather than attempting a new discussion, let us state our position regarding information assumptions that we believe to be appropriate for monetary policy analysis. In previous work (e.g., McCallum and Nelson, 2004), we have suggested that, when setting i_t (the one-period instrument interest rate in period t), the central bank does not know the values of π_t or x_t (the inflation rate and output gap, respectively, during period t). Let us now provisionally agree with Svensson that private agents also do not know π_t or x_t when making decisions in period t. But they *do* know i_t, for financial market prices are observable day by day (or hour by hour), so i_t rather than $E_{t-1}i_t$ appears in equation (7). Then, under the assumption of rational expectations and with common information sets—*except that* private agents do not know e_{t-1}, the central bank error made in setting i_t—private agents will be able to infer e_{t-1} from the central bank's policy rule together with the specification of the economy using equation (12) or (15). Therefore, expectations formed in period t of any variable for period t or the future will be the same for the central bank and private agents. The foregoing is, however, equivalent to the assumption used in our paper (as well as in Svensson, 2003a, and Svensson and Woodford, 2005). So the analysis as presented in our Section 6 seems to be realistically appropriate, as well as consistent with the two just-cited papers.

In the section of his comment that discusses volatility, Svensson also presents five claims ("first," "second," etc.) that are logically irrelevant to the discussion—*of course* his equation (9) is an approximation to (8)!—except for the fourth item. This one is basically incorrect, however, because to implement Svensson's (8) requires use of his (5); the function of (9) in this context is to constitute one way of implementing (8).

CONCLUSION

In conclusion, we note that on p. 621 Svensson warns as follows: "Central bankers, beware of McCallum and Nelson's instrument rule!" But the rule he is referring to—with a very large value of μ_1—is one that we say (explicitly) that we have *not* recommended (please see our discussion on p. 603). It was used in our 2004 paper as an implementation device; in our current paper, it serves to illustrate our analytical claim, namely, that our instrument rule (actually, class of rules) is usually superior in performance, with respect to Lars's own criterion, to the targeting rule that it approximates.

Finally we turn to Svensson's featured question: "What is wrong with McCallum and Nelson?" In terms of personal characteristics, we would admit to a multitude of flaws, weaknesses, and fundamental defects. In terms of the arguments of our paper, however, we believe that the correct answer is: "Nothing."

REFERENCES

Friedman, Milton. *A Program for Monetary Stability*. Fordham, NJ: Fordham University Press, 1960.

Friedman, Milton. "Monetary Policy: Theory and Practice." *Journal of Money, Credit, and Banking*, February 1982, *14*(1), pp. 98-118.

Jensen, Christian, and McCallum, Bennett T. "The Non-Optimality of Proposed Monetary Policy Rules under Timeless-Perspective Commitment." *Economics Letters*, 2002, *77*(2), pp. 163-68.

Levin, Andrew T. and Williams, John C. "Robust Monetary Policy with Competing Reference Models." *Journal of Monetary Economics*, 2003, *50*(5), pp. 945-75.

McCallum, Bennett T. and Nelson, Edward. "Timeless Perspective vs. Discretionary Monetary Policy in Forward-Looking Models." Federal Reserve Bank of St. Louis *Review*, March/April 2004, *86*(2), pp. 43-56.

McCallum, Bennett T. and Nelson, Edward. "Targeting vs. Instrument Rules for Monetary Policy." Federal Reserve Bank of St. Louis *Review*, September/October 2005, *87*(5), pp. 597-611.

Svensson, Lars E.O. "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules." *Journal of Economic Literature*, 2003a, *41*(2), pp. 426-77.

Svensson, Lars E.O. "The Inflation Target and the Loss Function," in Paul Mizen, ed., *Central Banking, Monetary Theory and Practice: Essays in Honour of Charles Goodhart.* Volume 1. Cheltenham: Edward Elgar, 2003b, pp. 135-52.

Svensson, Lars E.O. "Targeting Rules vs. Instrument Rules for Monetary Policy: What Is Wrong with McCallum and Nelson?" Federal Reserve Bank of St. Louis *Review*, September/October 2005, *87*(5), pp. 613-25.

Svensson, Lars E.O. and Woodford, Michael. "Implementing Optimal Policy through Inflation-Forecast Targeting," in Ben S. Bernanke and Michael Woodford, eds., *The Inflation-Targeting Debate*. Chicago: University of Chicago Press, 2005, pp. 19-83.

The Monetary Instrument Matters

William T. Gavin, Benjamin D. Keen, and Michael R. Pakko

This paper revisits the debate over the money supply versus the interest rate as the instrument of monetary policy. Using a dynamic stochastic general equilibrium framework, the authors examine the effects of alternative monetary policy rules on inflation persistence, the information content of monetary data, and real variables. They show that inflation persistence and the variability of inflation relative to money growth depend on whether the central bank follows a money growth rule or an interest rate rule. With a money growth rule, inflation is not persistent and the price level is much more volatile than the money supply. Those counterfactual implications are eliminated by the use of interest rate rules whether prices are sticky or not. A central bank's use of interest rate rules, however, obscures the information content of monetary aggregates and also leads to subtle problems for econometricians trying to estimate money demand functions or to identify shocks to the trend and cycle components of the money stock.

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Central banks around the world have long settled on the use of interest rates as instruments to implement monetary policy; but, until recently, there was no sound theory supporting this choice. The intuition for why interest rate rules dominate is straightforward in a world with sticky prices and interest-elastic money demand (see boxed insert). When the demand for real money balances is interest elastic, any shock that affects the path for expected inflation or the real interest rate causes money demand to shift. When the central bank follows a money growth rule, this shift causes the price level to jump. If price adjustment is costly, this jumping can create real distortions. When the central bank follows an interest rate rule, on the other hand, the money stock is endogenous and absorbs the adjustment. The central bank can accommodate this jump in the money stock almost instantaneously and with little cost.

This article explains the theory behind this intuition by comparing and contrasting the properties of four monetary general equilibrium models. The four models differ along two dimensions: the monetary authority's policy rule and the nature of price adjustments. We examine two monetary policy rules—an exogenous money growth rule and an interest rate rule based on Taylor (1993)—and two price adjustment mechanisms—flexible prices found in a typical real business cycle (RBC) model and sticky prices found in a typical New Keynesian model. The closest work to this article is Kim (2003), which looks at how the cyclical nature of the real economy depends on the specification of the policy rule and the form of the nominal frictions. The author concludes that getting the policy rule right is at least as important as getting the nominal frictions right. Our paper emphasizes the behavior of money and prices, but also reports results for real variables that are consistent with Kim's findings.

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MONEY DEMAND AND INTEREST RATE RULES

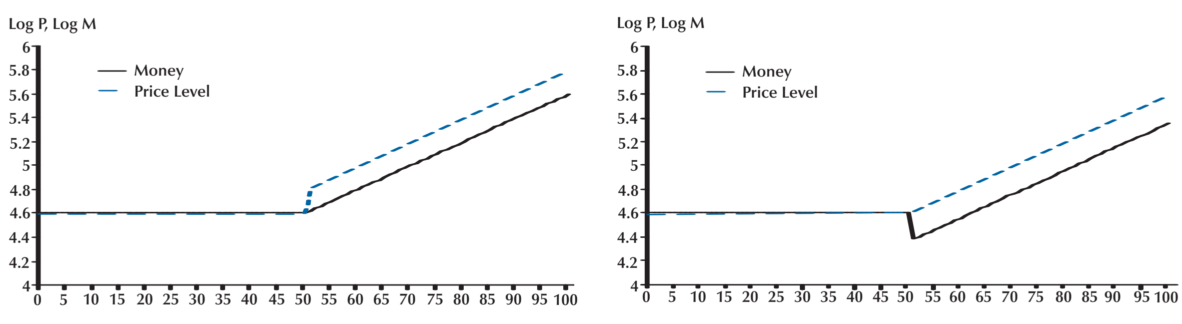
The intuition for the difference between an interest rate and a monetary aggregate instrument can be gleaned from the analysis of money demand in Friedman (1969). The demand for real money balances is a function of a scale variable, such as income, and an opportunity cost variable, such as the nominal interest rate, such that $M_t^D/P_t = H(\overset{+}{Y}_t, \overset{-}{R}_t)$. Panel A in the accompanying figure is based on Figure 3 from Friedman's illustration of the response of money demand and the price level following the central bank's surprise decision to permanently raise the money growth trend (inflation) from zero to a positive number—that is, 2 percent in Panel A. The money supply and the price level are indexed to 100 and remain fixed before the policy change. With the 2 percent rise of inflation, the nominal interest rate rises by 2 percent and the demand for money drops immediately. Because the central bank has exogenously fixed the money growth rate, the price level must rise to accommodate the fall in real balances. In an economy where the long-run expected inflation trend is subject to shocks, the inflation rate is highly variable relative to the money growth rate.

Panel B illustrates what happens if the central bank uses the interest rate as the monetary policy instrument. In that case, the credible announcement of 2 percent inflation requires raising the nominal interest rate target by 2 percent. The increase also leads to an immediate drop in the demand for real money balances. With a nominal interest rate rule, however, the money supply is endogenous and inflation is fixed by the policy rule. It is the money stock, rather than the price level, that responds by shifting downward to clear the money market. Hence, in an economy with stochastic inflation and an interest rate rule for monetary policy, the money growth rate is much more variable than the inflation rate. That result is consistent with our observations from modern economies where central banks generally use the nominal interest rate to implement policy.

Figure B1

Monetary Policy Rules and a Change in the Inflation Target

A. Money Growth Rule*　　　**B. Interest Rate Rule***



*There is a shift from 0 to 2 percent in the inflation objective in period 50.

Early dynamic stochastic general equilibrium models that featured money as the policy instrument also included flexible prices—and hence implied small effects of monetary shocks on real variables and unrealistically high price-level variability with low inflation persistence; examples include Cooley and Hansen (1989, 1995), Lucas (1990), Fuerst (1992), and Christiano and Eichenbaum (1992).[1] Later, models with sticky prices came to dominate the literature; Cho and Cooley (1995), Kimball (1995), King and Wolman (1996), and Yun (1996) are representative of this approach.[2]

Kimball (1995), for example, examined a sticky-price model that assumed a constant velocity of money and an exogenous money supply rule. This article demonstrates that two distinct elements omitted from Kimball's model are crucial for understanding price dynamics. The first is an interest-sensitive money demand function, and the second is a monetary policy reaction function based on an interest rate rule. King and Wolman (1996) present a model with a shopping-time role for money demand that is interest elastic, but most of their analysis assumes that the central bank either controls inflation directly or follows an exogenous money growth rule. They include only a very brief analysis of money growth rules versus interest rate rules.

We extend the methodology of King and Wolman (1996) to analyze more thoroughly the important distinctions between flexible-price and sticky-price models on the one hand and between interest rate rules and money supply rules on the other. Even though central banks do not use money growth rules in practice, we compare that regime to interest rate regimes because much of our conventional wisdom about money and monetary policy comes from analysis using models with money growth rules. We also emphasize a distinction between the steady-state inflation rate and the inflation target. Historically, most central banks have not had constant inflation targets, but their targets evolve over time. Here the expected inflation target converges to the steady state in the long run, but it can deviate for a considerable period. Consequently, we consider two types of policy shocks: a highly persistent inflation target shock and a relatively short-lived liquidity shock.

THE MODEL

In this model framework, agents are infinitely lived. Households get utility from consumption and leisure but need to spend time shopping for consumption goods; they can reduce the shopping time for a given level of consumption by holding higher money balances. The interest elasticity of money demand is a key parameter for determining the nature of inflation dynamics. Households consume a composite good that is a combination of outputs from monopolistically competitive firms. Sticky prices are introduced using a Calvo (1983) specification that allows for the possibility of perfect price flexibility as a nested special case.[3] Thus, it is straightforward to hold all other model features constant when comparing sticky-price and flexible-price specifications. Monetary policy is conducted through lump-sum monetary transfers that are determined by the central bank's monetary policy rule. Our focus is on the differences implied by policy rules that use the short-term interest rate as an instrument versus those that target money growth directly.

Households

Each period, households maximize the discounted present value of the expected utility they get from consumption and leisure:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, l_t\right), \tag{1}$$

where β is the household's discount factor, c_t is the consumption bundle, and l_t is leisure time.

[1] See Dittmar, Gavin, and Kydland (2005) and Dressler (2003) for recent examples with flexible-price models with interest rate rules. Ireland (2003) examines the role of policy in estimated versions of both flexible- and sticky-price models.

[2] See also influential papers by Ireland (1996), Rotemberg and Woodford (1997), and McCallum and Nelson (1999). This basic sticky-price model is developed rigorously by Woodford (2003, Chap. 3).

[3] The version with Calvo-style pricing and a money growth rule was presented by Keen (2004). Appendix A provides complete details of our model specification and solution procedures.

The momentary utility function is assumed to take the form

$$u(c_t, l_t) = \ln(c_t) + \chi \frac{l_t^{1-\sigma_1}}{1-\sigma_1},$$

where the values of the preference parameters σ_1 and χ are positive.

The household maximizes (1) subject to a budget constraint

$$\begin{aligned} &P_t c_t + P_t i_t + M_t + B_t \\ &= P_t w_t n_t + P_t q_t k_t + D_t + M_{t-1} + R_{t-1} B_{t-1} + T_t, \end{aligned} \tag{2}$$

where P_t is the nominal goods price; i_t is investment; k_t is the capital stock, which evolves following the capital accumulation process, $k_{t+1} = i_t + (1 - \delta)k_t$, and depreciates at rate δ. M_t and B_t are stocks of money and bonds, w_t is the real wage rate, q_t is the real rental price of capital, and R_{t-1} is the gross nominal interest rate on bonds purchased at time t–1. The household also receives monetary transfers, T_t, and distributed profits from the goods-producing sector, D_t.

The household also faces a time constraint, which specifies that total time (normalized to unity) can be allocated to leisure, labor, and time spent in transactions-related activities, s_t:

$$l_t + n_t + s_t = 1\,. \tag{3}$$

The amount of time households spend shopping, s_t, can be reduced by holding larger money balances relative to nominal consumption expenditures:

$$s_t = \zeta \left(\frac{P_t c_t}{M_t} \right)^{\gamma}. \tag{4}$$

Money-demand elasticities are determined by the curvature parameter, $\gamma > 0$, and $\zeta > 0$ is a scale parameter used to calibrate s.

As discussed by Lucas (2000), this type of shopping-time specification implies a set of general equilibrium relationships that resemble a standard money-demand function. In particular, after combining some of the first-order conditions from the household's utility maximization problem, optimal real money balances can be expressed as

$$\frac{M_t}{P_t} = \left[\frac{\zeta \gamma w_t c_t^{\gamma}}{\frac{R_t - 1}{R_t}} \right]^{\frac{1}{1+\gamma}}. \tag{5}$$

With the calibration $\gamma = 1$, this implies an interest elasticity of –1/2. Note also that the real wage rate and consumption spending enter this relationship in such a way that their combined relationship with real money balances is one-for-one; that is, so long as productivity and consumption move together (as they do on the steady-state path), the scale elasticity of this money "demand" function is unity.

Firms

The composite consumption good is a combination of outputs, $y_{j,t}$, produced in period t by monopolistically competitive firms. Each firm's output comes from a production function,

$$y_{j,t} = Z_t f(k_{j,t}, n_{j,t}), \tag{6}$$

where j indicates the number of periods since the firm last adjusted its price, $n_{j,t}$ is the firm's demand for labor, $k_{j,t}$ is the firm's demand for capital, and Z_t is an economywide productivity factor. The productivity factor is assumed to follow a stationary autoregressive process,

$$\ln(Z_t) = \rho_Z \ln Z_{t-1} + (1 - \rho_Z)\ln(Z) + \varepsilon_{Zt}, \tag{7}$$

where Z is the steady-state value of Z_t and ε_{Zt} is a mean-zero, independently and identically distributed (i.i.d.) shock. Every period, each firm must determine (i) the cost-minimizing combination of $n_{j,t}$ and $k_{j,t}$ given its output level, the real wage rate, w_t, and the real rental rate of capital, q_t; and (ii) whether or not it can adjust its price. Sticky prices are introduced using Calvo's (1983) model of random price adjustment. Specifically, the probability that a firm can set a new price, P_t^*, is η and the probability that a firm must keep the price that it set j periods ago is $(1 - \eta)$.

Each period, firms seek to minimize their costs,

$$w_t n_{j,t} + q_t k_{j,t}\,, \tag{8}$$

subject to the production function (6). Market-clearing conditions require that an individual firm's labor and capital demand must sum to the economy aggregates, n_t and k_t. Our goal here is merely to understand the workings of a simple model, so we have omitted capital adjustment and other frictions that are often included in this type of model.

Cost minimization by households yields the following demand equation facing each firm:

$$y_{j,t} = \left(\frac{P^*_{t-j}}{P_t}\right)^{-\varepsilon} y_t, \tag{9}$$

where $-\varepsilon$ is the price elasticity of demand. Aggregate output, y_t, is given by

$$y_t = \left[\sum_{j=0}^{\infty} \eta(1-\eta)^j \, y_{j,t}^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)}, \tag{10}$$

and the aggregate price level is a nonlinear combination of current and past prices,

$$P_t = \left[\sum_{j=0}^{\infty} \eta(1-\eta)^j \, P^{*\,(1-\varepsilon)}_{t-j}\right]^{1/(1-\varepsilon)}. \tag{11}$$

Appendix A describes in more detail the implications of this pricing structure for the evolution of the aggregate price level.

Policy Rules

Two classes of monetary policy regimes are considered: a regime in which the central bank follows an exogenous money growth rule and a regime with a nominal interest rate rule in which money growth is endogenous. Both policy rules have two sources of disturbance: One is a shock to the inflation target and the other is a shock to the liquidity position.[4] The shocks are identified only by how long they persist. A shock to the liquidity position is not expected to affect inflation expectations except at very high frequencies. Historical examples of extreme liquidity shocks would be the Fed's responses to the 1987 stock market crash and the September 11th attacks. In contrast, a shock to the inflation target is expected to be highly persistent, almost permanent. In our model, we assume that the Fed has full credibility and the inflation target is known.

In the United States today, the Fed does not have an explicit inflation target such that the public could distinguish perfectly between shocks to liquidity and those to the inflation target. (In extreme cases, this is not a problem; but it probably matters for less-extreme cases.) For example, it is not clear whether the Federal Open Market Committee (FOMC) and/or the public have been able to make this distinction during periods of countercyclical policy.[5]

The money growth rule is given as

$$\Delta\hat{M}_t = \hat{\mu}^*_t + (\upsilon_t - \upsilon_{t-1}), \tag{12}$$

where the hat over a variable indicates the percent (or log) deviation from the steady state and $\hat{\mu}^*_t$ is a stochastic money growth target, $\hat{\mu}^*_t = \rho_\mu \hat{\mu}^*_{t-1} + \varepsilon_{\mu t}$, where $\varepsilon_{\mu t}$ is a mean-zero, i.i.d. shock to the nominal growth trend. The second disturbance in (12), υ_t, represents a transitory policy disturbance that follows its own AR(1) process, $\upsilon_t = \rho_\upsilon \upsilon_{t-1} + \varepsilon_{\upsilon t}$, with a mean-zero, i.i.d. shock, $\varepsilon_{\upsilon t}$. Entering the money-growth rule in first differences, the υ-shock represents a transitory disturbance to the money stock that leaves the long-run growth path unchanged.

In the alternative regime, the central bank operates with a Taylor-type interest rate rule that is given by

$$\hat{R}_t = \hat{\pi}_t + \theta_\pi(\hat{\pi}_t - \hat{\pi}^*_t) + \theta_y \hat{y}_t + u_t, \tag{13}$$

where the inflation target follows a stochastic AR(1) process, $\hat{\pi}^*_t = \rho_\pi \hat{\pi}^*_{t-1} + \varepsilon_{\pi t}$, and the transitory policy shock, u_t, follows an AR(1) process, $u_t = \rho_u u_{t-1} + \varepsilon_{ut}$. Both error processes, $\varepsilon_{\pi t}$ and ε_{ut}, are mean-zero, i.i.d. shocks.

The inflation target shock in equation (13) plays the same role as the money growth shock in (12); both disturbances have a persistent effect on the nominal growth path of the economy. That is, the expected inflation target converges to the steady state in the long run, but the actual target may deviate for long periods. Thus, inflation in period t has three components: the steady-state

4 Both Ireland (2005) and Kozicki and Tinsley (2003) identify the inflation target shock by assuming that this component has a unit root.

5 See Goodfriend (1993) and Erceg and Levin (2003) for analysis of the Fed's credibility.

inflation rate, the stochastic component of the inflation target (trend), and the transitory component, which is due to other shocks.

It is not clear how to define a common transitory policy shock or liquidity shock under the alternative regimes. We define a transitory policy shock to the money growth rule as a deviation of the money stock that leaves the long-run growth path unchanged. In the case of the interest rate rule, we define a temporary liquidity shock in a straightforward way—as a temporary shock to the short-term interest rate. An expansionary liquidity shock is a positive shock to money growth, υ_t, or a negative shock to the nominal interest rate equation, u_t. An inflation target shock, $\hat{\pi}_t^*$, and a nominal interest rate shock, u_t, have qualitatively identical effects on the model's dynamics. They differ only by a scaling factor and, in our parameterization, by their persistence.[6]

CALIBRATION

To the extent possible, the parameters are calibrated to generally accepted values for all the experiments. Table 1 shows the baseline calibration used. In the utility function, the value of σ_1 is set at 7/9. The steady-state labor share is 0.3 and shopping time is 1 percent of that value. That calibration implies a labor supply elasticity of real wages approximately equal to 3.[7] The household discount factor is 0.99, so that the annual real interest rate is 4 percent. The shopping-time parameter, γ, is set to unity, implying an interest rate elasticity of money demand equal to –0.5. The capital share of output is set to 0.33, and the capital stock is assumed to depreciate at 2.5 percent per quarter. The price elasticity of demand is set equal to 6, implying a steady-state markup of 20 percent. We set the probability of price adjustment equal to 1 for the flexible-price case and equal to 0.25 for the sticky-price case. For the sticky-price case, this implies that firms change prices on average once per year. The model is calibrated so that the steady-state inflation rate is zero.[8]

The policy rule is calibrated to match Taylor's (1993) values. The coefficient on the deviation of inflation from target is set at 0.5, and the response of the interest rate—specified as a quarterly return—to the output gap is 0.125. Shocks to the nominal growth trend are assumed to be highly persistent, $\rho_\mu = \rho_\pi = 0.95$, whereas the transitory policy shocks have a lower value for their AR parameter, $\rho_\upsilon = \rho_u = 0.3$. The shocks to technology are calibrated to be highly persistent, $\rho_Z = 0.95$.[9]

MONETARY POLICY SHOCKS

As described previously, two types of monetary policy shocks are considered for each policy rule: a shock to the nominal growth trend that displays high persistence (near a random walk) and a transitory policy shock with little persistence. To gain insight about those shocks, we consider their effects separately, comparing their impact on the economy under flexible-price and sticky-price specifications.

Shocks to the Nominal Growth Trend

Figure 1 illustrates the response of the economy to a persistent money growth shock in a model where the central bank follows a money growth rule. Panels in the left column display the impulse responses produced by the flexible-price model, and the panels in the right column reflect the responses from the sticky-price model. The top row shows what happens to the price level and the money stock. In both models, the price level jumps immediately after the shock. While the money supply moves identically in both models, the initial price level increase in the sticky-price model is a bit more than half the

[6] The scaling is determined by the weight on deviations of inflation from target.

[7] The elasticity of labor supply with respect to the real wage equals $((1 - \bar{n} - \bar{h})/\bar{n})(1/\sigma_1)$.

[8] This is necessary to prevent the nonadjusting firms' prices from becoming too far out of line with the flexible-price benchmark. The same model dynamics result if there is positive steady-state inflation and the nonadjusting firms can index prices to rise each period by the steady-state inflation rate.

[9] See Appendix A for details about the nonlinear model, the equilibrium, the steady state, and the linear approximation around the steady state that are used to calculate the model dynamics. The solution method is based on King and Watson (1998, 2002).

Table 1

Baseline Calibration

	Symbol	Value
Model Parameters		
Utility	σ_1	7/9
Steady-state market labor share	n	0.3
Household discount factor	β	0.99
Shopping time	γ	1
Capital share of output	α	0.33
Depreciation rate	δ	0.025
Price elasticity of demand	ε	6
Probability of price adjustment	η	0.25 → sticky prices 1 → flexible prices
Policy Reaction		
Inflation	θ_p	0.5
Output	θ_y	0.125
Persistence		
Technology shock	ρ_z	0.95
Nominal growth shock	$\rho_\pi = \rho_\mu$	0.95
Liquidity shock	$\rho_\upsilon = \rho_u$	0.3
Standard deviation		
Technology shock	σ_z	0.0075
Nominal growth shock	σ_π	0.004

14 percent rise in the flexible-price case. The growth rates of money and prices in both models eventually converge back to their steady-state rates, but their levels remain permanently higher.

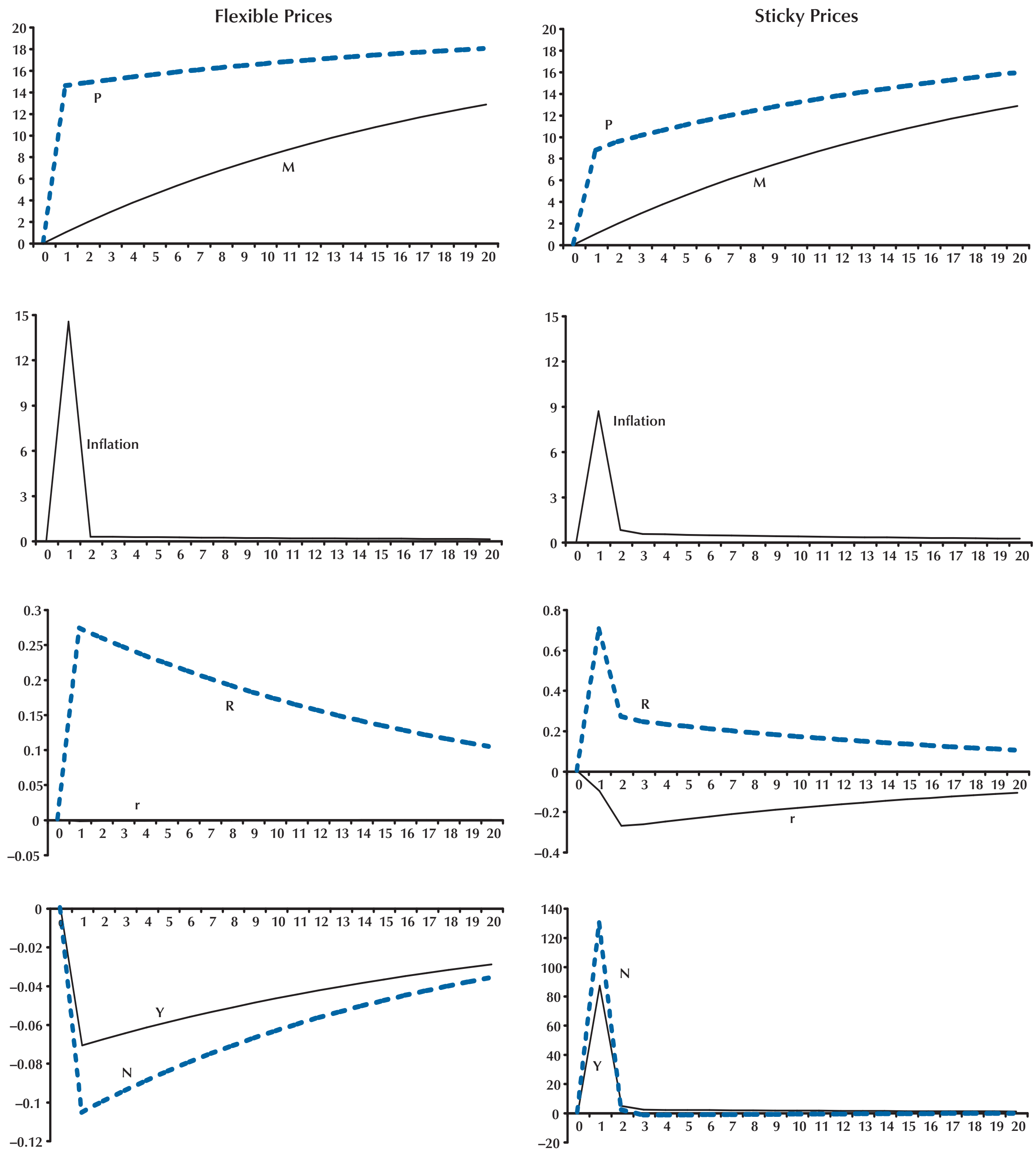
The second row of Figure 1 shows the impulse responses of the inflation rate to the money growth shock. The inflation spike in period 1 essentially reflects the immediate rise in the price level after the policy shock. In both cases, inflation is persistent following a money growth shock, but the persistence is masked by the surge in prices that occurs contemporaneously with the shock.

The third row shows the responses of the nominal and real interest rates to this shock. Because that initial jump in the price level is unanticipated, it does not affect nominal interest rates. In the flexible-price model, the nominal interest rate increases by about 0.3 percent, which is approximately equal to the expected inflation rate for period 2. The effect on the real rate is near zero in the flexible-price model. With sticky prices, the nominal interest rate rises about 0.75 percent above the steady state, reflecting the higher expected inflation, which is associated with the more gradual response in the price level to the policy shock. The real rate declines for two periods and then gradually returns to the steady state as the effects of the shock dissipate.

The bottom two panels in Figure 1 display the responses of output and hours worked. The higher inflation rate acts as a tax on real money balances, which leads households to spend more time shopping and less time working. With price flexibility, hours worked falls about 0.1 percent below the steady state. With sticky prices and an exogenous money growth rule, neither money nor prices are free to accommodate the jump in money demand. Therefore, the adjustment occurs in real variables. In our sticky-price model, the spike in output is over 80 percent. Given that such a large output response is highly counterfactual, sticky-price models typically incorporate additional

Figure 1

Responses to a Persistent Money Growth Shock with a Money Growth Rule



NOTE: P, price level; M, money supply; R, nominal interest rate; r, real interest rate; Y, output; N, hours worked.

frictions that limit the adjustment of capital and/or labor after a monetary policy shock.[10]

Shifting our analysis to models with an interest rate policy rule, Figure 2 shows how our models respond to an inflation target shock when the Fed is using the Taylor rule. The price level does not jump after the inflation target shock. The higher rate of inflation causes money demand to shift down; but, with an interest rate rule, the money stock declines in order to clear the money market. The size of the fall in the money supply depends on the interest elasticity of money demand. As money demand becomes more interest elastic, the size of the shift needed to clear the money market gets larger. Price level, inflation rate, and interest rate responses are very similar under both the flexible- and sticky-price specifications.

Output responses are much different under the alternative price specifications. In the flexible-price model, there are small negative effects on output associated with the inflation tax on money holdings. In the sticky-price case, output and hours worked rise, but the effects are much more reasonable than with a money supply rule.

Transitory Policy Shocks

Figure 3 shows the response of the economy to a transitory money shock. The immediate impact on the price level is smaller in the sticky-price model than in the flexible-price model. This is easiest to see in the second row of panels, which show that the brief spike in inflation is smaller in the sticky-price specification. In neither of these cases, however, does inflation exhibit any measurable persistence. In the third row, we see that the effect on interest rates is small. In the flexible-price case, all of the effect is on the nominal interest rate, which declines temporarily as the price level returns to the original steady-state path. In the sticky-price case, the real return falls by less than in the flexible-price case because the price level never strays far from its steady-state path. Output and hours worked both rise, but the size of the effect is an order of magnitude larger with sticky prices.

Note that, for the sticky-price case, we have a pattern of dynamics that corresponds to the textbook description of a liquidity effect. The decline in the nominal interest rate is associated with a corresponding reduction in the real interest rate and a brief surge in output; the relatively large response of output is due to the presence of frictions restricting movement in both the price level and the money supply. Again, the shift in money demand requires large shifts in the real variables.

Figure 4 shows the effect of a transitory liquidity shock when the central bank is using an interest rate rule. In general equilibrium, a 1 percent expansionary (negative) shock actually raises the nominal interest rate by 25 basis points. In both models, we see that the price level rises and the money supply declines. The price increase is large and permanent in the flexible-price model. In the sticky-price case, where only a subset of the firms can react to the shock, its transitory nature causes a smaller adjustment and an eventual decline in the price level below the initial equilibrium path. The third row of panels shows the response of real and nominal interest rates. The nominal rate rises by more in the flexible-price model because the expected inflation rate in periods 3 and beyond are larger. In the sticky-price model, the real interest rate rises slightly.

The output effect is small and negative in the flexible-price case. In the sticky-price model, a 1 percent shock to the short-term interest rate raises output 5 percent on impact, but the effect dissipates quickly. Note that this type of transitory policy shock—which is standard in the literature on interest rate rules—does not display a textbook liquidity effect under either the sticky-price or flexible-price specification.

Technology Shocks

The technology shock variable, z_t, affects the production function directly and therefore engenders a direct effect on output regardless of the nature of the policy rule or whether prices are sticky or flexible. However, the nature of the central bank's policy rule affects the endogenous responses of inputs to the production function—

[10] For example, by adding investment adjustment costs to this sticky-price model, one can get reasonable-looking changes in output and larger changes in the real interest rate.

Figure 2

Responses to an Inflation Objective Shock with an Interest Rate Rule

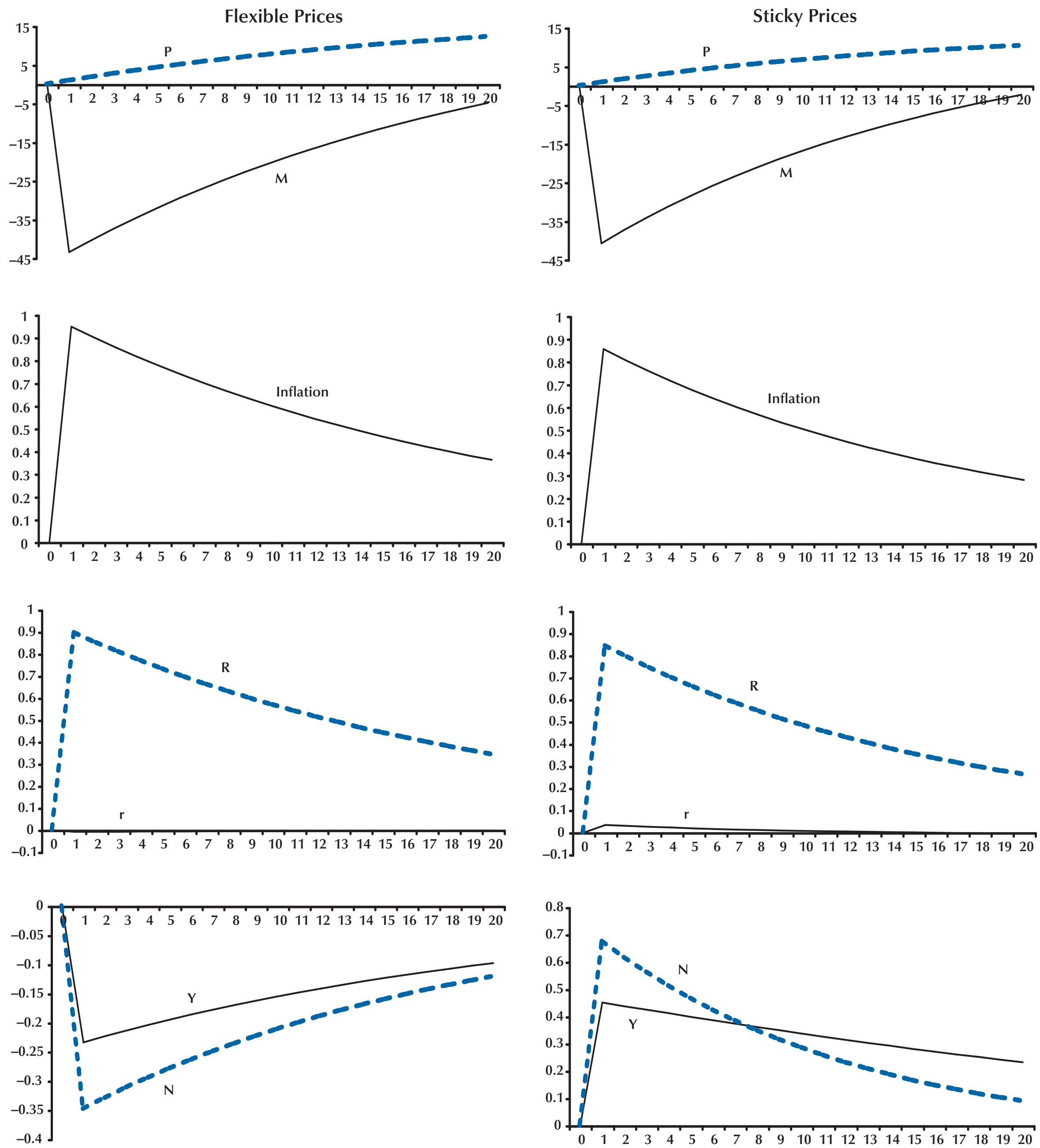


Figure 3

Responses to a Transitory Policy Shock in a Money Growth Rule

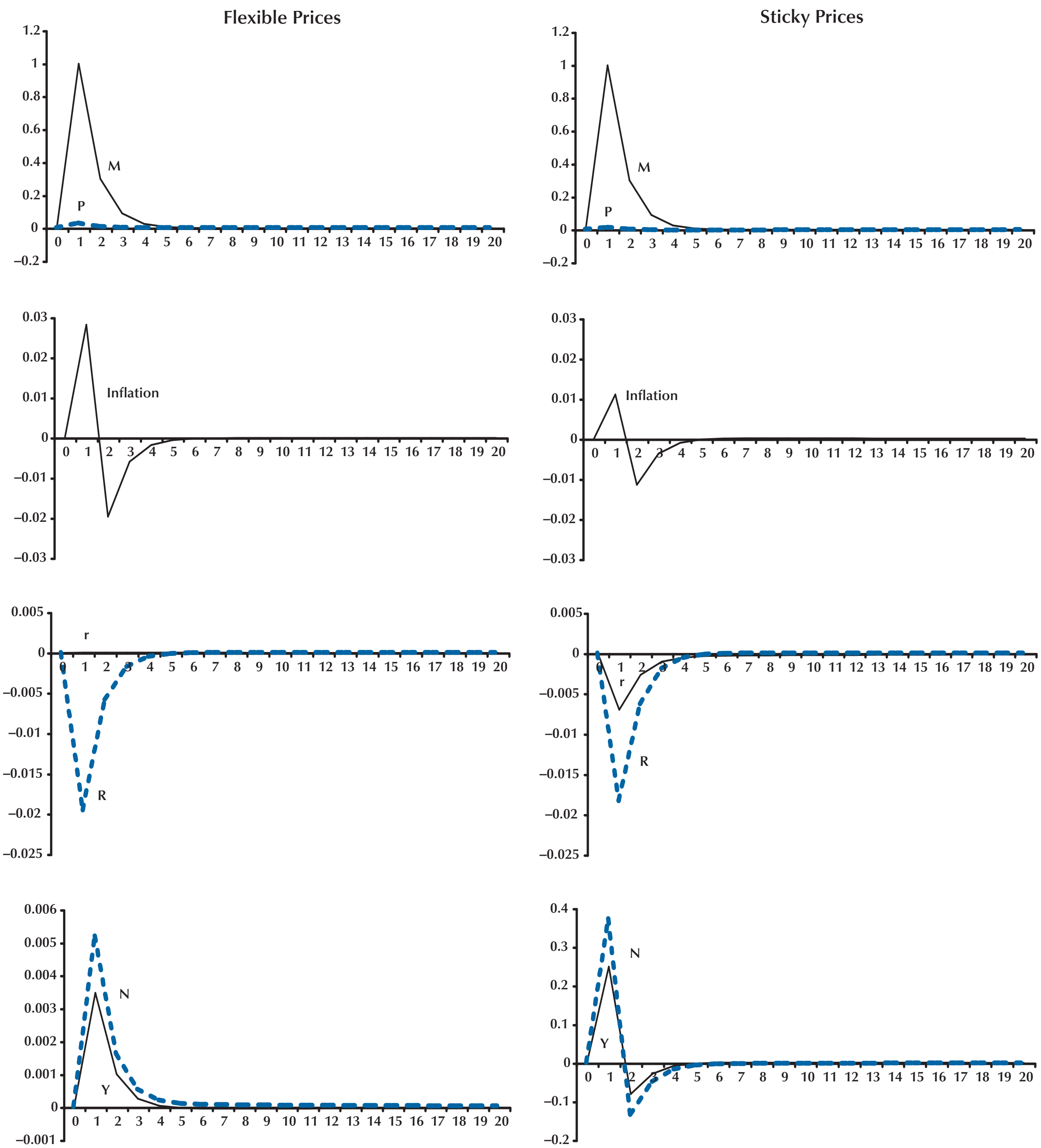
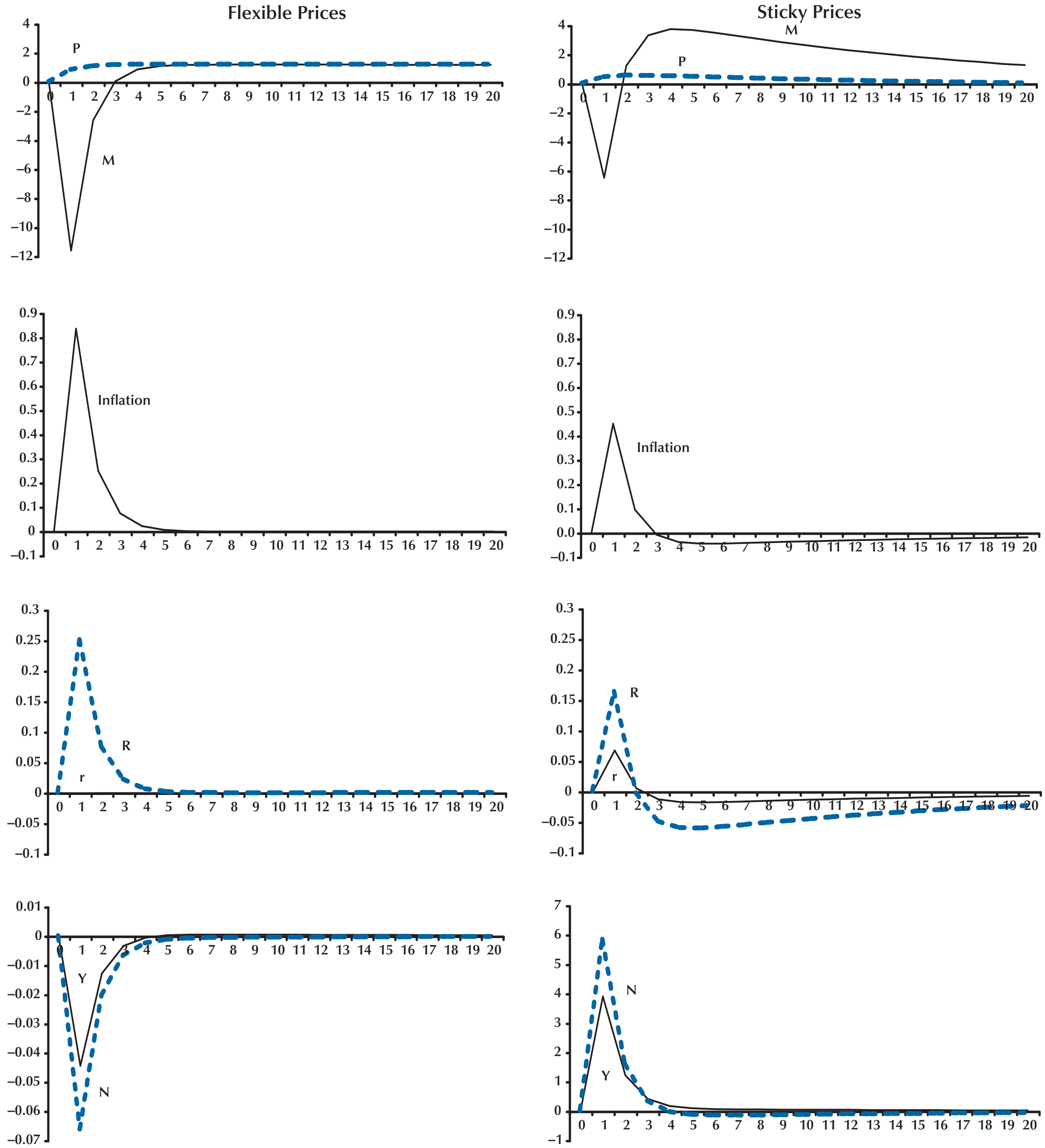


Figure 4

Responses to a Transitory Policy Shock in an Interest Rate Rule



which, in turn, affects the overall response of output. In this regard, the nature of the monetary policy reaction function is quantitatively important for the evolution of real variables only when prices are assumed to be sticky.

The left column of Figure 5 shows the response of the flexible-price, money growth rule economy. This setting serves as a convenient baseline for our comparison, because it most closely approximates an RBC model in which there are no monetary distortions at all. As is typical of this type of shock, the temporary but persistent increase in output that results from the direct effect of the disturbance is enhanced by an increase in the real wage rate and employment. Consequently, the initial rise in output is about 50 percent larger than the direct effect that the technology itself would imply. The increase in factor productivity also engenders an investment response that serves as a propagation mechanism.

However, as widely noted in the RBC literature, this mechanism is rather weak: If there were no persistence in the technology shock, there would be little persistence in output. Because monetary policy does not respond in any way to the shock under a money growth rule, the increase in output implies that the price level falls below trend; the ensuing anticipated disinflation requires an upward adjustment to real money balances, which takes place through a downward jump in the price level. As we saw with shocks to the inflation trend, the shifts in money demand are accommodated by jumps in the price level.

When prices are sticky and the central bank implements a money growth rule, as shown in the right column of Figure 5, the responses of the model to a technology disturbance are dramatically different: The initial downward jump in the price level is only half the size of the jump with flexible prices. Inflation is not persistent in either case. In both cases, the real rate responds as predicted in the benchmark RBC model. The responses of nominal rates are small, but in opposite directions. The most dramatic effects occur in output and hours worked, which decline sharply in the sticky-price model.[11] There is also an initial decline in investment (not shown), such that the endogenous propagation channel of capital accumulation is even less quantitatively important.

The key to understanding the responses of this version of the model to productivity shocks is in the nature of the Calvo pricing process: With a majority of firms unable to lower prices in response to the shock, relative demand for their products drops off, moving the firms back along their marginal cost curves. With higher costs and lower final demand, firms dramatically scale back their demand for factors of production until after they have an opportunity to adjust prices. When a larger proportion of firms is assumed to change prices each period, with $\eta = 1/2$, for example, the initial negative response of output and work does not occur. After prices have adjusted further—after four periods or more in the present calibration—the model economy has adjusted to a trajectory that resembles that of the flexible-price specification.

The pattern of responses shown in the lower right-hand panel of Figure 5 demonstrates the limitations of a recent influential assertion by Galí (1999). Using a long-run identifying assumption in a vector autoregression model, Galí found that a permanent shock to technology is associated with an initial decline in work effort. From this finding, he argues that sticky prices must play a role in the propagation of technology shocks.

But while our model predicts this type of response when the central bank is following a money growth rule, the response does not occur when policy follows an interest rate rule. As shown in Figure 6, the interest rate rule effectively eliminates the difference between the sticky-price and flexible-price models. The price response is muted by the interest rate rule, compared with the jump that is illustrated in Figure 5. Because interest rate targeting smooths price changes, the gap that develops between the firms that can change prices and those that cannot remains small. The model responses are nearly identical. In other words, the use of an interest rate rule, by eliminating large price-level swings, insulates the real responses of the model from the sticky-price distortions that arise under a money growth rule.

[11] Dotsey (1999) shows that changes in interest rate smoothing can have large real effects in a sticky-price model.

Figure 5

Responses to a Technology Shock with a Money Growth Rule

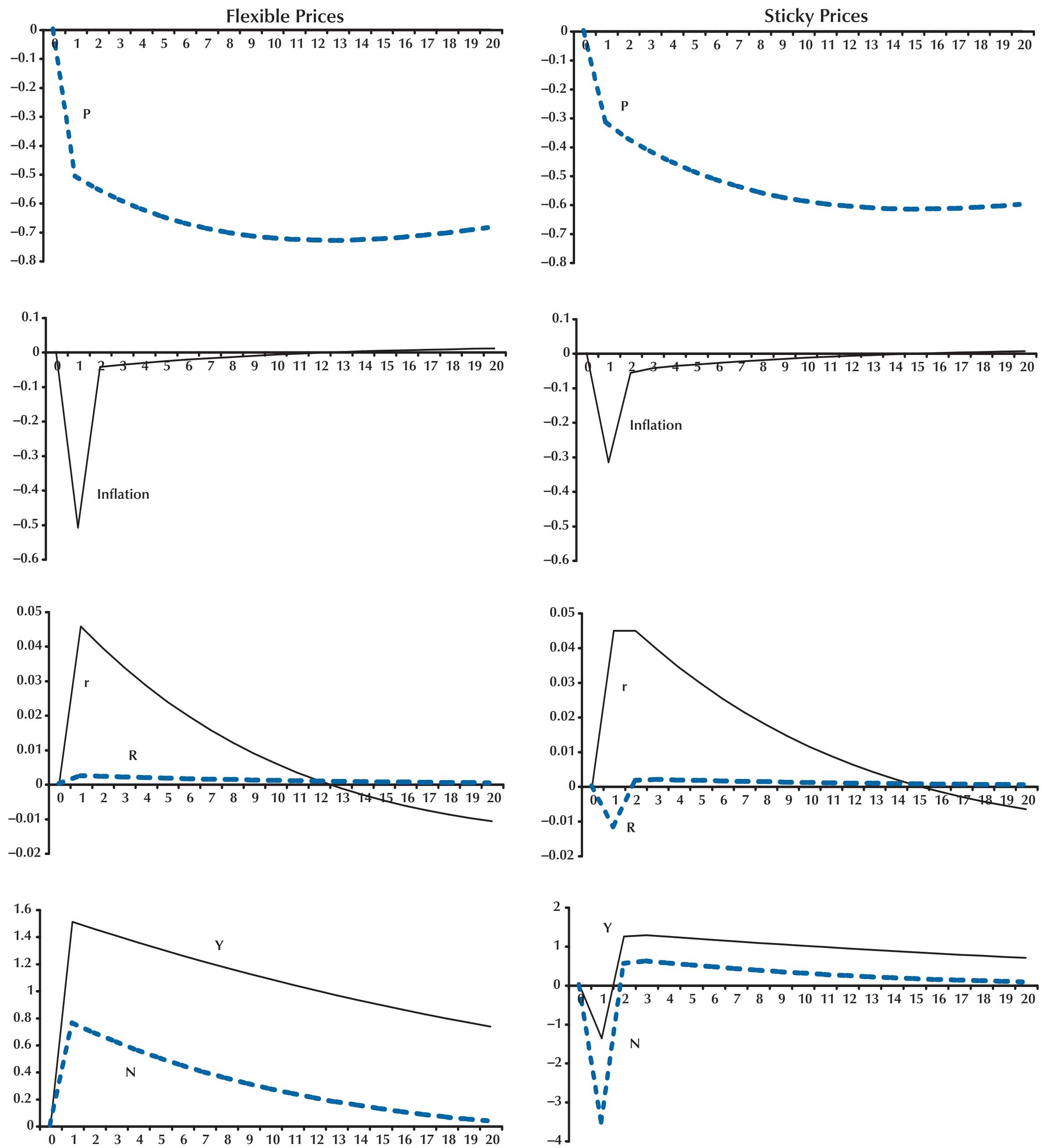
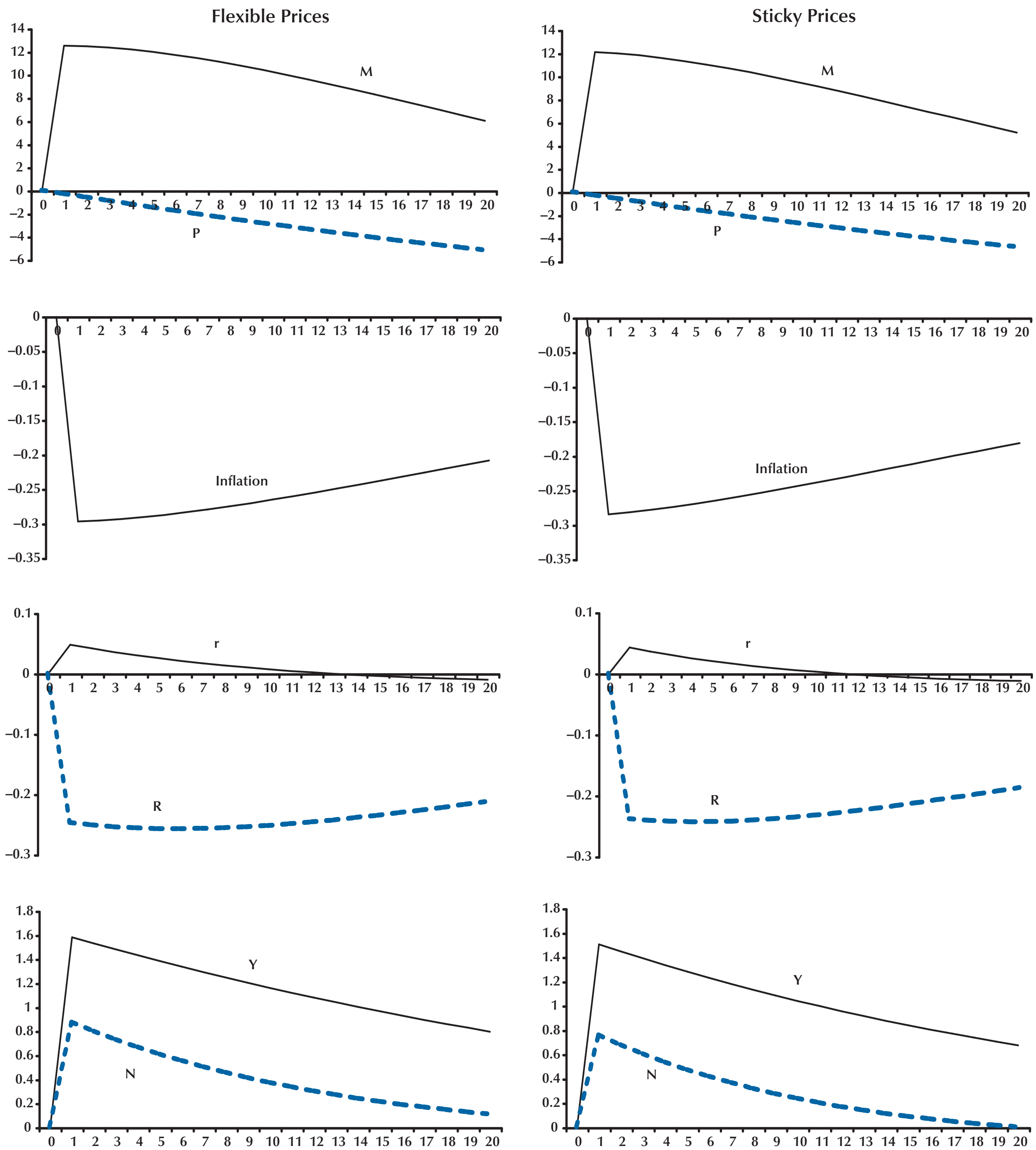


Figure 6

Responses to a Technology Shock with an Interest Rate Rule



TIME-SERIES PROPERTIES OF MONEY AND PRICES

This section documents how the time-series properties of money and inflation differ under the alternative monetary policy regimes.[12] There is a large seasonal element in money but not in prices or interest rates. Mankiw, Miron, and Weil (1987) showed that a strong seasonal component in U.S. interest rates disappeared after the creation of the Federal Reserve in 1913. Barsky and Miron (1989) showed that there are large seasonal components in quantities but not in prices. Both these empirical regularities are consistent with our model of a central bank that uses an interest rate procedure to implement monetary policy.

We begin with a brief look at data for the G7 countries for the period from 1980:Q2 to 1998:Q4. We use data on interest rates, consumer price index (CPI) inflation, and M1 growth, which are not seasonally adjusted.[13] To calculate the relative persistence in M1 growth and inflation, we calculated the largest root of each series using an augmented Dickey-Fuller equation. The relative volatility is measured by the standard error of the regression. We included five lags of quarterly data to account for the remaining serial correlation and the predictable seasonal component. The results are shown in the top panel of Table 2. The first column reports the standard error of the equation for the augmented Dickey-Fuller regression for CPI inflation. The second column reports the largest root in the CPI regression. The third and fourth columns report the results for M1.

The standard error of the equation for M1 is always larger than that for the CPI. On average it is almost four times larger. For the G7 average, the largest root in CPI inflation is 0.67 and the largest root in M1 is 0.36. As the results show, there is a large dispersion across countries in the estimates of persistence of M1 growth.[14]

The bottom panel in Table 2 (Panel B) reports results from our four alternative models under the baseline calibration shown in Table 1. Included are the standard deviations and the first-order autoregressive coefficients for inflation and money growth. We compute statistics for our model economies subject to technology shocks and persistent money growth shocks (with a money growth rule) or persistent inflation target shocks (with the Taylor rule). Those experiments do not include the short-run liquidity shocks. The first two rows of Panel B report the results for the money growth rule and the next two rows report the results for the Taylor rule. The policy rule makes a much bigger difference than does the degree of price flexibility. With a money growth rule, the standard deviation of the inflation rate is always greater than the standard deviation of the money growth rate. The first-order autocorrelation for inflation is near zero. The first-order autocorrelation coefficient for money growth reflects (but is substantially smaller than) the persistence in the shock to the money growth trend.

The model generated data that more closely resemble observed economic data when we use an interest rate rule. Money growth is more variable than inflation. Under both pricing regimes, the first-order autocorrelation of inflation is near 0.7, but money growth exhibits no autocorrelation.[15]

The last two rows in Panel B show that our results do not depend on persistent shocks to the nominal growth trend. When there are only technology shocks, inflation and money growth are about half as volatile; but the relative variability of money growth and inflation is approximately

[12] See Dressler (2003) and Sustek (2004) for models that include both inside and outside money and attempt to account for the dynamic behavior of the monetary aggregates.

[13] We used the *International Financial Statistics* measure of currency outside banks for the United Kingdom. We did not include 1998 for the United Kingdom because of a large break in the series in 1998:Q2.

[14] If we use data on currency and reserves, we find that the money growth rates are much more volatile than when we use M1. The autocorrelation functions of currency and reserve aggregates are dominated by negatively correlated seasonal components. For the United States, seasonally adjusting the data adds persistence to the time series for both money growth and inflation. The adjustment reduces the variability of money growth, but not inflation.

[15] Our models imply that univariate models will underestimate the persistence of shocks to the money growth trend when using data generated under interest rate regimes. For example, Cooley and Hansen (1989, 1995) estimate the autocorrelation of monetary shocks to be just 0.5. Using cross-section price and output data and long-run monetary neutrality to achieve identification, Balke and Wynne (2004) estimate that the permanent component in M2 growth is highly persistent—matching broad movements in inflation.

Table 2

Statistical Properties of Nominal Variables (1980:Q2 to 1998:Q4)

A. Country results

	CPI		M1	
	SEE	Largest root	SEE	Largest root
Canada	0.47	0.76	2.52	0.15
France	0.34	0.82	1.22	0.69
Germany	0.45	0.71	2.12	–0.33
Italy	0.41	0.91	1.67	0.54
Japan	0.50	0.43	1.37	0.44
United Kingdom	0.62	0.64	1.39	–0.68
United States	0.36	0.47	1.18	0.77
G7 average	0.45	0.68	1.64	0.36

B. Model results

	CPI		M1	
	SD	AR(1)	SD	AR(1)
Money growth rule				
Sticky prices	2.22	0.03	0.51	0.70
Flexible prices	4.36	–0.07	0.51	0.69
Taylor rule				
Sticky prices	0.60	0.72	10.55	–0.06
Flexible prices	0.55	0.70	9.56	–0.08
Technology shocks only				
Sticky prices	0.34	0.73	5.41	–0.04
Flexible prices	0.28	0.71	4.62	–0.07

NOTE: An augmented Dickey-Fuller equation with five lags of quarterly data was used to measure the largest root in M1 and CPI growth rates. The standard error of the equation (SEE) was used to measure the volatility in these series. In other cases, we report the standard deviation (SD) and first autocorrelation (AR(1)) in the growth rate series. The baseline calibration was used in the model calculations.

SOURCE: CPI and M1 data come from the OECD Main Economic Indicators. For the United Kingdom, M1 was not available, so we used currency outside banks ending in 1997:Q4. Exact sources and data definitions are listed in Appendix B.

unchanged. With interest rate rules, inflation persistence can be driven by persistent shocks to technology.

The high volatility of the money supply that accompanies interest rate targeting obscures the information content of monetary aggregates. Cooley and LeRoy (1981) document problems that econometricians have faced trying to estimate money demand functions. One of the ironic characteristics of the New Keynesian paradigm is that the model embeds the quantity theory of money as a long-run proposition, but money rarely appears in the policy rule. McCallum (2001) explores the reasons why money does not appear in the policy rule and concludes with support for the notion "that policy analysis in models without money, based on interest rate policy rules, is not fundamentally misguided."

CONCLUSION

A comparison of flexible- and sticky-price models with both money growth and interest rate policy rules leads to the following conclusions. First, interest rate rules rather than money growth rules can capture the degree of inflation persistence and the relative volatility of the price level observed in the data.

Second, with sticky prices the real effects of transitory policy shocks differ under the different policy rules. When the central bank uses a money growth rule, the real effects are much too large to be plausible in the sticky-price model unless other frictions, such as investment adjustment costs, are also included. But central banks do not use money growth rules, so this counterfactual implication does not seem important. It does, however, suggest a reason why central banks choose to implement monetary policy using an interest rate instrument.

Third, and most importantly for model builders, when shocks are highly persistent, the distinction between monetary policy rules is more important for price dynamics than is the choice of the price-adjustment assumption. The reason for this can be seen in how money demand adjusts under an interest rate rule. In this case, desired price changes are relatively smooth and there is not much difference between flexible- and sticky-price equililbria. A corollary of this result is that the response of nominal variables such as inflation and the money supply are very similar in both flexible- and sticky-price models when the central bank uses an interest rate rule. An important implication of this result is that it will be difficult to use information about firms' actual pricing policies to distinguish between macro theories.

Finally, a central bank's use of interest rate rules obscures the information content of monetary aggregates and leads to subtle problems for econometricians trying to estimate money demand functions or to identify shocks to the trend and cycle components of the money stock. Highly persistent money shocks will be masked by the high-frequency volatility associated with keeping the interest rate relatively constant in the short run.

REFERENCES

Balke, Nathan S. and Wynne, Mark A. "Sectoral Effects of Monetary Shocks." Unpublished manuscript, Federal Reserve Bank of Dallas, November 2004.

Barsky, Robert B. and Miron, Jeffrey A. "The Seasonal Cycle and the Business Cycle." *Journal of Political Economy*, June 1989, *97*(3), pp. 503-34.

Calvo, Guillermo A. "Staggered Prices in a Utility Maximizing Framework." *Journal of Monetary Economics*, September 1983, *12*(3), pp. 383-98.

Cho, Jang-Ok, and Cooley, Thomas F. "The Business Cycle with Nominal Contracts." *Economic Theory*, 1995, *6*(1), pp. 13-33.

Christiano, Lawrence J. and Eichenbaum, Martin. "Liquidity Effects and the Monetary Transmission Mechanism." *American Economic Review*, 1992, *82*(2), pp. 346-53.

Cooley, Thomas F. and Hansen, Gary D. "The Inflation Tax in a Real Business Cycle Model." *American Economic Review*, September 1989, *79*(4), pp. 733-48.

Cooley, Thomas F. and Hansen, Gary D. "Money and the Business Cycle?" in Thomas F. Cooley, ed., *Frontiers of Business Cycle Research*. Chap. 7. Princeton: Princeton University Press, 1995, pp. 175-216.

Cooley, Thomas F. and LeRoy, Stephen F. "Identification and Estimation of Money Demand." *American Economic Review*, December 1981, *71*(5), pp. 825-44.

Dittmar, Robert D.; Gavin, William T. and Kydland, Finn E. "Inflation Persistence and Flexible Prices." *International Economic Review*, February 2005, *46*(1), pp. 245-61.

Dotsey, Michael. "The Importance of Systematic Monetary Policy for Economic Activity." Federal Reserve Bank of Richmond *Economic Quarterly*, Summer 1999, *85*(3), pp. 41-59.

Dressler, Scott. "Monetary Policy Regimes and Causality." Unpublished manuscript, University of Texas, October 2003.

Erceg, Christopher J. and Levin, Andrew T. "Imperfect Credibility and Inflation Persistence." *Journal of Monetary Economics*, May 2003, *50*(4), pp. 915-44.

Friedman, Milton. *The Optimum Quantity of Money—And Other Essays*. Chicago: Aldine Publishing, 1969.

Fuerst, Timothy S. "Liquidity, Loanable Funds, and Real Activity." *Journal of Monetary Economics*, February 1992, *29*(1), pp. 3-24.

Galí, Jordi. "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" *American Economic Review*, March 1999, *89*(1), pp. 249-71.

Goodfriend, Marvin. "Interest Rate Policy and the Inflation Scare Problem: 1979-1992." Federal Reserve Bank of Richmond *Economic Quarterly*, Winter 1993, *79*(1), pp. 1-24.

Ireland, Peter N. "The Role of Countercyclical Monetary Policy." *Journal of Political Economy*, August 1996, *104*(4), pp. 704-23.

Ireland, Peter N. "Endogenous Money or Sticky Prices?" *Journal of Monetary Economics*, November 2003, *50*(8), pp. 1623-48.

Ireland, Peter N. "Changes in the Federal Reserve's Inflation Target: Causes and Consequences." Unpublished manuscript, Boston College, January 2005.

Keen, Benjamin D. "In Search of the Liquidity Effect in a Modern Monetary Model." *Journal of Monetary Economics*, October 2004, *51*(7), pp. 1467-94.

Kim, Soyoung. "Monetary Policy Rules and Business Cycles." *Scandinavian Journal of Economics*, 2003, *105*(2), pp. 221-45.

Kimball, Miles S. "The Quantitative Analytics of the Basic Neomonetarist Model." *Journal of Money, Credit, and Banking*, November 1995, *27*(4, Part 2), pp. 1241-77.

King, Robert G. and Watson, Mark W. "The Solution of Singular Linear Difference Systems Under Rational Expectations." *International Economic Review*, 1998, *39*(4), pp. 1015-26.

King, Robert G. and Watson, Mark W. "System Reduction and Solution Algorithms for Singular Linear Difference Systems Under Rational Expectations." *Computational Economics*, October 2002, *20*(1-2), pp. 57-86.

King, Robert G. and Wolman, Alexander L. "Inflation Targeting in a St. Louis Model of the Twenty-First Century." Federal Reserve Bank of St. Louis *Review*, May/June 1996, *78*(3), pp. 83-107.

Kozicki, Sharon and Tinsley, Peter A. "Permanent and Transitory Policy Shocks in an Empirical Macro Model with Asymmetric Information." CFS Working Paper No. 2003/41, Center for Financial Studies, October 2003.

Lucas, Robert E. Jr. "Liquidity and Interest Rates." *Journal of Economic Theory*, April 1990, *50*(2), pp. 237-64.

Lucas, Robert E. Jr. "Inflation and Welfare." *Econometrica*, March 2000, *68*(2), pp. 247-74.

Mankiw, N. Gregory; Miron, Jeffrey A. and Weil, David N. "The Adjustment of Expectations to a Change in Regime: A Study of the Founding of the Federal Reserve." *American Economic Review*, June 1987, *77*(3), pp. 358-74.

McCallum, Bennett T. "Monetary Policy Analysis in Models Without Money." Federal Reserve Bank of St. Louis *Review*, July/August 2001, *84*(4), pp. 145-60.

McCallum, Bennett T. and Nelson, Edward. "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis." *Journal of Money, Credit, and Banking*, August 1999, *31*(3, Part 1), pp. 296-316.

Rotemberg, Julio J. and Woodford, Michael. "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in Ben S. Bernanke and Julio J. Rotemberg, eds., *NBER Macroeconomics Annual 1997*. Cambridge, MA: MIT Press, 1997, pp. 297-345.

Sustek, Roman. "Monetary Aggregates and Structural Shocks." Unpublished manuscript, Carnegie Mellon University, August 2004.

Taylor, John B. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy*, 1993, *39*, pp. 195-214.

Woodford, Michael. *Interest & Prices*. Princeton University Press: Princeton, 2003.

Yun, Tack. "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles." *Journal of Monetary Economics*, April 1996, *37*(2), pp. 345-70.

APPENDIX A

TECHNICAL NOTES

This appendix provides detailed information on the sticky- and flexible-price models. It outlines the relevant equations in the model, determines the steady state, and linearizes the model. Furthermore, this appendix provides the necessary information to replicate the simulations of this paper, using the solution methods outlined in King and Watson (1998, 2002).

The Equilibrium

These equations describe the equilibrium for the households' problem. Households are infinitely lived agents who seek to maximize their expected utility from consumption, c_t, and leisure, l_t,

$$E_0\left[\sum_{t=0}^{\infty}\beta^t\left(\ln(c_t)+\chi\frac{l_t^{1-\sigma_1}}{1-\sigma_1}\right)\right],$$

subject to the following budget constraint, time constraint, and capital accumulation equation:

(A1)
$$P_t(c_t+i_t)+M_t+B_t=P_tw_tn_t+P_tq_tk_t+D_t+M_{t-1}+R_{t-1}B_{t-1}+T_t,$$
$$l_t+n_t+s_t=1,$$

(A2)
$$k_{t+1}=i_t+(1-\delta)k_t,$$

where B_t is government bonds, P_t is the price level, i_t is investment, M_t is the nominal money stock, w_t is the real wage rate, n_t is labor, q_t is the rental rate on capital, k_t is the capital stock, D_t is the firms' profits remitted to the households, R_t is the gross nominal interest rate, T_t is a transfer from the monetary authority, δ is the depreciation rate, and s_t represents the shopping-time costs of holding money balances,

(A3)
$$s_t=\zeta(P_tc_t/M_t)^{\gamma}.$$

Utility maximization by the households yields the following first-order conditions for c_t, l_t, n_t, M_t, B_t, i_t, and k_t:

(A4)
$$\frac{\partial u}{\partial c_t}=P_t\lambda_t+\gamma(s_t/c_t)\tau_{1,t},$$

(A5)
$$\frac{\partial u}{\partial l_t}=\tau_{1,t},$$

(A6) $$\tau_{1,t} = P_t w_t \lambda_t,$$

(A7) $$\lambda_t - \gamma(s_t / M_t)\tau_{1,t} = \beta E_t[\lambda_{t+1}],$$

(A8) $$\lambda_t = \beta E_t[R_t \lambda_{t+1}],$$

(A9) $$\lambda_t P_t = \tau_{2,t}, \text{ and}$$

(A10) $$\tau_{2,t} = \beta E_t[\tau_{2,t+1}(1-\delta) + \lambda_{t+1} P_{t+1} q_{t+1}],$$

where λ_t, $\tau_{1,t}$, and $\tau_{2,t}$ are the Lagrangian multipliers of the budget constraint, time constraint, and the capital accumulation equation, respectively. By substituting (A5) into (A4), (A6), and (A7), the first-order conditions for c_t, n_t, and M_t become

(A11) $$\frac{\partial u}{\partial c_t} = P_t \lambda_t + \gamma(s_t / c_t)\frac{\partial u}{\partial l_t},$$

(A12) $$\frac{\partial u}{\partial l_t} = P_t w_t \lambda_t, \text{ and}$$

(A13) $$\lambda_t - \gamma(s_t / M_t)\frac{\partial u}{\partial l_t} = \beta E_t[\lambda_{t+1}].$$

By substituting (A9) into (A10), the first-order condition for k_{t+1} becomes

(A14) $$\tau_{2,t} = \beta E_t\left[\tau_{2,t+1}(1-\delta) + \tau_{2,t+1} q_{t+1}\right].$$

The marginal utilities of c_t and l_t are

$$\frac{\partial u}{\partial c_t} = \frac{1}{c_t} \text{ and } \frac{\partial u}{\partial l_t} = \chi l_t^{-\sigma_1}.$$

As a result, the households' problem is described by equations (A1), (A2), (A3), (A8), (A11), (A12), (A13), and (A14).

The next set of equations comes from the firms. The firms are monopolistically competitive producers of output, $y_{j,t}$, according to

(A15) $$y_{j,t} = Z_t (k_{j,t})^{\alpha} (n_{j,t})^{1-\alpha},$$

where j indicates the number of periods since the firm last adjusted its price, $n_{j,t}$ is firm labor demand, $k_{j,t}$ is firm demand for capital, and Z_t is an economywide productivity factor. This productivity factor evolves in the following manner:

(A16) $$\ln(Z_t) = \rho_Z \ln(Z_{t-1}) + (1-\rho_Z)\ln(Z) + \varepsilon_{Z,t},$$

where Z is the steady-state value of Z_t and $\varepsilon_{Z,t}$ is a mean-zero, independently and identically distributed (i.i.d.) shock. Each period, every firm must make two decisions. First, firms determine the cost-minimizing combination of $k_{j,t}$ and $n_{j,t}$ given their output level, the wage rate, and the rental rate of capital services. Second, they make pricing decisions. In particular, the probability a firm can set a new price, P_t^*, is η and the probability a firm must charge the price that it last set j periods ago, P_{t-j}^*, is $(1-\eta)$.

Each period, firms seek to minimize their costs,

$$w_t n_{j,t} + q_t k_{j,t},$$

subject to (A15). This cost minimization implies the following two-factor demand equations:

$$\psi_t \alpha Z_t \left[n_{j,t} / k_{j,t} \right]^{1-\alpha} = q_t, \tag{A17}$$

$$\psi_t (1-\alpha) Z_t \left[k_{j,t} / n_{j,t} \right]^{\alpha} = w_t, \tag{A18}$$

where ψ_t is the Lagrangian multiplier from the production function and accordingly is interpretable as the real marginal cost of output. The market-clearing conditions for capital, k_t, and labor given the conditional probability of price adjustment (η) are

$$k_t = \sum_{j=0}^{\infty} \eta (1-\eta)^j k_{j,t} \text{ and } n_t = \sum_{j=0}^{\infty} \eta (1-\eta)^j n_{j,t}. \tag{A19}$$

Because the real wage and user cost of capital are economywide costs, the real marginal cost and capital services/labor ratio will be the same for all firms (i.e., $k_{j,t}/n_{j,t} = k_t/n_t$).

The composition of output purchased by households is

$$y_t = \left[\sum_{j=0}^{\infty} \eta (1-\eta)^j y_{j,t}^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)}, \tag{A20}$$

where

$$y_t = c_t + i_t. \tag{A21}$$

Cost minimization by households yields the following product-demand equation:

$$y_{j,t} = \left(P_{t-j}^* / P \right)^{-\varepsilon} y_t, \tag{A22}$$

where P_t is a nonlinear price index such that

$$P_t = \left[\sum_{j=0}^{\infty} \eta (1-\eta)^j P_{t-j}^{*(1-\varepsilon)} \right]^{1/(1-\varepsilon)}. \tag{A23}$$

Because the probability of price adjustment is constant, (A23) can be reduced to

$$P_t = \left[\eta P_t^{*(1-\varepsilon)} + (1-\eta) P_{t-1}^{(1-\varepsilon)} \right]^{1/(1-\varepsilon)}. \tag{A24}$$

Furthermore, when (A19) is used to aggregate capital and labor over all firms, (A15) becomes

$$\bar{y}_t = \sum_{j=0}^{\infty} \eta (1-\eta)^j y_{j,t} = Z_t (k_t)^{\alpha} (n_t)^{1-\alpha}. \tag{A25}$$

Recall that the aggregate level of output is (A20). The relationship of y_t to $\bar{y}_t$ is shown by substituting (A22) into (A25) to get

(A26) $$\bar{y}_t = \sum_{j=0}^{\infty} \eta (1-\eta)^j \left(P^*_{t-j} / P_t\right)^{-\varepsilon} y_t.$$

To eliminate the infinite number of lags of P^*_t in (A26), an auxiliary price index is defined as

(A27) $$\bar{P}_t = \left[\eta P_t^{*-\varepsilon} + (1-\eta)\bar{P}_{t-1}^{-\varepsilon}\right]^{-1/\varepsilon}.$$

Given this price index, (A27) is substituted into (A26) to produce

(A28) $$\bar{y}_t = \left(\bar{P}_t / P_t\right)^{-\varepsilon} y_t.$$

The fraction η of firms that are able to adjust its price seek to maximize the expected value of its profits:

(A29) $$\sum_{j=0}^{\infty} \beta^j E_t \left[\lambda_{t+j} (1-\eta)^j \left[P_t^* y_{0,t+j} - P_{t+j} w_{t+j} n_{0,t+j} - P_{t+j} q_{t+j} k_{0,t+j}\right]\right],$$

subject to (A15). Using the factor-demand equations, (A17) and (A18), the production function, (A15), and the firm-demand equation, (A22), the firms' maximization problem, (A29), is rewritten as

(A30) $$\sum_{j=0}^{\infty} \beta^j E_t \left[\lambda_{t+j} (1-\eta)^j \left(P_t^* - P_{t+j}\psi_{t+j}\right)\left(P_t^* / P_{t+j}\right)^{-\varepsilon} y_{t+j}\right].$$

Maximizing (A30) with respect to P_t^* yields

$$\sum_{j=0}^{\infty} \beta^j E_t \left[\lambda_{t+j} (1-\eta)^j (1-\varepsilon) P_{t+j}^{\varepsilon} y_{t+j} P_t^* + \beta^j \lambda_{t+j} \eta (1-\eta)^j \varepsilon P_{t+j}^{1+\varepsilon} \psi_{t+j} y_{t+j}\right] = 0.$$

Thus, the profit-maximizing price is

(A31) $$P_t^* = V_{C,t} / V_{R,t},$$

where

$$V_{R,t} = \sum_{j=0}^{\infty} \beta^j E_t \left[(1-\eta)^j (\varepsilon - 1) \lambda_{t+j} P_{t+j}^{\varepsilon} y_{t+j}\right] \text{ and } V_{C,t} = \sum_{j=0}^{\infty} \beta^j E_t \left[(1-\eta)^j \varepsilon \lambda_{t+j} P_{t+j}^{1+\varepsilon} \psi_{t+j} y_{t+j}\right].$$

Furthermore, the evolution of $V_{R,t}$ and $V_{C,t}$ can be written in the following manner:

(A32) $$V_{R,t} = (\varepsilon - 1)\lambda_t P_t^{\varepsilon} y_t + \beta(1-\eta) E_t\left[V_{R,t+1}\right] \text{ and}$$

(A33) $$V_{C,t} = \varepsilon \lambda_t P_t^{1+\varepsilon} \psi_t y_t + \beta(1-\eta) E_t\left[V_{C,t+1}\right].$$

Therefore, the firms' problem is summarized by (A16), (A17), (A18), (A21), (A24), (A25), (A27), (A28), (A31), (A32), and (A33).

The Steady State

These are the steady-state equations for the households. To begin, the steady-state equations for the time constraint, (A1), the capital accumulation equation, (A2), and the shopping-time costs, (A3), are

$$n + l + s = 1,$$
$$i/k = \delta k, \text{ and}$$
$$s = \xi\left(Pc/M\right)^{\gamma}.$$

The steady-state first-order conditions for the households' problem, (A8), (A11), (A12), (A13), and (A14), are

$$\pi = \beta R,$$
$$1/c = P\lambda + \gamma\left(s/c\right)\chi l^{-\sigma_1},$$
$$\chi l^{-\sigma_1} = Pw\lambda,$$
$$\lambda - \gamma\left(s/M\right)\chi l^{-\sigma_1} = \beta\lambda/\pi, \text{ and}$$
$$1 = \beta\left[\left(1-\delta\right)+q\right].$$

Next are the steady-state equations for the firms. The first two equations are the steady states of the factor-demand equations, (A17) and (A18):

$$\psi\alpha Z\left[n_j / k_j\right]^{1-\alpha} = q \text{ and}$$
$$\psi\left(1-\alpha\right)Z\left[k_j / n_j\right]^{\alpha} = w.$$

Recall that $k_{j,t}/n_{j,t} = k_t/n_t$, so that $k_j/n_j = k/n$ in the steady state. The steady-state aggregate production function, (A25), is

$$\bar{y} = Z\left(k\right)^{\alpha}\left(n\right)^{1-\alpha}.$$

The steady-state relationship between y and $\bar{y}$ from (A28) is

$$\bar{y} = \left(\bar{P}/P\right)^{-\varepsilon} y,$$

where the steady-state value of $\bar{P}$ from (A25) is

$$\bar{P} = \left[\eta P^{*-\varepsilon} + \left(1-\eta\right)\pi^{\varepsilon}\bar{P}^{-\varepsilon}\right]^{-1/\varepsilon},$$

and where π is the steady-state inflation rate. The steady-state profit-maximizing price from (A31) is

$$P^{*} = V_C / V_R,$$

where the steady-state values of V_R and V_C in (A32) and (A33) are

$$V_R = \left(\varepsilon-1\right)\lambda P^{\varepsilon} y + \beta\left(1-\eta\right)\pi^{\varepsilon-1}V_R \text{ and}$$
$$V_C = \varepsilon\lambda P^{1+\varepsilon}\psi y + \beta\left(1-\eta\right)\pi^{\varepsilon}V_C.$$

Finally, the steady-state identity equations for y and P from (A21) and (A24) are

$$y = c + i \text{ and } P = \left[\eta P^{*(1-\varepsilon)} + \left(1-\eta\right)\left(P/\pi\right)^{(1-\varepsilon)}\right]^{1/(1-\varepsilon)}.$$

Linearization Around the Steady State

This section linearizes the model around its steady state. A hat is used to signify percent deviation from the steady state. Thus, $\hat{n}_t$ is the percent deviation of labor from its steady state.

Beginning with households, the linearized equations for the time constraint, (A1), the capital accumulation equation, (A2), and the shopping-time costs, (A3), are

$$l\hat{l}_t + n\hat{n}_t + s\hat{s}_t = 0,$$
$$\hat{k}_{t+1} = (i/k)\hat{i}_t + (1-\delta)\hat{k}_t, \text{ and}$$
$$\hat{P}_t + \hat{c}_t - \hat{M}_t - (1/\gamma)\hat{s}_t = 0.$$

The linearized first-order conditions for the households' problem, (A8), (A11), (A12), (A13), and (A14), are

$$\hat{\lambda}_t = \hat{R}_t + E_t\left[\hat{\lambda}_{t+1}\right],$$
$$-(1/c)\hat{c}_t = P\lambda\left(\hat{\lambda}_t + \hat{P}_t\right) + \gamma(s/c)\chi l^{-\sigma_1}\left(\hat{s}_t - \hat{c}_t - \sigma_1\hat{l}_t\right),$$
$$\hat{\lambda}_t + \hat{P}_t + \hat{w}_t + \sigma_1\hat{l}_t = 0,$$
$$\lambda\hat{\lambda}_t - \gamma(s/M)\chi l^{-\sigma_1}\left(\hat{s}_t - \hat{M}_t - \sigma_1\hat{l}_t\right) = \lambda(\beta/\pi)E_t\left[\hat{\lambda}_{t+1}\right], \text{ and}$$
$$\hat{\tau}_{2,t} = E_t\left[\hat{\tau}_{2,t+1} + \beta q\hat{q}_{t+1}\right].$$

Now, on the firm side, the linearized factor-demand equations for capital and labor, (A17) and (A18), are

$$\hat{\psi}_t + \hat{Z}_t + (1-\alpha)\left(\hat{n}_t - \hat{k}_t\right) = \hat{q}_t \text{ and}$$
$$\hat{\psi}_t + \hat{Z}_t + \alpha\left(\hat{k}_t - \hat{n}_t\right) = \hat{w}_t.$$

The linearizations of (A25) and (A28) are as follows:

$$\hat{\bar{y}}_t = \hat{Z}_t + \alpha\hat{k}_t + (1-\alpha)\hat{n}_t, \text{ and}$$
$$\hat{\bar{y}}_t = \varepsilon\left[\hat{P}_t - \hat{\bar{P}}_t\right] + \hat{y}_t,$$

where the linearization of (A27) is

$$\hat{\bar{P}}_t = \eta\left[P^*/\bar{P}\right]^{(-\varepsilon)}\hat{P}_t^* + (1-\eta)\mu^{\varepsilon}\hat{\bar{P}}_{t-1}.$$

The linearized profit-maximizing price from (A31) is

$$\hat{\bar{P}}_t^* = \hat{V}_{C,t} - \hat{V}_{R,t},$$

where the linearized values of V_R and V_C in (A32) and (A33) are

$$\hat{V}_{R,t} = \frac{(\varepsilon-1)\lambda P^{\varepsilon}y}{V_R}\left(\hat{\lambda}_t + \varepsilon\hat{P}_t + \hat{y}_t\right) + \beta(1-\eta)\pi^{\varepsilon-1}E_t\left[\hat{V}_{R,t+1}\right] \text{ and}$$
$$\hat{V}_{C,t} = \frac{\varepsilon\lambda P^{1+\varepsilon}\psi y}{V_C}\left[\hat{\lambda}_t + (1+\varepsilon)\hat{P}_t + \hat{y}_t + \hat{\psi}_t\right] + \beta(1-\eta)\pi^{\varepsilon}E_t\left[\hat{V}_{C,t+1}\right].$$

The linearized versions of the identity equations for aggregate output and the price level, (A21) and (A24), are

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{i}{y}\hat{i}_t \text{ and}$$

$$\hat{P}_t = \eta\left(P^* / P\right)^{(1-\varepsilon)}\hat{P}_t^* + (1-\eta)\pi^{(\varepsilon-1)}\hat{P}_{t-1}.$$

The monetary authority's policy instrument is either money or the nominal interest rate. When money is the instrument, the linearized policy rule is

(A34) $$\Delta\hat{M}_t = \hat{\mu}_t^* + \left(\upsilon_t - \upsilon_{t-1}\right),$$

where μ_t^* is the target money growth rate, which follows an AR(1) process, $\hat{\mu}_t^* = \rho_\mu \hat{\mu}_{t-1}^* + \varepsilon_{\mu t}$; and υ_t is a transitory shock to the money growth rule, which also follows an AR(1) process, $\upsilon_t = \rho_u \upsilon_{t-1} + \varepsilon_{\upsilon t}$. Both error terms, $\varepsilon_{\mu t}$ and $\varepsilon_{\upsilon t}$, are mean-zero, i.i.d. shocks.

When the nominal interest rate is the instrument, the linearized policy rule is

(A35) $$\hat{R}_t = \hat{\pi}_t + \theta_\pi\left(\hat{\pi}_t - \hat{\pi}_t^*\right) + \theta_y \hat{y}_t + u_t,$$

where $\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1}$; $\hat{\pi}_t^*$ is the target inflation rate, which follows an AR(1) process, $\hat{\pi}_t^* = \rho_\pi \hat{\pi}_{t-1}^* + \varepsilon_{\pi t}$; and u_t is a shock to the interest rate rule, which also follows an AR(1) process, $u_t = \rho_u u_{t-1} + \varepsilon_{ut}$. Both error terms, $\varepsilon_{\pi t}$ and ε_{ut}, are mean-zero, i.i.d. shocks.

APPENDIX B

DATA

The data set contains quarterly time series for the G7 countries on the CPI and a narrow money measure, usually M1. All the series are available from 1980:Q1 through 1998:Q4. We could not get M1 for the United Kingdom, so we used a measure of currency. For this series, we excluded the 1998 data because there was a break in the series in the second quarter. All of the series are from the Organisation for Economic Co-operation and Development's (OECD) Main Economic Indicators database or the International Financial Statistics database. The data are not seasonally adjusted, and the quarterly figures are computed as averages of monthly data. The data were retrieved in mid-October 2004 from the Haver database, and Haver mnemonics are listed for each variable.

Canada: money supply (M1) is c156fm1n@oecdmei; CPI inflation is c156czn@oecdmei.

France: money supply (M1) is c132fm1n@oecdmei; CPI inflation is c132czn@oecdmei.

Germany: money supply (M1) is c134fm1n@oecdmei; CPI inflation is c134czn@oecdmei.

Italy: money supply (M1) is c136fm1n@oecdmei; CPI inflation is c136czn@oecdmei.

Japan: money supply (M1) is c158fm1n@oecdmei; CPI inflation is c158czn@oecdmei.

United Kingdom: money supply (currency outside of banks) is c112mlc@ifs; CPI inflation is c112czn@oecdmei.

United States: money supply (M1) is c111fm1n@oecdmei; CPI inflation is c111czn@oecdmei.

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