Handout 7

Taylor Rule and the Term Structure of Interest Rates

Professor Coleman
Fuqua School of Business, Duke University
Vice Chairman Donald L. Kohn
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John Taylor Rules

The Role of Simple Rules in Monetary Policymaking

It is a pleasure and an honor to speak at this conference honoring John Taylor and his contributions to monetary theory and policy. As you have already heard from Chairman Bernanke and the other speakers today, John has made a number of seminal contributions to the field of macroeconomics. What has distinguished John's work, in my view, is that he takes policymaking in the real world seriously.\(^1\)

Taking policymaking seriously involves understanding the constraints imposed on our decisions by partial information and incomplete knowledge of economic relationships. It also implies the use of empirically valid models that acknowledge the efforts of households and businesses to anticipate the future and maximize their welfare over time. In the late 1980s and early 1990s, macroeconomics was focused mainly on real business cycles and endogenous growth theory. During this period, John was one of a very small number of academic economists who continued to pursue research aimed at informing the conduct of monetary policy. John's Carnegie Rochester conference paper published in 1993 is an excellent example of this research.

Importantly, John's legacy to the Federal Reserve has not been confined to enhancing our understanding of monetary policy. In addition, he has turned out legions of students who have followed in his footsteps in their interest in policy. Many of them have spent time in the Federal Reserve, producing a rich array of contributions to policymaking and research.

John and I have spent countless hours discussing how the Federal Reserve arrives at decisions about monetary policy and how it should arrive at decisions. Those conversations began in earnest in the late 1980s, when John was on the Council of Economic Advisers, and they have continued to the present day. They have occurred not only in offices and classrooms in Washington and Stanford and at numerous conferences around the globe, but also around dinner tables in Washington and Palo Alto and on hiking trails from Vermont to Wyoming. Those conversations made me a better policy adviser and then policymaker, and they have had the added and very special bonus of allowing Gail and me to count John and Allyn among our friends. I can't think of a better way to honor John's contributions than to continue that discussion around the dinner tables of Dallas by reflecting on the role of simple rules in informing policymaking.

Three Benefits of Simple Rules in Monetary Policymaking

In his Carnegie Rochester conference paper, John considered a simple policy rule under which the nominal federal funds rate is adjusted in response to both the gap between real and trend gross domestic product (GDP) and the gap between the inflation rate and policymakers' target. Based on data for the previous few years, John calibrated the long-run target for inflation and the two parameters that determine the responsiveness of the federal funds rate to the two gaps. The equilibrium real interest rate was based on a
longer history of actual real interest rates. In the handout, Figure 1A depicts the actual nominal funds rate and the Taylor rule prescriptions between 1987 and 1992, as presented in John's paper. Despite its simplicity, this policy rule fits the data remarkably well; it described a period of generally successful policymaking; and it adhered to the Taylor principle of adjusting the nominal rate more than one-for-one with changes in the inflation rate, so it provided a plausible template for future success. It is no wonder that John has been such a dedicated salesman and that his efforts have been so well received in academia and policy councils.

Following John's seminal contribution, many other economists have engaged in research on similar policy rules and, together with John, have identified several benefits of such rules in conducting monetary policy. I will elaborate on three of them.

The first benefit of looking at a simple rule like John's is that it can provide a useful benchmark for policymakers. It relates policy setting systematically to the state of the economy in a way that, over time, will produce reasonably good outcomes on average. Importantly, the emphasis is on levels and gaps, not growth rates, as inputs to the policy process. This emphasis can be a problem when a level, say of potential GDP, is in question, but in many respects it is also a virtue. For the United States, the two gaps relate directly to the legislative mandate of the Federal Reserve to achieve stable prices and maximum employment. Moreover, those two gaps fit directly into most modern macroeconomic theories, which tell us something about their relationship and how that relationship can be affected by the type of shock hitting the economy.

Model uncertainties make the simplicity of the rule particularly important for the policymaker because research suggests that the prescriptions from simple rules can be more robust than optimal-control policies. Optimal-control policies can depend critically on the exact specification of the model, and clearly there is no consensus about which model best describes the U.S. economy.

Federal Reserve policymakers are shown several versions of Taylor rules in the material we receive before each meeting of the Federal Open Market Committee (FOMC). I always look at those charts and tables and ask myself whether I am comfortable with any significant deviation of my policy prescription from those of the rules.
A second benefit of simple rules is that they help financial market participants form a baseline for expectations regarding the future course of monetary policy. Even if the actual policy process is far more sophisticated than any simple rule could completely describe, the rule often provides a reasonably good approximation of what policymakers decide and a framework for thinking about policy actions. Indeed, many financial market participants have used the Taylor rule to understand U.S. monetary policy over the past fifteen years. Investors and other market participants are going to form expectations about policy and act on those expectations. The more accurate and informed those expectations are, the more likely are their actions to reinforce the intended effects of policy.

A third benefit is that simple rules can be helpful in the central bank’s communication with the general public. Such an understanding is important for the transmission mechanism of monetary policy. Giving the public some sense of how the central bank sees the output and inflation gaps and how they are expected to evolve will help it understand the central bank’s objectives and how policymakers are likely to respond to surprises in incoming data.

**Four Limitations of Simple Rules**

Simple rules have limitations, of course, as benchmarks for monetary policy. To quote from John’s Carnegie Rochester paper, "a policy rule can be implemented and operated more informally by policymakers who recognize the general instrument responses that underlie the policy rule, but who also recognize that operating the rule requires judgment and cannot be done by computer" (p. 198). In that context, four limitations of simple rules are important.

The first limitation is that the use of a Taylor rule requires that a single measure of inflation be used to obtain the rule prescriptions. The price index used by John in the Carnegie Rochester paper was the GDP price deflator. Other researchers have used the inflation measure based on the consumer price index (CPI). Over the past fifteen years, the Federal Reserve has emphasized the inflation rate as measured by changes in the price index for personal consumption expenditures (PCE). Many researchers have also explored the use of core price indexes, which exclude the volatile food and energy components, as better predictors of future inflation or as more robust indicators of the sticky prices that some theories say should be the targets of policy. To be sure, over long periods, most of these measures behave very similarly. But policy is made in the here and now, and the various indexes can diverge significantly for long stretches, potentially providing different signals for the appropriate course of monetary policy.

Second, the implementation of the Taylor rule and other related rules requires determining the level of the equilibrium real interest rate and the level of potential output; neither of them are observable variables, and both must be inferred from other information. John used 2 percent as a rough guess as to the real federal funds rate that would be consistent with the economy producing at its potential. But the equilibrium level of the real federal funds rate probably varies over time because it depends on factors such as the growth rate of potential output, fiscal policy, and the willingness of savers to supply credit to households and businesses. Inaccurate estimates of this rate will mislead policymakers about the policy stance required to achieve full employment. In a similar vein, real-time estimates of potential output can be derived in a number of ways and—as shown by Orphanides (2003) and others—they are subject to large and persistent errors. If policymakers inadvertently rely on flawed estimates, they will encounter persistent problems in achieving their inflation objective.

The third limitation of using simple rules for monetary policymaking stems from the fact that, by their nature, simple rules involve only a small number of variables. However, the state of a complex economy like that of the United States cannot be fully captured by any small set of summary statistics. Moreover, policy is best made looking forward, that is, on the basis of projections of how inflation and economic activity may evolve. Lagged or current values of the small set of variables used in a given simple rule may not provide a sufficient guide to future economic developments, especially in periods of rapid or unusual change. For
these reasons, central banks monitor a wide range of indicators in conducting monetary policy. In his Carnegie Rochester paper, John mentioned the stock market crash of October 1987 as an example of how other variables can and should influence the course of monetary policy in some situations.

The final limitation I want to highlight is that simple policy rules may not capture risk-management considerations. In some circumstances, the risks to the outlook or the perceived costs of missing an objective on a particular side may be sufficiently skewed that policymakers will choose to respond by adjusting policy in a way that would not be justified solely by the current state of the economy or the modal outlook for output and inflation gaps.

**Policy Rules around 2003**

Some of the ambiguities and potential pitfalls in the use of simple policy rules are highlighted by considering their prescriptions for a period earlier in this decade. Turning to Figure 1B, the solid line indicates the actual federal funds rate between the first quarter of 1993 and the second quarter of 2007, and the dashed line shows the prescriptions of the Taylor rule using the same methodology that John used in his Jackson Hole remarks this year. For the earlier part of the sample, the prescription from this simple rule tracks the actual funds rate relatively well. As John pointed out, a notable deviation happened beginning in 2002, and I would like to discuss that period to illustrate the limitations I noted earlier.

**Figure 1B**

Inflation Measure

The first limitation is related to the measure used for the inflation variable included in the rules. The rule prescriptions depicted by the dashed line in Figure 1B are based on the headline CPI. But as you know, the FOMC often looks at core inflation, stripping out the effects of energy and food prices, as a better indicator of future price behavior. The dotted line represents the rule prescriptions based on the chain-weighted core CPI, which the Bureau of Labor Statistics has produced since 2000. Using this measure lowers the prescribed funds rate by about 2 percentage points during 2003, bringing the rule prescriptions much closer to the actual path of policy. The reason for the improvement is evident from Figure 2A, on the other side of the handout: Even though the headline and core CPI measures were broadly similar in the mid- to late 1990s, these measures diverged substantially between 2003 and 2005.
Potential Output
The second limitation relates to the challenge of judging the level of potential output in real time. To illustrate this point, Figure 2B plots three measures of the output gap. The solid line is the real-time estimate by the Congressional Budget Office (CBO) that was used in the Taylor rule prescriptions in Figure 1B, while the dashed line depicts the CBO’s ex post estimate of the output gap as of the third quarter of 2007. Back in 2003, the CBO estimated that output at that time was below potential by only 1 percent. With the benefit of four more years of data, the CBO currently estimates that the output gap for the first half of 2003 was considerably wider—about 3 percent. In addition, the dotted line represents an alternative measure of resource utilization derived from the unemployment rate and an estimate of the natural rate of unemployment (NAIRU) taken from the Board staff’s FRB/US model. In fact, the unemployment rate was rising through the middle of 2003, so the FOMC had every reason to believe that the output gap was widening at that time. Using this unemployment-based measure rather than the real-time CBO measure would reduce the prescriptions of simple policy rules by roughly 1/2 percentage point in early 2003.

Other Variables
The third limitation in my list was that the small set of economic measures included in simple rules may not
fully reflect the state of the economy. Around 2003, financial market conditions may not have been adequately summarized by the assumed 2 percent equilibrium federal funds rate. Accounting scandals caused economic agents to lose confidence in published financial statements and in bond ratings. The result was higher uncertainty about the financial health of firms, and credit spreads widened substantially. Figure 2C shows that risk spreads on corporate bonds were elevated in this period. Other things equal, such spreads would reduce the federal funds rate needed to achieve full employment, perhaps explaining a portion of the gap between the actual federal funds rate and the outcome from the policy rule during this period.

Risk Management
The last item on my list of limitations was that simple rules do not take account of risk-management considerations. As shown in Figure 2A, the core CPI inflation rate for 2003 was falling toward 1 percent. The real-time reading of the core PCE inflation rate (not shown) was on average even lower than the comparable CPI figure. Given these rates, the possibility of deflation could not be ruled out. We had carefully analyzed the Japanese experience of the early 1990s; our conclusion was that aggressively moving against the risk of deflation would pay dividends by reducing the odds on needing to deal with the zero bound on nominal interest rates should the economy be hit with another negative shock. This factor is not captured by simple policy rules.

A Final Note
I have offered this analysis in the spirit of so many of the discussions I have had with John. His framework has been enormously important to policymaking in the Federal Reserve, and it has yielded many benefits. Nevertheless, it's important to keep in mind that some significant practical limitations also are associated with the application of such rules in real time. In other words, it's not so simple to use simple rules!

References


Footnotes

1. I am sure my colleagues join me in honoring John. However, my thoughts on policy rules are my own and not necessarily those of my colleagues on the Federal Open Market Committee. Jinill Kim and Andrew Levin, of the Board's staff, contributed to the preparation of these remarks. Return to text

2. Following John, the rule specification and the data used for the prescriptions closely follow the implementation of the Taylor rule in Bill Poole's speech in August 2006 (Poole, 2007). The inflation measure used for this rule is the four-quarter average headline CPI inflation rate, with the benchmark value set to 2 percent. Through 2001, the gap between real GDP and its potential is the value measured in real time by the staff of the Board of Governors. Because subsequent staff estimates of the output gap are not yet publicly available, the rule prescriptions for the post-2001 period are computed with the real-time output gap as constructed by the Congressional Budget Office. Return to text
Do yield curves normally slope up?
The term structure of interest rates, 1862-1982

John H. Wood

The downward-sloping yield curves of recent years have been called perverse, but an examination of the history of American interest rates reveals that, at least since the Civil War, falling yield curves have been nearly as common as those with upward slopes. This article summarizes yield curve patterns since 1862 and suggests that (1) the traditional expectations theory remains a viable explanation of observed yield curves and (2) yield curves since the abandonment of the gold standard in 1971 have much in common with those of the greenback era of 1862-78 but are distinct from those of the gold standard years of 1879-1970. The slopes of yield curves appear to depend upon expectations of future yields as determined by expectations of inflation, which, in turn, depend upon the prevailing monetary standard.

U.S. yield curves in the 20th century

Yield curves for high-grade corporate bonds from 1900 to 1982 are shown in the two panels of Figure 1. Each curve shows the term structure of yields in a particular year, i.e., the relationship between bond yields and terms to maturity at a point in time. Panel A shows yield curves for the period prior to 1930. Yield curves for 1930 through 1982 are shown in Panel B. Curves since 1966 have been identified by year of occurrence.

A striking feature of the yield curves in Figure 1 is their tendency to be positively sloped when yields are "low" and to be negatively sloped when yields are "high." Suppose, for example, that between 1900 and 1970 one-year bond yields above 4.40 percent were considered high and yields below 3.25 percent were thought to be low. The upper portion of Table 1 shows that if "high" and "low" are distinguished in this manner all yield curves had negative slopes when short-term yields were high and all yield curves had positive slopes when short-term yields were low.

This observation applies throughout the 1900-1970 period, but breaks down after 1970. In order to understand yield patterns since 1970, it is first necessary to examine a popular and persuasive explanation of the shapes of observed yield curves.

An explanation: the traditional expectations theory with regressive expectations

Any theory of equilibrium relations among bond yields must specify (1) the criteria by which investors select bonds given their expectations of future yields and (2) how those expectations are formed. With regard to (1), the traditional expectations theory of the term structure of interest rates asserts that bond-market equilibrium requires equal expected returns on...
bonds of all maturities. For the simple case of pure discount (zero-coupon) bonds, this implies long-term yields that are averages of current and expected short-term yields (see Box).

To convert the expectations theory into an operational explanation of the term structure, a mechanism for determining expected short-term yields must be specified. Only two of the simplest and most common types of expectations—extrapolative and regressive—are considered here.

This statement may be illustrated as follows for 1- and 2-period bonds and a 1-period holding period. The 1-period rate-of-return on a 2-period zero-coupon bond worth $1 at maturity is

where \( P_2 \) is the current price of the 2-period bond and \( P_1^e \) is the price currently expected to prevail next period on a 1-period bond. If the expectations theory holds, (see equation (1) in Box) this rate-of-return equals \( R_1 \)—i.e., the expected 1-period returns on 1- and 2-period bonds are equal. As indicated in the Box, these results hold precisely only under conditions of certainty.

Figure 1
Panel A: yield curves for high-grade corporate bonds, 1900-1929
Panel B: yield curves for high-grade corporate bonds, 1930-1982

SOURCE: Durand (1942, 1958); Durand and Winn (1947); and Scudder, Stevens, and Clark.
The traditional expectations theory of the term structure

The equilibrium term structure is

$$
(1+R_n)^n = (1+R_1)(1+R_1^e)(1+R_1) \ldots (1+n^{-1}R_1^e),
$$

where \( R_1 \) and \( R_n \) are the yields-to-maturity currently prevailing on bonds maturing after one and \( n \) periods, respectively, and

$$
R_1^e, R_2^e, \ldots, R_{n-1}^e
$$

are the one-period yields currently expected by investors to prevail one, two, \ldots, and \( (n-1) \) periods in the future.

A convenient linear approximation of the equilibrium term structure describes long-term yields as arithmetic averages, instead of geometric averages as in equation (1), of current and expected short-term yields:

$$
R_n = \frac{R_1 + R_1^e + R_2^e + \ldots + R_{n-1}^e}{n}
$$

This approximation deteriorates as short and long yields diverge. For example, let \( R_2^e \) be the approximate two-period yield given by equation (2). Then comparing \( R_2^e \) with \( R_2 \) from equation (1):

$$
R_2 = R_2^e = .10 \quad \text{if} \quad R_1 = .10; \\
R_2 = .10 \quad \text{and} \quad R_2 = .0997 \quad \text{if} \quad R_1 = .075 \quad \text{and} \\
1 R_1^e = .125; \quad \text{and} \quad R_2 = .10 \quad \text{and} \quad R_2 = .0989 \quad \text{if} \quad R = .05, \quad \text{and} \quad 1 R_1^e = .15.
$$

Equation (1) is itself an approximation of observed yield curves even if all the usual assumptions of the traditional expectations theory are satisfied. One reason is that equation (1) neglects uncertainty and is therefore valid only under conditions of perfect foresight. (This point has been made in different ways by Nelson [1972, pp. 21-28] and Cox, Ingersoll, and Ross [1981].) Second, equation (1) strictly applies only to zero-coupon bonds—whereas most yield curves, including those in Chart 1, are for coupon bonds. Garbade [1982, pp. 293-99] and others have shown that the effect of coupons is to moderate the slopes of yield curves implied by equation (1).

Although it would be difficult to assess the empirical importance of these deficiencies, it is shown in the text that the traditional expectations theory with regressive expectations is at least roughly consistent with observed yield curves.

Extrapolative expectations mean that investors expect short-term yields to continue to move in the same direction as recent yield movements. If yields have been rising, they are expected to continue to rise in the future. If yields have been falling, they are expected to fall further.

Regressive expectations imply just the opposite of extrapolative expectations. If yields have been rising, they are expected to reverse course, or regress, towards what are considered "normal" levels. If yields are below "normal," they are expected to rise.

Now, suppose that yields have fallen to low levels such that the current short-term yield is \( R_1 = .02 \) and, because investors extrapolate recent events into the future, the short-term yield expected to prevail in the next period is \( R_1^e = .01 \). Using the approximation provided by equation (2) in the Box, this means a two-period yield of \( R_2 = (.02 + .01)/2 = .015 \), and the yield curve has a negative slope.

Considering another example, suppose yields have risen to high levels such that \( R_1 = .20 \). If expectations are formed extrapolatively, so that, perhaps, \( R_1^e = .21 \), we have \( R_2 = .205 \) and the yield curve is rising. Thus, the traditional expectations theory with extrapolative expectations suggests that yield curves will tend to have positive slopes when yields are high and negative slopes when yields are low. This is inconsistent with the data in Figure 1 and Table 1, at least for 1900-1970.

On the other hand, suppose short-term yields are expected to regress toward some "normal" level denoted by \( R_1^* \). Assume \( R_1^* = .06 \) and that the change in each later period is expected to be one-half the difference between the normal yield and the short-term yield prevailing in the preceding period. Given \( R_1 = .02 \) and \( R_1^* = .06 \), these assumptions imply that

$$
R_1^e = R_1 + s(R_1^* - R_1) = .02 + .5(.06 - .02) = .04.
$$
where $s = .5$ is the expected speed of adjustment. The resulting yield curve has a positive slope because $R_2 = (.02 + .04)/2 = .03$. Following the same procedure and letting $R_1 = .20$, we obtain $R_2 = .165$, so that the yield curve has a negative slope when $R_1 = .20$. These examples support the view that the traditional expectations theory supplemented by regressive expectations is consistent with observed yield curves, at least during 1900-1970.

An upward revision of expectations in the 1970s?

The upper portion of Table 1 suggests that yield curves between 1900 and 1970 were consistent with the traditional expectations theory with regressive expectations, if the normal one-year, high-grade corporate bond yield was thought by investors to be between 3.25 and 4.40 percent. But notice the high and rising yield curves for 1971-1978 and 1982 in Figure 1. Either (1) the explanation that is so effective for 1900-1970 has failed in recent years because investors no longer behave according to the tenets of the traditional expectations theory and/or they no longer form expectations reggressively, or (2) they have revised their estimates of the normal rate.

The extrapolative expectations version of the traditional expectations theory appears broadly consistent with the generally rising yields and positively sloped yield curves of 1971-78. But it does not look as promising in light of the yield curves of 1979-81, which had negative slopes during a period of rapidly rising yields. A variety of other explanations of the events of 1971-82 might be worth pursuing, but the analysis of this paper will remain with the explanation emphasized thus far—the traditional expectations theory with regressive expectations. That is, we will examine the extent to which alternative (2) in the preceding paragraph is capable of explaining yield curves since 1971. But this approach requires an additional hypothesis, one that supplies a rule by which investors revise their estimates of the normal rate. However, such a rule, whatever it is, cannot be subjected to any kind of test on the basis of data considered so far because the only unambiguous 20th century revision or revisions have occurred since about 1970. For other possible revisions we must go to the 19th century.

The 19th and 20th centuries compared

No complete yield curves such as those in Figure 1 are available for the 19th century. However, the slopes of yield curves may be inferred...

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Table 1

Frequencies of rising, flat, and falling yield curves, 1900-1982

<table>
<thead>
<tr>
<th>One-year corporate bond yield (percent per annum)</th>
<th>Slope of yield curve</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Above 4.40</td>
<td>0</td>
</tr>
<tr>
<td>3.25 - 4.40</td>
<td>10</td>
</tr>
<tr>
<td>Below 3.25</td>
<td>26</td>
</tr>
<tr>
<td>Above 8.00</td>
<td>1</td>
</tr>
<tr>
<td>Below 8.00</td>
<td>8</td>
</tr>
</tbody>
</table>

SOURCES: Durand, Durand and Winn, and Scudder, Stevens and Clark.

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from data on the prime commercial paper rate (the short-term yield) and Frederick Macaulay's railroad bond yield index (the long-term yield). Annual averages of commercial paper and railroad bond yields for 1862-1929 are shown in Figure 2. This figure tells, in a different way, essentially the same stories as Figure 1: first, that yield curves tended to be positively sloped when yields were low and negatively sloped when yields were high and, second, that there was apparently a revision of the notions of "high" and "low". However, instead of an upward revision, as in the early 1970s, Figure 2 suggests a downward adjustment of the normal rate in the late 1870s. Notice, for example, that the seven short-term yields between 5.58 percent and 7.55 percent during 1866-1875 were all associated with rising yield curves, while after those years all short-term yields above 5.40 percent were associated with falling yield curves.

No precise dating of the normal rate's revision, which may have occurred over several years, is immediately obvious from the data. (This is also true of the shift in the 1970s, or perhaps the late 1960s.) But suppose, for simplicity of exposition, that most of the adjustment took place early in 1879. Using this date to divide 1862-1929 into two periods, Table 2 suggests that the normal rate may have been in the vicinity of 7.50 percent during 1862-1878 and between 4 and 5.50 percent during the 1879-1929 period.

What events triggered these upward and downward revisions in investors' expectations of normal rates? A look at the history of U.S. monetary standards since 1862 may provide an answer.

<table>
<thead>
<tr>
<th>Commercial paper yield (percent per annum)</th>
<th>Slope of yield curve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Above 7.57</td>
<td>0</td>
</tr>
<tr>
<td>Below 7.56</td>
<td>12</td>
</tr>
<tr>
<td>1879-1929</td>
<td></td>
</tr>
<tr>
<td>Above 5.40</td>
<td>0</td>
</tr>
<tr>
<td>4.21 - 5.40</td>
<td>4</td>
</tr>
<tr>
<td>Below 4.21</td>
<td>14</td>
</tr>
</tbody>
</table>

*See Macaulay (1938, Table 10) for data on the unadjusted index of railroad bond yields. "Choice" and "prime" commercial paper rates, reported on a discount basis, have been converted to bond equivalent yields. Macaulay tried to construct yield curves for railroad bonds like those later reported by Durand, but he found the correlation between yield and maturity too small. However, the use of Macaulay's data in Table 2 is consistent with the use of Durand's yield curves in Table 1 because Macaulay found that longer-term bonds tended to have higher yields when short-term rates (such as the commercial paper rate) were low and that shorter-term bonds tended to have higher yields when short-term rates were high (p. 80).

*During 1900-1929, when Figures 1 and 2 overlap, the yield curves implied by the latter figure have the same sign as those in the former on three-quarters of the occasions on which Durand's yield curves are not flat. Furthermore, the slopes implied by Figure 2 tend to be smaller in absolute value when Durand's curves are flat than when they have non-zero slopes.

The monetary standard and the yield curve

The American monetary standard has undergone the following changes since early in the
Civil War. The gold standard was abandoned when banks suspended specie payments on December 30, 1861. In February 1862, Congress authorized the first of several issues of legal tender currency (the famous greenbacks). After a period of monetary expansion accompanied by depreciation of the dollar, followed by prolonged monetary controversy, a bill for the resumption of the gold standard at the prewar exchange rate was passed in January 1875. Resumption was achieved on the target date of January 1, 1879, although success was not assured until late in 1878.

The monetary standard remained unchanged until banks were legally prohibited from paying out gold in March 1933. The international gold standard was resumed in January 1934, although the gold value of the dollar was reduced to 59 percent of that prevailing between 1879 and 1933. Finally, in August 1971, the United States suspended the international convertibility of the dollar and embarked on a paper standard identical in all important respects to the greenback era of 1862-1878.

The following line of reasoning suggests that the monetary standard should be expected to be an important, perhaps the dominant, influence on the normal rate. First, define the normal rate on securities of a particular risk class as the yield expected by investors to apply to those securities in long-run equilibrium. (References from this point are to normal rates instead of to a single normal rate.) Second, the available evidence strongly suggests that interest rates are to a considerable extent determined by inflationary expectations, which in turn depend on actual inflation. Finally, inflation has for centuries been highly correlated, and generally believed to be highly correlated, with the choice of monetary standard.

These arguments are supported by the data in Charts 1 and 2 and Tables 1 and 2, which are consistent with a downward revision in the 1870s and an upward revision in the 1970s of investor estimates of normal rates. The rising 1982 yield curve suggests that the latter revision may not yet be complete. It is not clear from the data whether another revision occurred in the 1930s because the steeply rising yield curves of that decade (and of the 1940s and 1950s) were, in view of the record-low yields prevailing at the time, consistent with normal rates based on experience of both gold and paper standards.

The values in Table 2 are not directly comparable with those in Table 1, because the yields in the two tables apply to different securities. Nevertheless, these tables and the figures upon which they are based combine to tell a single story—that American yield curves since 1862 are at least roughly consistent with the traditional expectations theory supplemented by regressive expectations where the normal rate is a function of the monetary standard. That is the hypothesized rule for revising the normal rate that earlier was declared to be required for a complete explanation of observed yield curves.

Concluding comment: Inflation and the monetary standard as parts of the same political decision.

The data presented above suggest that changes in inflationary expectations are asso-
ciated with, and perhaps influenced by, changes in the monetary standard. But it is important to stress that the monetary standard is not imposed upon an economic system from outside. A shift from a fixed-rate to a flexible-rate system, for example, may be viewed as merely one of several reflections of a decision by one or more countries to abandon long-run price stability as a goal. This means that the data contain no implications for monetary policy. The monetary authority is not free to attempt to influence inflationary expectations by manipulating the monetary standard. Both are chosen and imposed upon the central bank by the political process.

References

Thomas Attwood, A Second Letter to the Earl of Liverpool on the Bank Reports as Occasioning the National Dangers and Distresses, R. Wrightson, Birmingham, 1819.


The Yield Curve as a Predictor of U.S. Recessions

Arturo Estrella and Frederic S. Mishkin

The yield curve—specifically, the spread between the interest rates on the ten-year Treasury note and the three-month Treasury bill—is a valuable forecasting tool. It is simple to use and significantly outperforms other financial and macroeconomic indicators in predicting recessions two to six quarters ahead.

Economists often use complex mathematical models to forecast the path of the U.S. economy and the likelihood of recession. But simpler indicators such as interest rates, stock price indexes, and monetary aggregates also contain information about future economic activity. In this edition of Current Issues, we examine the usefulness of one such indicator—the yield curve or, more specifically, the spread between the interest rates on the ten-year Treasury note and the three-month Treasury bill. To get a sense of the relative power of this variable, we compare it with other financial and macroeconomic variables used to predict economic events.

Our analysis differs in two important respects from earlier studies of the predictive power of financial variables. First, we focus simply on the ability of these variables to forecast recessions rather than on their success in producing quantitative measures of future economic activity. We believe this is a useful approach because evidence of an oncoming recession is of clear interest to policymakers and market participants. Second, we choose to examine out-of-sample, rather than in-sample, performance—that is, we look at accuracy in predictions for quarters beyond the period over which the model is estimated. This feature of our study is particularly important because out-of-sample performance provides a much truer test of an indicator’s real-world forecasting ability.

Why Consider the Yield Curve?
The steepness of the yield curve should be an excellent indicator of a possible future recession for several reasons. Current monetary policy has a significant influence on the yield curve spread and hence on real activity over the next several quarters. A rise in the short rate tends to flatten the yield curve as well as to slow real growth in the near term. This relationship, however, is only one part of the explanation for the yield curve’s usefulness as a forecasting tool.2 Expectations of future inflation and real interest rates contained in the yield curve spread also seem to play an important role in the prediction of economic activity. The yield curve spread variable examined here corresponds to a forward interest rate applicable from three months to ten years into the future. As explained in Mishkin (1990a, 1990b), this rate can be decomposed into expected real interest rate and expected inflation components, each of which may be helpful in forecasting. The expected real rate may be associated with expectations of future monetary policy and hence of future real growth. Moreover, because inflation tends to be positively related to activity, the expected inflation component may also be informative about future growth.

Although the yield curve has clear advantages as a predictor of future economic events, several other variables have been widely used to forecast the path of the
economy. Among financial variables, stock prices have received much attention. Finance theory suggests that stock prices are determined by expectations about future dividend streams, which in turn are related to the future state of the economy. Among macroeconomic variables, the Commerce Department’s (now the Conference Board’s) index of leading economic indicators appears to have an established performance record in predicting real economic activity. Nevertheless, its record has not always been subjected to careful comparison tests. In addition, because this index has often been revised after the fact to improve its performance, its success could be overstated. An alternative index of leading indicators, developed in Stock and Watson (1989), appears to perform better than the Commerce Department’s index of leading economic indicators. In the discussion below, we compare the predictive power of all three of these variables with that of the yield curve.3

Estimating the Probability of Recession
To assess how well each indicator variable predicts recessions, we use the so-called probit model, which, in our application, directly relates the probability of being in a recession to a specific explanatory variable such as the yield curve spread.4 For example, one of the most successful models in our study estimates the probability of recession four quarters in the future as a function of the current value of the yield curve spread between the ten-year Treasury note and the three-month Treasury bill. The results of the model, based on data from the first quarter of 1960 to the first quarter of 1995, are presented in a table showing the values of the yield curve spread that correspond to estimated probabilities of a recession four quarters in the future. As the table indicates, the estimated probability of a recession four quarters ahead estimated from this model is 10 percent when the spread averages 0.76 percentage points over the quarter, 50 percent when the spread averages -0.82 percentage points, and 90 percent when the spread averages -2.40 percentage points.

The yield curve spread averaged -2.18 percentage points in the first quarter of 1981, implying a probability of recession of 86.5 percent four quarters later. As predicted, the first quarter of 1982 was in fact designated a recession quarter by the National Bureau of Economic Research.

### Estimated Recession Probabilities for Probit Model Using the Yield Curve Spread

<table>
<thead>
<tr>
<th>Recession Probability (Percent)</th>
<th>Value of Spread (Percentage Points)</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>1.21</td>
</tr>
<tr>
<td>10</td>
<td>0.76</td>
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<tr>
<td>15</td>
<td>0.46</td>
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<td>25</td>
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<tr>
<td>30</td>
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<tr>
<td>40</td>
<td>-0.50</td>
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<tr>
<td>50</td>
<td>-0.82</td>
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<tr>
<td>60</td>
<td>-1.13</td>
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<tr>
<td>70</td>
<td>-1.46</td>
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<tr>
<td>80</td>
<td>-1.85</td>
</tr>
<tr>
<td>90</td>
<td>-2.40</td>
</tr>
</tbody>
</table>

Note: The yield curve spread is defined as the spread between the interest rates on the ten-year Treasury note and the three-month Treasury bill.

Tracking the Performance of the Variables
Using the results of our model, we can compare the forecasting performance of the yield curve spread with that of the New York Stock Exchange (NYSE) stock price index, the Commerce Department’s index of leading economic indicators, and the Stock-Watson index. For each of these four variables, the chart on page 3 plots the forecasted probabilities of a recession in the United States for one, two, four, and six quarters in the future together with the actual periods of recession (the shaded areas).5

To understand how to read the chart, consider the forecast for the fourth quarter of 1990, which is the first quarter after the peak of the business cycle and is thus at the start of the last shaded recession region in each panel. In Panel 1, which shows the forecast one quarter ahead, the probability of recession from the probit model using the yield curve spread variable (Spread) forecasted in the third quarter of 1990 for the
Forecasted Probability of Recession: A Comparison of Four Indicators

Source: Authors’ calculations.

Notes: The probabilities in this chart are derived from out-of-sample forecasts one, two, four, and six quarters ahead. For example, the forecasted probabilities in Panels 1 and 2 are for one quarter ahead—that is, the probability shown is a forecast for the quarter indicated, using data from one quarter earlier—while for Panels 7 and 8, the forecasted probabilities are for six quarters ahead. Spread denotes the forecasts from the model using the yield curve spread (the difference between the interest rates on ten-year Treasury notes and three-month Treasury bills, both on a bond-equivalent basis) as the explanatory variable. NYSE denotes the results from the model using the quarterly percentage change in the New York Stock Exchange stock price index as the explanatory variable. Leading indicators denotes the forecasts from the model using the quarterly percentage change in the Commerce Department’s (now the Conference Board’s) index of leading indicators as the explanatory variable. Stock-Watson denotes the forecasts using the quarterly percentage change in the Stock-Watson (1989) leading economic indicator index as the explanatory variable. Shaded areas designate “recessions” starting with the first quarter after a business cycle peak and continuing through the trough quarter. The peak and trough dates are the standard ones issued by the National Bureau of Economic Research.
fourth quarter of 1990 is 13 percent. Similarly, in Panel 7, which shows forecasts six quarters ahead, the forecasted probability of recession for the fourth quarter of 1990—22 percent—is generated from a model using the yield curve spread as of the second quarter of 1989.

In assessing these panels, note that even a probability of recession that is considerably less than one can be a strong signal of recession. Because in any given quarter the probability of recession is quite low, a forecasted probability of, say, 50 percent is going to be quite unusual. Indeed, the successful forecasting model described in the table yields probabilities of recession that are typically below 10 percent in nonrecession (unshaded) periods (as shown in Panel 5). Thus, even a probability of recession of 25 percent—the figure forecast for the fourth quarter of 1990 from data on the yield curve spread one year earlier—was a relatively strong signal in the fourth quarter of 1989 that a recession might come one year in the future.

The chart invites two basic conclusions about the performance of the four variables:\(^5\)

- Although all the variables examined have some forecasting ability one quarter ahead, the leading economic indicator indexes, particularly the Stock-Watson index, produce the best forecasts over this horizon.
- In predicting recessions two or more quarters in the future, the yield curve dominates the other variables, and this dominance increases as the forecast horizon grows.

Let’s look in more detail at the probability forecasts in Panels 1-8. Panels 1 and 2 show that the indexes of leading economic indicators typically outperform the yield curve spread and the NYSE stock price index for forecasts one quarter ahead. For the 1973-75, 1980, and 1981-82 recessions, both indexes of leading economic indicators, and particularly the Stock-Watson index, are quite accurate, outperforming the yield curve spread and the NYSE stock price index with a high predicted probability during the recession periods. However, despite excellent performance in these earlier recessions, the Commerce Department indicator provides several incorrect signals in the 1982-90 boom period, and the Stock-Watson index completely misses the most recent recession in 1990-91.\(^7\) Although the financial variables—the yield curve spread and the NYSE stock price index—are not quite as accurate as the leading economic indicators in predicting the 1973-75, 1980, and 1981-82 recessions one quarter ahead, they do provide a somewhat clearer signal of an imminent recession in 1990.

As the forecasting horizon lengthens to two quarters ahead and beyond, the performance of the NYSE stock price index and the leading economic indicator indexes deteriorates substantially (Panels 3-8). Indeed, at a six-quarter horizon, the probabilities estimated using the three indexes are essentially flat, indicating that these variables have no ability to forecast recessions. In contrast, the performance of the yield curve spread

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_The performance of the yield curve spread improves considerably as the forecast horizon lengthens to two and four quarters._

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improves considerably as the forecast horizon lengthens to two and four quarters. The estimated probabilities of recession for 1973-75, 1980, and 1981-82 based on the yield curve spread are substantially higher than at the one-quarter horizon, and the signal for the 1981-82 recession no longer comes too early (compare Panel 5 with Panel 1).

Furthermore, in contrast to the other variables, the yield curve spread gives a relatively strong signal in forecasting the 1990-91 recession four quarters ahead. Although the forecasted probability is lower than in previous recessions, it does reach 25 percent (Panel 5).

There are two reasons why the signal for this recession may have been weaker than for the earlier recessions. First, restrictive monetary policy probably induced the 1973-75, 1980, and 1981-82 recessions, but it played a much smaller role in the 1990-91 recession. Because the tightening of monetary policy also affects the yield curve, we would expect the signal to be more pronounced at such times. Second, the amount of variation in the yield curve spread has changed over time and was much less in the 1990s than in the early 1980s, making a strong signal for the 1990-91 recession difficult to obtain.\(^8\)

When we look at how well the yield curve spread forecasts recessions six quarters in the future (Panel 7), we see that the performance deteriorates from the four-quarter-ahead predictions. Nonetheless, unlike the other variables considered, the yield curve spread continues to have some ability to forecast recessions six quarters ahead.

**Conclusion**

This article has examined the performance of the yield curve spread and several other financial and macroeconomic variables in predicting U.S. recessions. The
results obtained from a model using the yield curve spread can have a useful role in macroeconomic prediction, particularly with longer lead times. Policymakers value longer term forecasts because policy actions typically take effect on the economy with long time lags. Thus, the fact that the yield curve strongly outperforms other variables at longer horizons makes its use as a forecasting tool even more compelling.

With the existence of large-scale macroeconomic models and the judgmental assessments of knowledgeable market observers, why should we care about the predictive ability of the yield curve? There is no question that judgmental and macroeconomic forecasts are quite helpful. Nevertheless, the yield curve can usefully supplement large econometric models and other forecasts for three reasons. First, forecasting with the yield curve has the distinct advantage of being quick and simple. With a glance at the ten-year note and three-month bill rates on the computer screen, anyone can compute a probability forecast of recession almost instantaneously by using a table such as ours.

Second, a simple financial indicator such as the yield curve can be used to double-check both econometric and judgmental predictions by flagging a problem that might otherwise have gone unidentified. For example, if forecasts from an econometric model and the yield curve agree, confidence in the model’s results can be enhanced. In contrast, if the yield curve indicator gives a different signal, it may be worthwhile to review the assumptions and relationships that led to the prediction. Third, using the yield curve to forecast within the framework outlined here produces a probability of future recession, a probability that is of interest in its own right.

Notes

1. A list of references on this literature can be found in Estrella and Mishkin (1996).

2. The analyses in Estrella and Hardouvelis (1990, 1991) and Estrella and Mishkin (1995) suggest why the yield curve contains information beyond that related to monetary policy.

3. In Estrella and Mishkin (1996), we have examined in detail the predictive ability of these and other variables, including interest rates by themselves, other stock market indexes, interest rate spreads, monetary aggregates (both nominal and real), the component series of the index of leading economic indicators, and an additional experimental index of leading indicators developed in Stock and Watson (1992). Of all the variables, the four singled out in this article have the best ability to predict recessions.

4. For a technical discussion of this model and how it is estimated, see Estrella and Mishkin (1996). The economy is designated as “in recession” starting with the first quarter after a business cycle peak and continuing through the trough quarter. The peak and trough dates are the standard ones issued by the National Bureau of Economic Research (NBER) and used in most business cycle analysis. These dates are not without controversy, however, because the NBER methodology makes implicit assumptions in arriving at these dates.

5. Note that the forecasts in these panels are true out-of-sample results, obtained in the following way: First, a given model is estimated using past data up to a particular date, say the first quarter of 1970. Then these estimates are used to form the forecasts, say four quarters ahead. In this case, the projection would apply to the first quarter of 1971. After adding one more quarter to the estimation period, the procedure is repeated. That is, data up to the second quarter of 1970 are used to make a forecast for the second quarter of 1971. In this way, the procedure mimics what a forecaster would have predicted with the information available at any point in the past.

6. Note that all conclusions drawn from looking at the charts are confirmed by more precise statistical measures of out-of-sample fit in Estrella and Mishkin (1996).

7. These results have already been noted in very useful postmortem analyses by Watson (1991) and Stock and Watson (1992).

8. Another potential explanation is that the 1990-91 recession was relatively mild and so a weaker signal might be expected. However, as shown in Estrella and Hardouvelis (1991), the yield curve spread also provides much weaker signals for recessions in the 1950s, even though they were not mild. Furthermore, the signal for the 1969-70 recession is strong, although the recession itself was mild. Thus, the severity of the recessions does not seem to be associated with the strength of the signal from the yield curve.

References


About the Authors

Arturo Estrella is Vice President in the Capital Markets Function of the Research and Market Analysis Group. Frederic S. Mishkin is Executive Vice President and Director of Research for the Bank.

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