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Let's Twist Again: A High-Frequency Event-Study Analysis of Operation Twist and Its Implications for QE2

ABSTRACT This paper undertakes a modern event-study analysis of Operation Twist and uses its estimated effects to assess what should be expected for the recent policy of quantitative easing by the Federal Reserve, dubbed "QE2." The paper first shows that Operation Twist and QE2 are similar in magnitude. It then identifies six significant, discrete announcements in the course of Operation Twist that could have had a major effect on financial markets and shows that four did have statistically significant effects. The cumulative effect of these six announcements on longer-term Treasury yields is highly statistically significant but moderate, amounting to about 15 basis points (bp). This estimate is consistent both with time-series analysis undertaken not long after the event and with the lower end of empirical estimates of Treasury supply effects in the literature. The effects of Operation Twist on long-term agency and corporate bond yields are also statistically significant but smaller, about 13 bp for agency securities and 2 to 4 bp for corporates. Thus, the effects of Operation Twist seem to diminish substantially as one moves from Treasury securities toward private sector credit instruments.

On December 16, 2008, the Federal Reserve's Federal Open Market Committee (FOMC) lowered the target for the interest rate on federal funds to essentially zero in response to the most severe U.S. financial crisis since the Great Depression. Since U.S. currency carries an interest rate of zero, it is virtually impossible for the FOMC to target a value for the federal funds rate that is substantially below zero. Faced with this zero lower bound, the FOMC in 2008 and 2009 endeavored to find alternative ways to stimulate the weak economy, such as by purchasing large quantities of mortgage-backed securities and longer-term Treasury securities in

an effort to improve the functioning of those markets and reduce long-term interest rates.[1]

In late 2010, in response to continuing economic weakness and the zero lower bound, the FOMC embarked on a second round of quantitative policies, announcing its intention to purchase "a further $600 billion of longer-term Treasury securities by the end of the second quarter of 2011."[2] This program has become known in the financial community and the financial press as QE2.

The QE2 program has been controversial, with detractors conjecturing that the risks or costs of the policy are large while the benefits are small. For example, an open letter to Federal Reserve Chairman Ben Bernanke, signed by several prominent economists and published in full-page ads in the *Wall Street Journal* and the *New York Times,* asserted that the purchases "risk currency debasement and inflation" and could "distort financial markets"; the signatories said further, "we do not think they will achieve the Fed's objective of promoting employment" and that they are "neither warranted nor helpful in addressing either U.S. or global economic problems."[3]

The present paper aims to estimate the potential benefits of QE2 by measuring the effect on long-term interest rates of Operation Twist, a very similar program undertaken by the Kennedy administration and the Federal Reserve in 1961. Although previous studies of Operation Twist using low-frequency (quarterly) data have generally found no significant effect of the program on long-term interest rates (see, for example, the exhaustive time-series analysis by Franco Modigliani and Richard Sutch 1966, 1967), the present paper undertakes a more modern, high-frequency event-study approach. The event-study methodology restricts attention to major announcements in the course of Operation Twist that can be pinpointed to a single day. By focusing on changes in Treasury yields

1. On November 25, 2008, the FOMC announced that it would purchase $500 billion of mortgage-backed securities and $100 billion of debt directly issued by the housing-related government-sponsored enterprises (GSEs). On March 18, 2009, the FOMC announced that it would purchase an additional $750 billion of mortgage-backed securities, an additional $100 billion of GSE debt, and $300 billion of longer-term Treasury securities. FOMC statements and minutes are available on the Federal Reserve Board's public website.

2. FOMC statement, November 3, 2010, available on the Federal Reserve Board's public website.

3. "An Open Letter to Ben Bernanke," *Wall Street Journal,* November 16, 2010, p. A17 (advertisement). Also available at www.economics21.org/commentary/e21s-openletter-ben-bernanke.

in a narrow window of time surrounding each announcement, an event study holds other factors affecting the macroeconomic outlook constant, and thereby isolates the effects of the announcement itself on the yield curve. Lower-frequency time-series analyses must attempt to control for other factors affecting the yield curve directly, a procedure fraught with difficulties such as unobserved variables (financial market expectations of future interest rates and inflation), large residual errors, and endogeneity, as will be discussed in section II.

In contrast to Modigliani and Sutch, this paper finds that Operation Twist had a highly statistically significant effect on longer-term Treasury yields. However, consistent with Modigliani and Sutch's finding (1966, p. 196) that any effects of Operation Twist "are most unlikely to exceed some ten to twenty base points," this paper estimates that the size of these effects is moderate, with a cumulative effect on long-term Treasury yields of about 15 basis points (bp). This is also consistent with the lower end of Treasury supply effects estimated in the literature, discussed in section III. Finally, the paper examines to what extent the effects of Operation Twist spilled over to credit markets other than the Treasury market. It finds that long-term yields on government agency securities declined by almost as much as those on long-term Treasuries, but that long-term corporate bond yields declined by substantially less, only 2 to 4 bp. The paper presents evidence that this smaller effect is at least partly due to limited substitutability between corporate bonds and long-term Treasuries.

Operation Twist has several advantages over more recent episodes as a laboratory for estimating the likely effects of QE2. For example, estimates of the effects of the Federal Reserve's initial round of quantitative policies in 2008 and 2009—what some have called QE1—such as the studies by Joseph Gagnon and coauthors (2011) and Stefania D'Amico and Thomas King (2010), are subject to the concern that the 2008–09 financial crisis was a time of severe financial market disruption and low liquidity (see, for example, Gürkaynak and Wright 2011). The exceptionally poor functioning of financial markets during this period may have led Federal Reserve purchases to have an uncharacteristically large effect on markets. Thus, it is not clear that the effects of such purchases during QE1 are representative of the effects that one might expect in more normal times, such as the present environment in which QE2 is being conducted.

In addition, foreign governments have become increasingly large participants in the U.S. Treasury market over time: foreign official institutions now hold about $3.1 trillion of U.S. Treasury securities—about one-third of the market—of which about $2.6 trillion is held in longer-term Treasury

notes and bonds.[4] Foreign official purchases of U.S. Treasuries often vary by $100 billion or more over the course of just a few months, responding to largely exogenous factors such as domestic economic developments and exchange rate interventions (Warnock and Warnock 2009). Francis Warnock and Veronica Warnock (2009) estimate that these purchases have a large effect on Treasury yields, implying that studies of Treasury supply effects using data since the 1980s must control for variation in foreign official purchases. An advantage of the Operation Twist period is that foreign government involvement in the U.S. Treasury market was so small that it can safely be ignored.

The paper proceeds as follows. Section I provides the historical context for Operation Twist and shows the remarkable similarities between that program and QE2. Section II describes the event-study methodology and the data. The effects of Operation Twist on Treasury yields are analyzed in section III. Section IV compares these results with those of previous studies. Section V investigates to what extent the effects of Operation Twist spilled over to markets other than the Treasury market. Section VI concludes.

I. Operation Twist

John F. Kennedy was elected president of the United States in November 1960 and inaugurated on January 20, 1961. The economy had been in recession since April of 1960; the recession would end in February 1961, although economic activity would remain weak for several months into the recovery. The incoming administration wanted to stimulate the economy with easier monetary as well as fiscal policy, but European interest rates were already higher than U.S. rates, leading to substantial flows of dollars and gold to Europe under the Bretton Woods fixed exchange rate system. The Federal Reserve (and the Kennedy administration) were very reluctant to lower short-term interest rates any further for fear of worsening the U.S. balance of payments and increasing the outflows of gold.

The Kennedy administration's proposed solution to this dilemma was to try to lower longer-term interest rates while keeping shorter-term interest rates unchanged. The idea was that business investment and

4. Data are for October 2010 and come from the Treasury's monthly "Major Foreign Holders of U.S. Treasury Securities," available at www.treasury.gov/resource-center/data-chart-center/tic.

housing demand were primarily determined by longer-term interest rates, whereas the balance of payments and gold flows were determined by cross-country arbitrageurs who acted on the basis of short-term interest rate differentials.[5] If longer-term Treasury yields could be lowered without affecting short-term Treasury yields, the reasoning went, then investment could be stimulated without worsening the balance of payments and gold outflows.[6]

Thus, on February 2, 1961, Kennedy announced in a message to Congress a policy in which the Treasury and the Federal Reserve would cooperate to change the relative supplies of long-term and short-term Treasury securities in the open market. The Federal Reserve would maintain the current level of the federal funds rate but would buy longer-term Treasury securities to try to nudge longer-term interest rates lower.[7] The Treasury meanwhile would reduce its issuance of longer-term notes and bonds and instead issue primarily short-term securities.[8] At the time, this policy was referred to by Federal Reserve staff as "Operation Nudge," but in retrospect it has become known as "Operation Twist," in homage to the dance craze that swept the nation at about the same time (Meulendyke 1998, p. 39).

According to statistics from the Federal Reserve Bank of New York, the Federal Reserve ultimately purchased about $8.8 billion of longer-term bonds as part of Operation Twist.[9] Recent authors (for example, Gagnon and others 2011) have sometimes dismissed this program as being small, but in fact Operation Twist is comparable to QE2 relative to the size of the economy and the Treasury market. This is demonstrated in table 1,

5. The price of a Treasury bill is much less volatile than the price of a longer-term Treasury bond, making bills and other short-term debt a much more appealing vehicle for short-term arbitrage across currencies.

6. See "White House Sees Backing by FRB on Rate Policy," *Wall Street Journal,* February 3, 1961, p. 2, and "Kennedy Says FRB to Control Long-Term Rates," *Wall Street Journal,* February 9, 1961, p. 3.

7. Technically, the Federal Reserve in the late 1950s and early 1960s followed a policy of targeting the quantity of free reserves rather than the level of the federal funds rate (Friedman and Schwartz 1963, chapter 11). However, it was recognized that the federal funds rate varied inversely with the quantity of reserves, so for practical purposes this policy can be thought of as a loose federal funds rate target.

8. For additional details and discussion, see the *Wall Street Journal* articles cited in note 6.

9. Meulendyke (1998). Over the same period, the Federal Reserve reduced its holdings of short-term Treasury bills by $7.4 billion. For several years before Operation Twist, the Federal Reserve had subscribed to a "bills only" policy under which it bought no longer-term Treasury securities ("Reserve Is Buying Long Treasurys in Open Market in Policy Reversal," *Wall Street Journal,* February 21, 1961, p. 3.)

Table 1. Comparing Operation Twist and QE2
Billions of current dollars except where stated otherwise

	Operation Twist	*QE2*
Size of Federal Reserve program	8.8	600
GDP	528	14,871
Treasury marketable debt outstanding[a]	189.3	8,543
Agency debt outstanding[b]	7.4	6,379
Agency-guaranteed debt outstanding[c]	0.2	1,166
Size of Federal Reserve program		
As percent of GDP	1.7	4.0
As percent of Treasury debt outstanding	4.6	7.0
As percent of Treasury-guaranteed debt outstanding	4.5	3.7
Additional supporting program by Treasury?[d]	Yes	No

Sources: Meulendyke (1998), U.S. Treasury Bureau of the Public Debt, Federal Reserve Flow of Funds, and Bureau of Economic Analysis.

a. Includes nominal and inflation-indexed Treasury securities in the hands of the public and excludes nonmarketable securities issued to the Social Security Administration, state and local governments, and households (savings bonds).

b. Primarily securities issued by Fannie Mae and Freddie Mac, which were implicitly (and later explicitly) guaranteed by the Treasury.

c. Primarily mortgage-backed securities. In 2010Q1 about $4 trillion of mortgage-backed securities guaranteed by Fannie Mae and Freddie Mac were shifted directly onto the balance sheets of those agencies in the Flow of Funds. This reclassification does not affect the sum of U.S. agency debt and U.S. agency-guaranteed debt, but it has a large effect on the breakdown between these two categories.

d. During Operation Twist (but not QE2), the Treasury deliberately issued securities with shorter maturities than usual; the size of this shift is difficult to quantify but amounted to several billion dollars. See text for details.

which reports the nominal size of both programs along with nominal GDP and various measures of debt outstanding.

Although the debt of the U.S. agencies—the Federal National Mortgage Association (Fannie Mae), the Federal Home Loan Mortgage Corporation (Freddie Mac), the Federal Home Loan Banks, and a few smaller entities—was not officially backed by the full faith and credit of the U.S. government, these agencies had close historical ties to the government, and their securities were widely viewed as having an implicit government guarantee. (That view was confirmed in September 2008, when the U.S. government placed Fannie and Freddie into receivership and explicitly guaranteed their debt obligations.[10]) As a result, agency-issued and agency-backed securities have been, ex ante and ex post, close substitutes for U.S. Treasury securities.

10. The Treasury initially announced a capital injection into Fannie and Freddie of up to $100 billion each. This guarantee was later doubled to $200 billion each and then made unlimited in December 2009.

As can be seen from table 1, the Federal Reserve's purchases of long-term Treasury securities during Operation Twist were roughly comparable to QE2 in several respects. First, Operation Twist was about half as large as QE2 relative to GDP—smaller, but similar enough in magnitude to be informative. Second, if changes in the supply of long-term Treasuries have any effect on long-term Treasury yields, then the initial quantity of long-term Treasury securities in the market, rather than the size of GDP, should be the relevant initial condition. This observation suggests that the total Treasury market would be a better benchmark for the size of each program, and by this metric Operation Twist was closer in size to QE2. Third, to the extent that agency and agency-guaranteed debt are close substitutes for Treasury securities, the relevant market arguably includes all three of these Treasury-guaranteed classes of assets.[11] Relative to this market, Operation Twist was an even larger program than QE2.

Finally, a key feature of Operation Twist, emphasized by the Kennedy administration from the outset, was the joint participation by *both* the Federal Reserve and the Treasury. While the Federal Reserve was purchasing $8.8 billion of longer-term Treasuries in the open market, the Treasury was actively supporting this policy by concentrating its issuance of new debt at shorter rather than longer maturities, by an amount that totaled at least several billion dollars.[12] By contrast, QE2 has had no support from the Treasury (Hamilton and Wu forthcoming).[13] Taking into account the Treasury as well as the Federal Reserve contribution to

11. One could extend this argument to all triple-A-rated debt securities, or even to all debt securities, but at each successive step the similarity of state-contingent payoffs to those of Treasury securities diminishes. Table 1 draws a line for the scope of the market at agency and agency-backed debt, since the substitutability of these securities for Treasuries is much greater and their state-contingent payoffs are much more similar to those of Treasuries than is the case for other types of debt.

12. For example, the issuance announced by the Treasury on February 2 (table 2) totaled $6.9 billion. However, the Treasury's March 15 announcement revealed that its commitment to Operation Twist was only partial rather than full—see the discussion of that announcement in section II.B. Thus, it is difficult to come up with a more precise estimate of the size of the Treasury's participation in the program, other than that it amounted to several billion dollars.

13. In fact, during late 2010 and early 2011 the average duration of Treasury securities issued and outstanding both *increased,* directly counter to the goals of QE2 (Hamilton and Wu forthcoming). Thus, de facto, the effect of QE2 has been to partially offset the increase in supply of long-term securities coming from the Treasury. For purposes of this paper, the "effects of QE2" will refer to the effects of the policy relative to a benchmark in which there is no QE2 by the Federal Reserve—that is, taking the Treasury's increased issuance of long-term securities as given.

Operation Twist, then, the former program appears to have been substantially larger than QE2.[14]

Operation Twist and QE2 are very similar qualitatively as well as quantitatively. In both episodes the Federal Reserve was unable or unwilling to lower its target for the federal funds rate—in the case of QE2 because of the zero lower bound on short-term rates, and in the case of Operation Twist because of a fear of increasing gold outflows that were already viewed as unacceptably large. Thus, the goal of both programs was to lower longer-term Treasury yields without lowering the federal funds rate. The methods used to implement each program are also very similar: for Operation Twist, the Federal Reserve and the Treasury essentially sold short-term Treasury bills and purchased longer-term Treasury notes and bonds. To implement QE2, the Federal Reserve is financing purchases of longer-term Treasuries by issuing bank reserves. Bank reserves are short-term liabilities of the Federal Reserve rather than of the Treasury, but aside from this technical distinction, the implementation of the two policies, Operation Twist and QE2, is essentially identical.

In summary, Operation Twist and QE2 are much more similar than has generally been appreciated. Nevertheless, there are notable differences between the two programs. First, Operation Twist was strongly endorsed by the Kennedy administration as well as the Federal Reserve, whereas QE2 has been backed only by the latter. Kennedy's strong support for Operation Twist also may have been interpreted by financial markets as a signal that the future course of fiscal as well as monetary policy would be more aggressive than expected; moreover, it suggested cooperation between the Treasury and the Federal Reserve that may have boosted financial market expectations regarding the overall size and aggressiveness of the program. In addition, monetary policy in the 1960s was less transparent than it is today, so the Federal Reserve's explicit endorsement of Operation Twist (discussed in section II.B) was more extraordinary and may have sent a stronger signal to the markets regarding the Federal Reserve's view of the program's importance.

These observations suggest that the effects of Operation Twist may have been even larger than what one might expect for QE2. Other differences between Operation Twist and QE2 include several background factors,

14. It is sometimes argued that QE2 was an "open-ended" policy, that the initial $600 billion was expected to be only the first round, and thus that QE2 should be regarded as substantially larger than the initial figure would suggest. However, Operation Twist was also an open-ended policy, and it is not clear that it was expected to be any smaller than QE2, especially once the Treasury's participation in Operation Twist is taken into account.

such as the difference in exchange rate regimes (fixed then, floating today), the fact that today's financial markets are more globally integrated, and the substantially worse long-term government budget outlook today than in the 1960s. However, it is less clear whether these background factors would increase or decrease the expected effectiveness of Operation Twist relative to QE2.

II. Methods and Data

Given the similarities between Operation Twist and QE2, it seems reasonable to use the former program to estimate the likely effects of the latter. However, previous studies of Operation Twist using lower-frequency regression methods, such as the exhaustive analysis by Modigliani and Sutch (1966, 1967) using quarterly data, have generally found no statistically significant effects. This section reexamines the episode using a high-frequency event-study approach.

II.A. High-Frequency Event-Study Analysis

A high-frequency event-study analysis uses changes in financial markets within narrow windows of time around major, discrete announcements to measure the effects of those announcements. Under the hypothesis of rational expectations in financial markets, asset prices should completely incorporate all information from a public announcement shortly after the announcement is made. In particular, studying the 1- or 2-day change in Treasury yields around a major macroeconomic announcement should be sufficient to provide an unbiased estimate of the complete effect of that announcement on the yield curve. Charles Jones, Owen Lamont, and Robin Lumsdaine (1998) and Michael Fleming and Eli Remolona (1999) provide evidence supporting this hypothesis, with no evidence of either "momentum" or "backtracking" in yields in the days following such announcements.[15] Intuitively, it also seems reasonable that financial markets would not leave large profitable trading opportunities unexploited for more than a few hours, let alone 1 or 2 days, so long as the risks of those opportunities were not excessively large.

15. Although the finance literature has found evidence of over- or underreaction in some cases for small-capitalization stocks, such effects have not been documented for larger, more liquid markets such as the S&P 500 or the Treasury market. Indeed, Jones and others (1998) and Fleming and Remolona (1999) provide evidence to the contrary for the Treasury market.

There are several reasons to think that a high-frequency event-study analysis would be more powerful than lower-frequency time-series methods for detecting the effects of Operation Twist. First, longer-term Treasury yields are very sensitive to market expectations about macroeconomic variables such as inflation and the expected path of the federal funds rate. Unfortunately, these expectational variables can change quite dramatically from one quarter to the next and are unobserved by the econometrician, making them very difficult to incorporate into a regression framework.[16] A high-frequency event-study analysis holds the macroeconomic outlook essentially constant by considering changes in yields across a 1- or 2-day window surrounding the announcement, during which the macroeconomic outlook changes very little except for the possible effects of the announcement itself.[17]

Second, the effects of Operation Twist may have been relatively small, on the order of 10 or 20 basis points, which is no bigger than the quarterly standard deviation of long-term Treasury yields. Modigliani and Sutch's (1966) quarterly regression model has a residual standard error of 9.3 basis points, which they characterize as "remarkably low" (p. 190) relative to the rest of the literature. Given the size of this standard error, it might be impossible to find statistically significant effects of Operation Twist in a low-frequency regression model even if the model is correctly specified and the size of those effects is correctly estimated. By contrast, daily changes in long-term interest rates average about 2 basis points, so it is much easier to determine whether a major announcement regarding Operation Twist had a statistically significant impact on long-term bond yields that day.

Finally, there is an endogeneity problem with monthly or quarterly interest rate data that can make obtaining structural or causal estimates of the effects of Operation Twist difficult, if not impossible. This is similar to the problem of identifying the effects of a monetary policy shock in a vector autoregression, which requires an identifying assumption to disentangle the effects of changes in interest rates on the macroeconomy from the effects of changes in the macroeconomy on interest rates (see,

16. One can try to control for expectations to some extent by using survey data; however, survey data do not exist for the Operation Twist period.

17. Of course, this requires that no other major macroeconomic data surprises or announcements occur on the same day as the announcement in which one is interested. For each of the identified announcements below, this assumption is verified from the bond market commentary for that day.

for example, Christiano, Eichenbaum, and Evans 1999). Modigliani and Sutch (1966, 1967) estimated a reduced-form time-series model for long-term interest rates and then investigated to what extent changes in the relative supply of longer-term Treasury securities could explain the residuals of that reduced-form model. But if the Federal Reserve tended to step up its purchases of longer-term Treasuries whenever long-term interest rates started to rise—a plausible hypothesis—then Modigliani and Sutch's reduced-form approach will be biased toward finding no effect of Federal Reserve purchases on longer-term yields, or even the perverse effect that such purchases caused longer-term yields to *increase.* A high-frequency event-study analysis avoids this endogeneity problem as long as each major announcement being considered was not a response to changes in long-term interest rates *on that same day.*[18]

For all of these reasons, then, an event-study approach offers many advantages over—or at least a worthwhile alternative to—low-frequency time-series analysis for estimating the effects of Operation Twist.

II.B. Six Major Announcements

To perform an event-study analysis of Operation Twist, one must first identify major announcements that carried significant news about the program and whose release can be pinpointed to a single day or two. For this study the ProQuest Historical Newspapers database was searched for all articles in the *Wall Street Journal* in 1961 and early 1962 that mentioned the Federal Reserve or the Treasury.[19] This produced several hundred results. These articles and the *Wall Street Journal*'s weekly bond market recaps were quickly read through to identify episodes related to Operation Twist—that is, the objective of lowering longer-term interest rates. This narrowed the number of relevant articles down to a few dozen. Of these, six were identified that, rather than rehashing the goals and methods of the program, represented major new announcements in the development of Operation Twist. These six announcements are summarized in table 2.

18. For more discussion of this point and an application of high-frequency methods to identify the effects of monetary policy shocks in a vector autoregression, see Faust, Swanson, and Wright (2004).

19. Unfortunately, a search for the phrase "Operation Twist" over this period yields no results because the program did not come to be known by that name until a few years later. Also, the widely used LexisNexis database does not cover news articles before 1977.

Table 2. Significant Announcements Regarding Operation Twist

Announcement date	*Time*[a]	*Description*	*Event window*[b]	*Expected effect on long-term Treasury yields*
February 2, 1961 (Thursday)	"early Thursday"	President Kennedy announces goals and methods of Operation Twist, and says Federal Reserve and Treasury will both participate.	1 day (February 1–2)	Decrease
February 2, 1961 (Thursday)	"after the end of regular trading hours"	Treasury announces it will auction $6.9 billion of new debt at only the 18-month maturity, instead of longer maturities.	1 day (February 2–3)	Decrease
February 9, 1961 (Thursday)	Not reported[c]	Federal Reserve statistics are released showing that the Fed made a rare purchase of longer-term Treasury securities.	2 days (February 8–10)	Decrease
February 20, 1961 (Monday)	2:45 p.m., "too late for the investment community . . . to become heavily involved in the market"[c]	Federal Reserve releases rare public statement explicitly endorsing Operation Twist and announces a new policy of buying Treasury securities with maturities longer than 5 years.	2 days (February 17–21)	Decrease
March 15, 1961 (Wednesday)	After the market close	Treasury announces a "surprise" refunding using 5- and 6-year notes, longer maturities than expected; markets interpret this as a decrease in Treasury and Federal Reserve commitment to Operation Twist.	1 day (March 15–16)	Increase
April 6, 1961 (Thursday)	"after the market had closed"	Federal Reserve statistics are released showing a sharp increase in Fed buying of longer-dated Treasuries on the open market, including maturities longer than 10 years for the first time.	1 day (April 6–7)	Decrease

Sources: *New York Times* and *Wall Street Journal,* various issues.

a. Quotations are from the *Wall Street Journal,* February 6 (p. 16), February 3 (p. 18), and February 21 (p. 21), and the *New York Times,* April 7 (p. 46). See text footnotes 20, 26, and 33 for the full article citations.

b. Days are business days, beginning with the market close before the announcement and ending with the market close after the announcement.

c. The timing of the February 9 announcement is unclear from contemporary accounts, but it probably occurred late in the afternoon. The February 20 announcement occurred during market hours but late enough in the day that markets may not have fully incorporated the announcement into prices by the end of trading. In both these cases a 2-day event window was used. See text for details.

The first of these announcements is President Kennedy's introduction of the program on February 2, 1961. According to the *Wall Street Journal,* the announcement took place early in the day as part of an "economic message" to Congress, in which the president outlined the rationale, goals, and methods of Operation Twist and announced that the Federal Reserve would support the Treasury in its implementation.[20] According to bond market commentary in the *Wall Street Journal*, the announcement had a significant impact on bond markets and was the main driver of bond yields that day. Because the announcement occurred early in the day, leaving plenty of time for markets to respond, a 1-day event window, from the market close on February 1 to the market close on February 2, is used here to measure the effects on Treasury yields.

A few hours after the president's message, "after the end of regular trading hours," the Treasury declared that its upcoming refunding of $6.9 billion of Treasury debt would be concentrated entirely at the 18-month maturity, instead of longer maturities.[21] The announcement was obviously intended to bolster the president's introduction of Operation Twist earlier in the day, but the size and complete concentration of the refunding at shorter maturities may have been a surprise to financial markets and could have created additional follow-on effects on bond yields the next day. Because the announcement occurred after the close of trading on February 2, a 1-day event window, from the market close on February 2 to the market close on February 3, is again used to measure the effects.

Several days later, on February 9, the Federal Reserve released its weekly breakdown of Treasury security holdings by maturity for the week

20. This economic message should not be confused with the *Economic Report of the President* of that year, which was released by President Eisenhower on January 18. Kennedy's economic message announced and outlined Operation Twist, and the details were subsequently filled in by administration officials in conversations with reporters. Although the economic message contained other economic proposals, such as a temporary extension of unemployment benefits, many of these other proposals had been anticipated by Kennedy's January 30 State of the Union Address, executive orders, and speeches. Contemporary accounts in the *Wall Street Journal* focus almost entirely on Operation Twist, so there appears to have been little else in the message of comparable interest to financial markets. See "White House Sees Backing by FRB on Rate Policy," *Wall Street Journal,* February 3, 1961, p. 2; "Treasurys, Prime Corporates Advance as Trading Picks Up," *Wall Street Journal,* February 3, 1961, p. 18; and "The Bond Markets: Top-Grade Corporates, Treasurys Up in Week As Trading Increased," *Wall Street Journal,* February 6, 1961, p. 16. For the texts of Kennedy's economic message, State of the Union Address, and executive orders, see Woolley and Peters (2010).

21. The articles describing this announcement are the same as for the previous announcement. The quotation is from "Treasurys, Prime Corporates Advance as Trading Picks Up," *Wall Street Journal,* February 3, 1961, p. 18.

ended Wednesday, February 8. The report showed that the Federal Reserve had made a rare addition to its holdings of longer-term Treasury securities during the week, which was noteworthy because for the previous 10 years the Federal Reserve had followed a "bills-only" policy, purchasing only Treasury bills with 12 months or less to maturity, except in the event of a substantial disruption in longer-term Treasury markets.[22] Although the purchase was not particularly large and the average maturity of the purchased securities was not very long (just over 1 year), it was a clear departure from the bills-only policy and the first signal from the Federal Reserve (as opposed to the administration) that it was at least tentatively supporting Operation Twist.[23] The intraday timing of the February 9 statistical release is not reported by either the *Wall Street Journal* or the *New York Times,* but other such releases were typically made late in the day (see, for example, the April 6 announcement below). Since the timing of this release is unclear, a 2-day event window, from the market close on February 8 to the market close on February 10, is used to measure its impact.[24]

The Federal Reserve dramatically increased its commitment to Operation Twist a few days later, on February 20, 1961. That afternoon, the FOMC released what was in those days an extremely rare public statement, describing a change in its government bond-buying policy. The announcement read, in part,

> During recent years, transactions for the system account, except in correction of disorderly markets, have been made in short-term U.S. Government securities. Authority for transactions in securities of longer maturity has been granted by the open market committee of the Federal Reserve System in the light of conditions that have developed in the domestic economy and in the U.S. balance of payments with other countries.[25]

22. For more discussion of the Federal Reserve's bills-only policy, see "Reserve Is Buying Long Treasurys in Open Market in Policy Reversal," *Wall Street Journal,* February 21, 1961, p. 3.

23. For example, the *Wall Street Journal* ("Reserve Board Raises Long-Term Treasury Holdings," February 10, 1961, p. 6) reported that "the Kennedy Administration has been seeking the cooperation of the Federal Reserve Board to bring down long-term interest rates," but that "the Federal Reserve has not said whether it plans any change in its open-market operations to nudge long-term rates downward."

24. Given the timing of the April 6 announcement, it is very likely that the February 9 announcement also occurred after the market close. The 2-day window used here is on the conservative side, but using a 1-day window would make essentially no difference in the results (see table 3).

25. "Reserve Is Buying Long Treasurys in Open Market in Policy Reversal," *Wall Street Journal,* February 21, 1961, p. 3.

The release also explicitly extended the scope of Federal Reserve purchases of Treasury securities to maturities greater than 5 years.[26] The announcement was striking, both for the manner of its release and because of its clear endorsement of the goals and methods of Operation Twist. Any previous doubts about the degree to which the Federal Reserve was committed to the Kennedy administration's program would have been immediately dispelled with this announcement.

The Federal Reserve's statement was released at 2:45 p.m., reportedly "too late for the investment community at large to become heavily involved in the market."[27] Thus, a 2-day event window is used for this announcement, from the market close on Friday, February 17, to the market close on Tuesday, February 21.

The four announcements above each signaled an increasing degree of commitment by the Treasury or the Federal Reserve to Operation Twist. In contrast, a Treasury announcement on March 15, 1961, was perceived by financial markets as a *decreased* degree of commitment to the program. After the markets closed that afternoon, the Treasury announced an advance debt refunding operation, in which an offer is made to exchange soon-to-mature Treasury securities for newly issued, longer-maturity Treasuries.[28] The refunding itself was not so much a surprise as were the timing of the announcement (during Operation Twist) and the length of the debt maturities being offered in exchange (5 and 6 years). As reported by the *New York Times,* "Market circles had expected that the advance refunding device . . . would be used by the Treasury again, but not so soon, and especially not while the Federal Reserve System was engaged in a market operation . . .

26. "Reserve Is Buying Long Treasurys in Open Market in Policy Reversal," *Wall Street Journal,* February 21, 1961, p. 3, and "Long Treasurys Show Gains, Top-Quality Corporates Up a Bit," *Wall Street Journal,* February 21, 1961, p. 21. A few days later, on February 23, the Federal Reserve's weekly balance sheet report confirmed that it had purchased a significant quantity of such securities. However, these purchases were not a surprise given the February 20 statement ("FRB Last Week Bought Treasurys in 5–10 Year Range," *Wall Street Journal,* February 24, 1961, p. 6), and therefore the February 23 report is not included among the announcements in table 2.

27. "Long Treasurys Show Gains, Top-Quality Corporates Up a Bit," *Wall Street Journal,* February 21, 1961, p. 21. In the early 1960s, government securities trading desks typically closed at 3:30 p.m. Moreover, daily quotation sheets distributed to clients and newspapers typically were based on 2:30 p.m. price quotations, so it is unclear whether any effects of the Federal Reserve's 2:45 p.m. announcement are reflected in the market quotations for February 20. See Scott (1965, chapter 3) for more details.

28. Paul Heffernan, "Bonds: Treasury Bills Firm as Other Gilt-Edge Issues Show Declines," *New York Times,* March 16, 1961, p. 56.

aimed at reducing long-term interest rates."[29] According to the *Wall Street Journal,* "Some interpreted the advance refunding as indicating a change of thinking by the Treasury and the Federal Reserve System," in particular that it "may mean the monetary authorities, including the Federal Reserve, are satisfied with prices and rates prevailing in the bond market [and] may believe that business in general is on the road to recovery."[30] James Tobin, a member of Kennedy's Council of Economic Advisers in 1961, is said to have been "furious" with the Treasury for this announcement.[31] The expected effect of the announcement on long-term Treasury yields is thus opposite to the effects of the first four announcements. Because the announcement was made after the market close, a 1-day event window is used here to measure its effects, from the market close on March 15 to the market close on March 16.

The sixth and final major announcement regarding Operation Twist during 1961 and 1962 occurred on April 6, 1961, and again involves a weekly statistical release by the Federal Reserve. The release showed a substantial increase in the Federal Reserve's holdings of longer-term Treasury securities for the week ending Wednesday, April 5, and in particular its first purchase in many years of Treasury bonds with greater than 10 years to maturity. These purchases provided renewed confirmation of the Federal Reserve's commitment to Operation Twist and were reported as such by the press.[32] The statistical release occurred "after the market

29. Paul Heffernan, "Bonds: Prices for Most Issues Decline in Light Trading," *New York Times,* March 17, 1961, p. 48.

30. "Bond Markets: Treasurys Led Week's Drop; Top Corporates Fell as Much as ½-Point," *Wall Street Journal,* March 20, 1961, p. 20. The market's interpretation of Treasury's announcement was at least partly correct: Treasury staff had decided that *new* Treasury issuance would continue to focus on short maturities (consistent with Operation Twist) but that refundings of *outstanding* Treasury debt would continue to take place at long maturities (*Wall Street Journal,* "Treasury to Offer New 3 5/8%, 3 3/8% Bonds for Swap," March 16, 1961, p. 4). The thinking behind this policy, according to the *Journal,* was that holders of outstanding Treasury debt would roll their debt over anyway, so that issuing longer-term securities to these investors would not affect the spread between long- and short-term yields and thus would not interfere with Operation Twist. However, the market reaction to the Treasury announcement suggests that this policy may have been misguided and counterproductive. Thus, after the March 15 announcement, one could reasonably characterize the Treasury as being partially rather than fully committed to Operation Twist.

31. Richard N. Cooper, comment during the general discussion of this paper at the Brookings Papers conference. Cooper was a senior staff economist at the Council of Economic Advisers in 1961.

32. "Reserve System Steps Up Buying of Federal Issues," *Wall Street Journal,* April 7, 1961, p. 4, and "The Bond Markets: High-Grade Corporates Eased; Treasurys Were Mixed in Slow Week," *Wall Street Journal,* April 10, 1961, p. 17.

had closed,"[33] and so a 1-day event window is used for this announcement, from the market close on Thursday, April 6, to the market close on Friday, April 7.

For each of these six announcements, data on Treasury market closing prices were collected from the "Government Securities" column of the *Wall Street Journal* for the business days surrounding the announcement.[34] (Daily yield curve data are available in electronic format from the Federal Reserve Board and other sources only from 1962 onward.) For this study the focus was on collecting data for a wide range of maturities that accurately characterize the yield curve at both the short and the long ends; in particular, data were collected on Treasury securities with 3 months and 1, 2, 5, 10, and 30 years remaining to maturity. To reduce the influence of idiosyncratic changes in price for any single Treasury security on the results, the average yield to maturity of the three Treasury securities closest to the target maturity was computed for each maturity listed above.[35]

II.C. Hypothesis Tests

The null hypothesis for this analysis is that Operation Twist announcements had no effect on Treasury yields at any maturity. Under the alternative hypothesis, there are two main channels through which the announcements in table 2 might have affected yields. First, there is the direct effect of changes in the expected supply of long-term Treasuries on yields: A reduction in the net supply—through either a decrease in Treasury issuance or an increase in Federal Reserve purchases—should cause long-term Treasury yields to

33. Paul Heffernan, "Bonds: U.S. Issues Score Their First Good Gain in a Month," *New York Times,* April 7, 1961, p. 46.

34. These reported yields come from quotation sheets distributed by Treasury market dealers, which, as discussed above, were typically based on 2:30 p.m. price quotations; thus, they do not correspond exactly to the 3:30 p.m. closing prices in the market (Scott 1965). However, they would typically be very close to the closing prices and will be referred to here as closing prices for expositional convenience. Also, in a few cases (March 15–16 and April 7), data from the *Wall Street Journal* were unavailable or illegible, in which case Treasury yields for the same securities as reported by the *New York Times* were used.

35. Callable bonds (which are quoted with a range of maturity dates spanning several years) were excluded from the analysis to ensure that the maturities of all bonds are accurately measured and that the price is free from any implicit option premia associated with callability. At the 5-year maturity, there were only two noncallable securities with close to 5 years remaining to maturity, so those two rather than three securities were used to measure yields at that maturity.

fall.[36] In addition, the announcements in table 2 may have been interpreted by financial markets as signals about the future course of monetary or fiscal policy. For example, markets may have interpreted announcements by the Federal Reserve that it was supporting Operation Twist as a signal that the federal funds rate also would be held at its then low level for a greater length of time.[37] Similarly, Kennedy's announcement of Operation Twist may have signaled that the new administration would be more aggressive and imaginative than expected with respect to stimulating the economy, which may have led to increased expectations of fiscal stimulus.

In contrast to Treasury supply effects, the response of long-term Treasury yields to the signals described above does not have a clear sign prediction. For example, increased expectations of fiscal stimulus would tend to cause longer-term interest rates to rise, while expectations of easier monetary policy could conceivably cause longer-term nominal interest rates to either rise or fall. However, given the Federal Reserve and the administration's stated commitment to lowering long-term Treasury yields, the net effect of Operation Twist announcements, under the alternative hypothesis, should be to cause longer-term Treasury yields to decrease. A similar line of reasoning implies that announcements relating to Operation Twist, under the alternative hypothesis, should cause *short*-term Treasury yields to increase or stay the same.[38] Short-term interest rates should not fall, because the Federal Reserve and the administration were committed to preventing such a decline out of concern about gold outflows.

36. This sign prediction follows from the assumption of a downward-sloping demand curve for long-term Treasuries: as the available quantity decreases, the equilibrium price should increase and the yield to maturity should fall. Greenwood and Vayanos (2008) and Vayanos and Vila (2009) provide a formal model with preferred-habitat investors and risk-averse arbitrageurs that implies a downward-sloping demand curve for Treasury securities of each maturity. Note that this modeling framework is arbitrage-free, so that the alternative hypothesis does not require an assumption of irrational expectations or arbitrage opportunities.

37. As discussed in note 7, the Federal Reserve targeted a measure of reserves rather than the federal funds rate during this period, but for practical purposes and expositional convenience this policy can be thought of as a loose federal funds rate target.

38. President Kennedy and the Treasury gave no indication that the total quantity of Treasury issuance would change under Operation Twist, only its composition. Thus, the Treasury's issuance of *short*-term securities would have to increase, which would push short-term Treasury yields upward under the alternative. Signals about the future course of fiscal policy would also tend to push yields upward, although this might be offset to some extent by signals about easier monetary policy in the future. However, even under the alternative hypothesis, short-term Treasury yields could remain unchanged if the Federal Reserve maintained a constant target for the federal funds rate, since those yields are closely linked to the funds rate.

To estimate the effects of Operation Twist, one would ideally like to have data on financial market expectations regarding the net supply of long-term bonds and the paths of fiscal and monetary policy both before and after each announcement in table 2, in order to measure the change in market expectations attributable to each announcement. Unfortunately, no such data exist. Nevertheless, one can test the null hypothesis by measuring the change in yields across each announcement and determining whether and to what extent the change is statistically significant—that is, how large it is relative to the unconditional standard deviation of Treasury yields—and whether it is in the direction predicted by the alternative hypothesis. If the announcements consistently lead to significant effects in the predicted direction, one would reject the null hypothesis and turn to the question of estimating the total size of the effects of Operation Twist.

Finally, note that five of the six announcements in table 2 represent a perceived increase in the commitment of the Kennedy administration, the Treasury, or the Federal Reserve to Operation Twist. Each of these five announcements thus should have led to a decrease in long-term Treasury yields under the alternative. By contrast, the March 15 announcement was seen as a decrease in the commitment of the Treasury (and perhaps also of the Federal Reserve) to the program and thus should have led to an increase in long-term Treasury yields.

III. The Response of Treasury Yields to Operation Twist

The results of the event-study analysis described above are summarized in table 3. The top panel reports Treasury yields at the market close on each day of every event window in the sample. The second panel reports the change in Treasury yields across the event window for each announcement. The bottom panel reports the unconditional standard deviation of Treasury yield changes over 1- and 2-day windows as benchmarks for comparison.[39]

The statistical significance of each Treasury yield response in the table is assessed relative to the unconditional standard deviation for the same maturity and window size in the bottom panel. Statistical significance for

39. The 6- and 8-day changes are discussed below. Unconditional standard deviations are computed for 1962 rather than 1961 for two reasons: First, daily data on Treasury yields are available from the Federal Reserve Board beginning on January 2, 1962, but not before. Second, ideally one would compute an unconditional standard deviation that is not unduly influenced by Operation Twist itself, and 1962 largely postdates the Operation Twist period. The unconditional standard deviations of Treasury yield changes in 1963 and in 1964 are less than in 1962, so our measure of standard deviation here is conservatively large.

Table 3. Treasury Yields and Estimated Impacts on Yields around Operation Twist Announcements

	Maturity					
Date or change in yield	*3-month*	*1-year*	*2-year*	*5-year*	*10-year*	*30-year*
Treasury yields around announcement dates (percent per year)[a]						
February 1 (Wednesday)	2.263	2.787	3.05	3.565	3.783	3.90
February 2 (Thursday)	2.273	2.78	3.007	3.53	3.747	3.86
February 2 (Thursday)	2.273	2.78	3.007	3.53	3.747	3.86
February 3 (Friday)	2.272	2.81	3.043	3.51	3.713	3.845
February 8 (Wednesday)	2.327	2.81	3.077	3.51	3.753	3.84
February 9 (Thursday)	2.327	2.827	3.077	3.51	3.753	3.835
February 10 (Friday)	2.355	2.85	3.097	3.52	3.743	3.83
February 17 (Friday)	2.387	2.827	3.037	3.49	3.73	3.795
February 20 (Monday)	2.422	2.833	3.023	3.47	3.713	3.795
February 21 (Tuesday)	2.497	2.887	3.01	3.40	3.65	3.735
March 15 (Wednesday)	2.353	2.805	2.947	3.395	3.69	3.795
March 16 (Thursday)	2.328	2.77	2.937	3.48	3.723	3.81
April 6 (Thursday)	2.283	2.858	2.993	3.445	3.733	3.82
April 7 (Friday)	2.282	2.808	2.98	3.435	3.73	3.805

Estimated responses to announcements (basis points)[b]						
1-day change, February 1–2	1	–0.7	–4.3*	–3.5*	–3.7**	–4***
1-day change, February 2–3	–0.2	3	3.7	–2	–3.3*	–1.5
2-day change, February 8–10	2.8	4	2	1	–1	–1
2-day change, February 17–21	11***	6*	–2.7	–9***	–8***	–6***
1-day change, March 15–16	–2.5	–3.5*	–1	8.5***	3.3*	1.5
1-day change, April 6–7	–0.2	–5**	–1.3	–1	–0.3	–1.5
Cumulative, first four announcements[c]	14.7***	12.3**	–1.3	–13.5***	–16***	–12.5***
Cumulative, all six announcements	12*	3.8	–3.7	–6	–13***	–12.5***
Unconditional standard deviation of Treasury yield changes, 1962 (basis points)[d]						
1-day changes	2.14	1.99	2.25	1.93	1.73	1.15
2-day changes	3.18	3.08	3.50	2.95	2.58	1.67
6-day changes	5.41	5.19	5.88	4.99	4.39	2.87
8-day changes	6.20	5.90	6.68	5.68	5.02	3.30

Sources: *Wall Street Journal* and *New York Times,* various issues; Federal Reserve Board; author's calculations.

a. Average yield to maturity of the three noncallable Treasury securities with remaining maturity closest to that indicated. The choice of a 1- or a 2-day event window is based on the timing of each announcement, as reported in table 2.

b. Asterisks indicate statistical significance for two-sided *t* tests at the *10 percent, **5 percent, and ***1 percent level. Significance for the 1- and 2-day changes is relative to the unconditional standard deviations of 1- and 2-day changes (bottom panel); significance for the cumulative changes is relative to the 6- and 8-day changes.

c. Captures the initial effects of Operation Twist, since the fifth announcement was seen by markets as a policy reversal (see table 2).

d. Data for 1962 are used because of data availability and to prevent the effects of Operation Twist itself from affecting the measured standard deviations.

a *two*-sided *t* test is reported, even though the alternative hypothesis provides clear sign predictions for the shortest and longest maturities; this is done both to minimize confusion (since the one-sided tests go in opposite directions for short and long maturities and have no clear sign prediction at the intermediate, 2-year maturity) and to avoid the appearance of overstating the significance of the results in the table. The discussion of statistical significance in the text will also refer to two-sided *t* tests by default and will explicitly discuss the results of a one-sided *t* test only when they are interesting.

Of the six announcements in table 3, the Federal Reserve's endorsement of Operation Twist on February 20 shows the most remarkable effect. Treasury yields with 5 or more years to maturity fell by 6 to 9 bp; this effect is highly statistically significant, with *t* statistics in excess of 3. But what makes these movements even more striking is the response of 3-month and 1-year Treasury yields, which simultaneously *rose* by 11 and 6 bp, respectively, with the former statistically significant at the 1 percent level and the latter at the 5 percent level for a one-sided test in the direction of the alternative. The Wald statistic for the joint movement of all six Treasury yields during this 2-day window is 53.5, corresponding to a *p* value of less than 10^{-9}. Moreover, the yield curve response is completely consistent with the alternative hypothesis and thus raises serious questions about the validity of the null.

President Kennedy's introduction of Operation Twist on February 2 is almost as interesting. Longer-term yields fell by about 4 bp that day, while short-term yields were about unchanged. The 10- and 30-year yield responses are significant at the 5 percent level or better, and the 5-year yield response is significant at the 5 percent level for a one-sided test in the direction of the alternative. The Wald statistic for the joint change in yields is 16.6, with a *p* value of 1.1 percent, and the change is in the direction predicted by the alternative.

The response to the Treasury's announcement after the market close on February 2 is not as strong as for the Federal Reserve's and the president's announcements just discussed; nevertheless, the changes in the 10-, 30-, and 1-year Treasury yields are all statistically significant at the 10 percent level or better for one-sided tests in the directions predicted by the alternative (downward for the 10- and 30-year yields, upward for the 1-year yield). The Wald statistic for the joint change in yields is 28.6, even larger than for Kennedy's announcement, because of the stronger upward "twist" at the 1- and 2-year maturities, a more unusual pattern. The *p* value for this move is less than 10^{-4}, and it is again in the direction predicted by the alternative.

The Treasury's surprise refunding announcement on March 15 is the one announcement in the sample that was perceived as a decrease in the government's commitment to Operation Twist. Thus, the alternative hypothesis predicts that long-term interest rates should have increased in response to that announcement. In fact, this is what the data show, particularly at the 5-year maturity, which was precisely the maturity at which the Treasury announced that the new supply would be forthcoming. Yields for that maturity rose by 8.5 bp, with a t statistic of more than 4, but the increases at the 10- and 30-year maturities are also statistically significant at the 5 and 10 percent levels, respectively, for a one-sided test in the direction of the alternative. At the same time, short-term yields twisted downward by 2.5 to 3.5 bp, and the response of the 1-year yield is significant at the 5 percent level for a one-sided test. The Wald statistic for the joint movement of yields is 73.5, with a p value of less than 10^{-13}, and this movement is in the direction predicted by the alternative.

Finally, the Federal Reserve's statistical releases on February 9 and April 6 seem to have had little effect on the bond market. Although a statistically significant drop in the 1-year yield is observed around the April 6 announcement, that response is not in the direction predicted by the alternative, so it would not be significant for a one-sided test. The Wald statistic for the February 9 announcement is 5.0, with a p value of 55 percent, and the Wald statistic for April 6 is 10.9, with a p value of 9.2 percent.

Given the size and statistical significance of these responses to individual announcements, it is natural to investigate the size and significance of the effect of Operation Twist as a whole, which this paper does in two ways. The first is to look at the cumulative effect of the first four announcements in the sample, each of which represented an increase in Treasury or Federal Reserve commitment to Operation Twist. Taken together, these first four announcements provide a reasonable estimate of the initial effects of Operation Twist on the yield curve: not only is each of these announcements in the same direction, but they all occur within a period of 3 weeks during which essentially no other news regarding Operation Twist was released. As a result, one can have a high degree of confidence that these first four announcements capture essentially *all* of the information regarding Operation Twist that was released within the first 3 weeks of the program. One can interpret this cumulative effect as the *initial* effect of Operation Twist or what the total effect *could have been* with no future policy reversals or mixed signals.

The second way of investigating the overall effect of Operation Twist is by looking at the cumulative effect of all six of the announcements in the sample. Here, the interpretation is less clear-cut: For example, the

fifth announcement, on March 15, reversed some of the initial effects of the program. In addition, more time elapsed between the fourth and fifth, and fifth and sixth announcements, and after the sixth announcement, than between earlier announcements; as a result, there is more time for incremental information about Operation Twist to come to light, such as the weekly breakdown of Treasury holdings released by the Federal Reserve, periodic issuance and refunding announcements by the Treasury, and the actual quantities of securities purchased and issued by the Federal Reserve and the Treasury. Nevertheless, summing up the effects of the six announcements in the sample gives an estimate of the *total* effects of Operation Twist, inclusive of the effects of policy reversals.

These cumulative changes are reported in the third panel of table 3. The statistical significance of the cumulative changes is assessed by comparing them with the unconditional standard deviations of yields over a correspondingly sized 6- or 8-day window, reported in the bottom panel.[40] As the table shows, the cumulative change in yields after the first four announcements is highly statistically significant and in the direction predicted by the alternative. The Wald statistic for the joint yield curve response is 61.3, with a p value of less than 10^{-10}. The cumulative effect, however, is moderate, amounting to no more than about 15 bp even at the longest and the shortest maturities.

The cumulative effect of all six announcements is somewhat smaller and is statistically significant only at the longest and the shortest maturities (10 years, 30 years, and 3 months), although the t statistics for the long maturities remain close to 3, and the 3-month response is significant at the 5 percent level in the direction of the alternative. The Wald statistic for the joint response is 30.2, with a p value of less than 10^{-4}. The total effect on the longest and the shortest maturities appears to have been about 12 to 13 bp.

Thus, even though this analysis finds a highly statistically significant cumulative effect of Operation Twist on longer-term Treasury yields, one could argue that, at 15 basis points, the effect is not very important economically. Indeed, Modigliani and Sutch (1966, p. 196) argued, "Any effects, direct or indirect, of Operation Twist in narrowing the spread which further study might establish, are most unlikely to exceed some ten to twenty base

40. These 6-day and 8-day standard deviations are computed as $\sqrt{2sd_1^2 + 2sd_2^2}$ and $\sqrt{4sd_1^2 + 2sd_2^2}$, respectively, where sd_1 and sd_2 denote the standard deviations of 1- and 2-day changes.

points—a reduction that can be considered moderate at best." However, it should be noted that a 15-bp decline in the 10-year Treasury yield would be a typical response to a 100-bp surprise cut in the federal funds rate target (Gürkaynak, Sack, and Swanson, 2005). Such a change would usually be regarded as a nonnegligible easing of financial market conditions.[41]

Whether a reduction of 15 bp in long-term interest rates is economically significant or not may ultimately lie in the eye of the beholder. Nevertheless, it is reassuring that the effects in table 3 are consistent with Modigliani and Sutch's findings. As discussed above, the standard error of those authors' quarterly regression specification is over 9 bp, too large for the effects in table 3 to show up with any statistical significance in their analysis.

IV. Comparisons with Other Studies

Although the consistency of our results with Modigliani and Sutch's (1966, 1967) extensive analysis is reassuring, the literature contains a number of more recent studies of the effects of changes in the supply of Treasury securities and the announcement effects of such changes. For the purpose of comparability across studies, each estimate discussed in what follows is normalized in terms of its predicted effect for QE2, that is, the effect that an announcement of a $600 billion reduction in the supply of longer-term Treasury securities would have on longer-term Treasury yields.[42] As discussed in section I, Operation Twist and QE2 can be seen as roughly similar in size, so that the effect predicted by the present paper for QE2 would be about 15 bp.[43]

Gagnon and others (2011) study the Federal Reserve's purchases of longer-term Treasury and mortgage-backed securities between 2008 and mid-2009—what has been referred to as QE1. Using both high-frequency

41. However, a 100-bp cut in the federal funds rate would also typically imply large declines in short-term rates, whereas the effect of Operation Twist on short- and medium-term rates was zero or even positive. Thus, the effect of Operation Twist on the macroeconomy should not be thought of as equivalent to a 100-bp cut in the funds rate.

42. Some of the studies focus only on changes in the supply of Treasury securities, whereas others (particularly the event studies) implicitly include signaling effects as well as direct effects of changes in Treasury supply. In each case I simply scale the study's coefficient estimate to correspond to a change in Treasury supply of $600 billion. If the study in question excluded signaling effects, then the scaled-up estimate reported below also excludes signaling effects.

43. Implicit in this comparison is an assumption that any signaling effects of QE2 regarding fiscal and monetary policy are also roughly similar in size to any signals that markets inferred from Operation Twist.

event-study methods and a lower-frequency (monthly) time-series analysis, Gagnon and his coauthors estimate that QE1 had an effect on the 10-year Treasury yield of about 91 bp using their event-study methodology, and 52 bp according to their monthly time-series regressions. Since the $1.7 trillion QE1 program was roughly three times the size of QE2, this would imply an effect of QE2 on the 10-year Treasury yield of about 17 to 30 bp. The estimates in this paper are consistent with the very bottom of this range. To the extent that this represents a discrepancy, it may be due to the fact that QE1 took place during a period of severe disruption and very low liquidity in financial markets (see, for example, Gürkaynak and Wright 2011), an environment in which those markets may have been more segmented and supply effects may have been correspondingly more potent.[44]

D'Amico and King (2010) estimate the effects of Federal Reserve purchases of Treasury securities during QE1 using a panel dataset containing the quantity, maturity, date of purchase, and CUSIP of each Treasury security purchased by the Federal Reserve throughout the program. Using differences in the cross section of Treasury bond prices to estimate the effect of the Federal Reserve's purchases on Treasury yields, they estimate that, overall, the effect of the $300 billion Treasury component of QE1 on the 10-year Treasury yield was about 50 bp. Scaling this up to the size of QE2 implies an effect on the 10-year Treasury yield of about 100 bp, far larger than the effect estimated in this paper. Like those of Gagnon and others (2011), D'Amico and King's (2010) larger estimates may be due to greater market segmentation during the QE1 period, which would have made it easier for the Federal Reserve to move yields in any given market segment. Nevertheless, their estimates are substantially larger than the Federal Reserve's apparent experience during Operation Twist.

James Hamilton and Jing Wu (forthcoming) relate Treasury supply effects to an affine term structure model using a preferred-habitat framework developed by Dimitri Vayanos and Jean-Luc Vila (2009). Hamilton and Wu estimate that $400 billion of Treasury purchases by the Federal Reserve, focused on 2½- to 10-year maturities as in QE2, would decrease the 10-year Treasury yield by about 11 bp. Scaled up to the size of QE2 and Operation Twist, this would imply an effect of about 17 bp, consistent with the present paper.

44. It is also possible that financial markets interpreted QE1 as a signal that the Federal Reserve would do what was necessary to prevent a complete financial collapse; in that case the signaling effects of QE1 would have been greater than those of QE2 or Operation Twist. However, the sign of this effect is not clear—for example, such a signal could have *increased* Treasury yields by reducing the demand for default-free assets.

Robin Greenwood and Vayanos (2008) regress the monthly Treasury yield spread—the difference between long-term and short-term Treasury yields—on measures of the long-term (10+ years to maturity) share of Treasury debt outstanding. They estimate that a 1 percent increase in the long-term share of Treasury debt increases the 20-year Treasury yield by 7.7 bp. Scaled up to the size of Operation Twist and QE2, this would seem to imply an effect of those programs of about 36 and 54 bp, respectively (using the numbers in table 1). However, most of the Federal Reserve's purchases of Treasury securities during Operation Twist and QE2 were concentrated at intermediate maturities (less than 10 years), and only a small fraction (about one-fourth) took place at maturities of 10 years or more. When this difference is taken into account, Greenwood and Vayanos's estimates would imply an effect of those programs of roughly 9 to 14 bp, consistent with the findings of this paper.

Arvind Krishnamurthy and Annette Vissing-Jorgensen (2007) measure the effect of total Treasury supply on the overall level of Treasury yields relative to yields on triple-A-rated corporate bonds. They estimate that an increase in the total quantity of Treasuries outstanding equal to 1 percent of GDP raises Treasury yields overall by about 1.5 to 4.25 bp. This estimated effect is of the same order of magnitude as in the present paper (QE2 is about 4 percent of GDP), but the two estimates are nevertheless not directly comparable, because Krishnamurthy and Vissing-Jorgensen's analysis focuses on the total quantity of Treasury debt outstanding, whereas Operation Twist and QE2 involved no change in total Treasury debt, only a change in the relative supply of shorter- versus longer-maturity Treasury securities.

Warnock and Warnock (2009) estimate the effect of foreign official purchases of U.S. Treasury securities on Treasury yields. The idea is that purchases of Treasury securities by, for example, the Bank of China or the Bank of Japan are made primarily for exogenous reasons relating to the domestic economy or exchange rate interventions and thus represent exogenous changes in the net supply of Treasuries to the private sector. They estimate that a decrease in the supply of Treasury securities of about 1 percent of U.S. GDP reduces the 10-year Treasury yield by about 19 bp. Scaling this up to the size of Operation Twist and QE2 would imply reductions in longer-term Treasury yields of roughly 32 and 76 bp, respectively, substantially larger than the effect estimated by Krishnamurthy and Vissing-Jorgensen (2010). Again, Warnock and Warnock's estimates are not directly comparable to those of the present paper, since Operation Twist and QE2 changed only the composition, not the total quantity, of Treasury debt outstanding.

It is reassuring that several of the studies cited above, using completely different methods and a variety of samples, arrive at estimates of the effects of QE2 that are in line with those of this paper. A potential concern with the event-study methodology in general is that it restricts attention to only those newsworthy announcements that can be pinpointed to an exact date. If much of the news regarding Operation Twist was released incrementally, in between and after the six major announcements in table 2, then estimates of the cumulative effect of the six discrete announcements might miss much of the true cumulative effect of Operation Twist. The studies by Hamilton and Wu (forthcoming) and Greenwood and Vayanos (2008) do not suffer from this criticism, and so their findings provide some evidence that the six major announcements analyzed here may indeed have captured a large majority of the information and effects of the program.

V. The Response of Agency and Corporate Yields to Operation Twist

The previous section showed that Operation Twist had highly statistically significant but economically moderate effects on Treasury yields. The results in Krishnamurthy and Vissing-Jorgensen (2010, 2011) suggest that these effects may not pass through completely to yields on debt instruments other than Treasuries, so this section investigates to what extent the effects of Operation Twist spilled over to interest rates more generally.

V.A. Agency and Corporate Yield Results

Table 4 reports the behavior of short- and long-term agency and corporate borrowing rates around the six Operation Twist announcements identified above.

The first four columns of table 4 report yields on government-sponsored agency securities around each of the same announcements as in tables 2 and 3.[45] The next three columns report commercial paper yields, which are short-term borrowing rates available to large corporations. The next two columns report interest rates on long-term corporate borrowing as measured by Moody's corporate bond indexes. The final two columns report the corresponding 1- and 10-year Treasury yields as benchmarks for comparison.

45. The Federal Land Bank system was a large issuer of government agency bonds in the first half of the twentieth century, with more securities outstanding in 1961 than even Fannie Mae. Together, Fannie Mae and Federal Land Bank notes dominated the government agency listings in the *Wall Street Journal* and the *New York Times.*

The event windows in the top panel of table 4 are 1 day longer than those in table 3, for two reasons.[46] First, there is some evidence that the (less liquid) agency and corporate securities considered here may respond with a longer lag than do the Treasury securities in table 3. The strongest evidence appears after the Federal Reserve's announcement late on February 20, for which Treasury yields seem to respond on February 21 and not on February 23 (the next trading day after Washington's Birthday), whereas agency and commercial paper yields show little response on February 21 but a great deal of movement on February 23. The same effect is visible for agency yields around other announcement dates as well.[47]

The second reason to consider longer event windows in table 4 is pragmatic: because the response of corporate yields to Operation Twist announcements as found below is generally small, those markets are given the benefit of the doubt and allowed more time to respond to each announcement. The longer event windows considered in table 4 increase the size and statistical significance of the agency and corporate yield responses to Operation Twist; using the shorter event windows of table 3 would lead to estimates of even smaller and less statistically significant effects for these yields. (The response of Treasury yields over these longer event windows is very similar to that over the shorter windows, as can be seen by comparing the last columns of table 4 with the corresponding columns in table 3.)

The second panel of table 4 reports the changes in agency, commercial paper, and corporate bond yields across the event window for each announcement. The statistical significance of each response is measured relative to the unconditional standard deviation of the corresponding yield over similarly sized windows in 1962, reported in the bottom panel.[48]

Of the six announcements, the one that stands out the most in this analysis is the Federal Reserve's explicit endorsement of Operation Twist on

46. A 1-day event window is again used for the first announcement because a longer window would overlap with the second announcement and lead to double counting.

47. Krishnamurthy and Vissing-Jorgensen (2011) also find that more than 1 day is needed for the effects of announcements during QE1 and QE2 to become evident in less liquid securities markets such as those for agency and corporate bonds.

48. For commercial paper, Moody's bond indexes, and Treasuries, 1-, 2-, and 3-day standard deviations were computed directly from daily data. The 9- and 13-day standard deviations were then computed as $\sqrt{sd_1^2 + sd_2^2 + 2sd_3^2}$ and $\sqrt{sd_1^2 + 3sd_2^2 + 2sd_3^2}$, respectively. For agencies, weekly data on yields in late 1961 and 1962 were collected from the *Wall Street Journal,* the 5-day standard deviation (sd_5) was computed directly from the weekly data, and then the n-day standard deviations sd_n were set as $sd_n = \sqrt{n sd_5^2 / 5}$.

Table 4. Agency and Corporate Yields and Estimated Impacts on Yieldsaround Operation Twist Announcements

	Type of debt and maturity										
	Agency debt[a]				*Commercial paper*[b]			*Corporate bonds (Moody's indexes)*[c]		*Memorandum: Treasury debt*	
Date or change in yield	*1-year*	*2-year*	*5-year*	*10-year*	*1-month*	*3-month*	*6-month*	*Aaa*	*Baa*	*1-year*	*10-year*
Yields around announcement dates (percent per year)[d]											
February 1 (Wednesday)	2.84	3.163	3.703	4.07	2.375	2.625	2.75	4.31	5.09	2.787	3.783
February 2 (Thursday)	2.837	3.157	3.703	4.07	2.375	2.625	2.75	4.30	5.10	2.78	3.747
February 2 (Thursday)	2.837	3.157	3.703	4.07	2.375	2.625	2.75	4.30	5.10	2.78	3.747
February 3 (Friday)	2.787	3.157	3.703	4.06	2.375	2.625	2.75	4.29	5.08	2.81	3.713
February 6 (Monday)	2.813	3.193	3.67	4.027	2.375	2.625	2.75	4.29	5.08	2.82	3.723
February 8 (Wednesday)	2.827	3.187	3.673	4.013	2.375	2.625	2.75	4.28	5.07	2.81	3.753
February 9 (Thursday)	2.823	3.187	3.673	4.007	2.375	2.625	2.75	4.28	5.07	2.827	3.753
February 10 (Friday)	2.88	3.207	3.673	4.007	2.375	2.625	2.75	4.28	5.06	2.85	3.743
February 14 (Tuesday)	2.91	3.167	3.683	4.00	2.375	2.625	2.75	4.28	5.08	2.84	3.743
February 17 (Friday)	2.913	3.187	3.667	3.987	2.375	2.625	2.75	4.26	5.07	2.827	3.73
February 20 (Monday)	2.913	3.187	3.667	3.977	2.375	2.625	2.75	4.25	5.06	2.833	3.713
February 21 (Tuesday)	2.907	3.177	3.667	3.967	2.375	2.625	2.75	4.25	5.06	2.887	3.65
February 23 (Thursday)	2.897	3.16	3.597	3.90	2.5	2.75	2.75	4.24	5.05	2.883	3.643
March 15 (Wednesday)	2.90	3.09	3.547	3.86	2.625	2.75	2.75	4.21	5.02	2.805	3.69
March 16 (Thursday)	2.903	3.09	3.547	3.86	2.625	2.75	2.75	4.21	5.02	2.77	3.723
March 17 (Friday)	2.877	3.07	3.58	3.86	2.625	2.75	2.75	4.21	5.02	2.76	3.733
April 6 (Thursday)	2.887	3.13	3.78	3.967	2.25	2.625	2.625	4.23	5.01	2.858	3.733
April 7 (Friday)	2.857	3.13	3.79	3.993	2.25	2.625	2.625	4.23	5.00	2.808	3.73
April 10 (Monday)	2.863	3.123	3.787	3.977	2.25	2.625	2.625	4.23	5.00	2.823	3.747

Estimated responses to announcements (basis points)[e]											
1-day change, February 1–2	–0.3	–0.7	0	0	0	0	0	–1*	1	–0.7	–3.7**
2-day change, February 2–6	–2.3	3.7	–3.3	–4.3**	0	0	0	–1	–2**	4	–2.3
3-day change, February 8–14	8.3*	–2	1	–1.3	0	0	0	0	1	3	–1
3-day change, February 17–23	–1.7	–2.7	–7**	–8.7***	12.5	12.5**	0	–2**	–2*	5.7	–8.7***
2-day change, March 15–17	–2.3	–2	3.3	0	0	0	0	0	0	–4.5	4.3*
2-day change, April 6–10	–2.3	–0.7	0.7	1	0	0	0	0	–1	–3.5	1.3
Cumulative, first four announcements[f]	4	–1.7	–9.3	–14.3***	12.5	12.5	0	–4**	–2	12*	–15.7***
Cumulative, all six announcements	–0.7	–4.3	–5.3	–13.3**	12.5	12.5	0	–4**	–3	4	–10
Unconditional standard deviation of yield changes, 1962 (basis points)[g]											
1-day changes	2.15	2.19	2.01	1.52	4.44	3.63	5.00	0.56	0.62	1.99	1.73
2-day changes	3.04	3.10	2.84	2.15	6.28	5.14	7.07	0.72	0.87	3.08	2.58
3-day changes	3.72	3.80	3.48	2.64	7.69	5.90	8.65	0.90	1.05	4.17	3.31
9-day changes	6.44	6.58	6.03	4.57	13.32	10.45	14.99	1.56	1.83	6.94	5.62
13-day changes	7.74	7.91	7.25	5.49	16.01	12.73	18.01	1.87	2.21	8.20	6.70

Sources: *Wall Street Journal,* various issues; Federal Reserve H15 report, various issues; *Moody's Bond Survey,* various issues; author's calculations.

a. Averages of the three Fannie Mae and Federal Land Bank bonds with remaining maturity closest to that indicated in the column heading.

b. Yield on commercial paper directly placed by financial institutions.

c. Daily index values published in *Moody's Bond Survey;* each index includes about 30 corporate bonds with remaining maturity of 10 to 30 years.

d. Event windows are 1 day longer than in table 3 because the securities analyzed here appear to take longer than Treasuries to respond to news. Bond markets were closed on February 13 and 22, 1961, in observance of Lincoln's Birthday and Washington's Birthday, respectively.

e. Asterisks indicate statistical significance at the *10 percent, **5 percent, and ***1 percent level. Significance for the 1-, 2-, and 3-day changes is relative to the corresponding unconditional standard deviations of 1-, 2-, and 3-day changes (bottom panel); significance for the cumulative changes is relative to the 9- and 13-day changes.

f. Captures the initial effects of Operation Twist, since the fifth announcement was seen by markets as a policy reversal (see table 2).

g. Data for 1962 are used because of data availability and to prevent the effects of Operation Twist itself from affecting the measured standard deviations.

February 20. Long-term agency, commercial paper, and corporate bond yields all responded substantially, and in most cases statistically significantly, to the announcement. The Treasury's refunding announcement on February 2 is also noteworthy, with moderately large and significant responses of 10-year agency bonds and Moody's Baa index (although part of the response may reflect a carryover from President Kennedy's announcement earlier that same day). The March 15 announcement is also interesting in that the response of the 5-year agency yield is moderate (3.3 bp) and in the same direction as the 5-year Treasury yield, although not statistically significant. (Recall that the Treasury's refunding announcement had an outsized effect on yields at precisely the 5-year maturity, at which the new issuance was concentrated.) The Moody's corporate bond indexes, which refer to bonds with 10 to 30 years remaining to maturity and thus differ substantially from the new issues announced by the Treasury, show no response to the March 15 announcement.

The third panel of table 4 estimates the total effect of Operation Twist on agency and corporate yields by summing over their responses to the first four and all six announcements, as was done in the third panel of table 3. The cumulative response of 10-year agency yields is highly statistically significant and moderate, about 13 to 14 bp, similar to the roughly 15-bp cumulative response of long-term Treasuries. This suggests that Operation Twist had substantial spillovers from Treasury to agency yields at the longest maturities. However, the cumulative response of 5-year agency yields to either the first four or all six announcements is not statistically significant and, at 5 to 9 bp, is more muted than that of the 5-year Treasury yield in table 3. There is also little evidence of pass-through of Operation Twist to 1-year agency yields (and the cumulative responses of 2-year agencies and Treasuries are both insignificant).

The cumulative response of commercial paper yields in table 4 is likewise not significant, and those yields do not respond to any of the six announcements in the table except that of February 20. To some extent this may reflect the fact that the commercial paper yields in the sample were expressed only in increments of ⅛ percentage point, which is such a coarse resolution that any announcement effects could be difficult to observe. The cumulative effect of Operation Twist on 1- and 3-month commercial paper yields is of roughly the same magnitude as the effect on short-term Treasury yields—about 12 bp—but is not statistically significant, because of the much larger standard deviation of changes in commercial paper yields.

In contrast to the data on commercial paper yields during this period, Moody's corporate bond indexes are calculated to the nearest basis point

and have small standard deviations, and the underlying bonds have 10 to 30 years remaining to maturity, precisely matching the region of the Treasury yield curve that responded the most to Operation Twist. Nevertheless, the response of corporate bonds to Operation Twist appears to have been quite modest, no more than 1 or 2 bp in response to any single announcement, and no more than 2 to 4 bp cumulatively (although many of these responses are statistically significant). The 4-bp cumulative response of Aaa-rated corporate bonds to Operation Twist is both larger and more significant than the response of the Baa-rated bonds, consistent with the former being closer substitutes for long-term Treasuries. But even the 4-bp fall in Aaa bond yields is far less than the 13- to 14-bp drop in agency yields.

V.B. Discussion of Agency and Corporate Yield Responses

The observation that corporate bonds responded less to Operation Twist than did agencies and Treasuries is in line with a similar finding by Krishnamurthy and Vissing-Jorgensen (2011) for QE2 and has two main interpretations. First, it could be that the Moody's Aaa and Baa corporate bond indexes are simply very slow to respond to news and require even more than 2 days to respond to each of the Operation Twist announcements. For example, if many of the individual bonds in the Moody's index were illiquid, and the bond indexes themselves were based on transaction prices, it could have taken the indexes several days to fully respond to news, the precise delay depending on the liquidity of the underlying bonds. Alternatively, one could argue that the purchases of long-term Treasury securities in Operation Twist primarily affected long-term Treasury yields and spilled over to other markets only to the extent that the securities in those markets are substitutes for long-term Treasuries. If corporate bonds are not very good substitutes for long-term Treasuries, the spillovers from Operation Twist to even the highest-quality corporate bond markets could have been quite small.

There are a few reasons to be suspicious of an explanation that relies entirely on illiquidity. First, bond yield quotations in the newspapers and in *Moody's Bond Survey* are not transaction prices but rather are based on the bid and offer prices of dealers who make a market for each type of bond (for example, the quoted yield is often the midpoint between bid and offer). Thus, even if no transactions for a particular bond take place, one should still see the quoted yield respond to news as the dealers' bid and offer prices respond. One would think that 2 days would be a sufficiently long time for dealers to adjust their stated bids and offers.

Second, if the Moody's indexes were slow to respond to news, one would expect daily changes in those bond indexes to be positively serially

correlated. In fact, the serial correlations of daily changes in Moody's Aaa and Baa indexes in 1962 are low, –0.09 and –0.06, respectively, and are not statistically significant, which is inconsistent with the view that those indexes systematically responded sluggishly to news.[49]

Third, Krishnamurthy and Vissing-Jorgensen (2011) observe the same phenomenon for QE2 that this paper finds for Operation Twist. To the extent that U.S. corporate bond markets have become deeper and more liquid over time, one would expect Moody's corporate bond indexes to behave more like agency and Treasury yields during QE2. In fact, Gagnon and others (2011) find that corporate bonds did respond by an amount closer to agencies and Treasuries during QE1.[50] Thus, the fact that Krishnamurthy and Vissing-Jorgensen's estimates for QE2 agree with those in the present paper suggests that low corporate bond liquidity is not by itself a sufficient explanation.

In contrast, the hypothesis that Operation Twist (and QE2) had smaller effects on securities that were less substitutable for long-term Treasuries can potentially explain all of the results both in the present paper and in Krishnamurthy and Vissing-Jorgensen's. Long-term Treasury yields responded the most to the program. Yields on long-term agency debt, which is very similar to long-term Treasury debt in many respects, also seem to have responded substantially. Aaa corporate bonds responded less, and Baa bonds even less than Aaa bonds.

Under this interpretation, QE1 could have had a larger impact on corporate yields than did QE2 or Operation Twist, for two main reasons. First, almost $1.3 trillion of the assets purchased in QE1 were mortgage-backed securities rather than Treasuries; since the market for these securities is more similar to private sector borrowing markets, those markets may have experienced larger effects during QE1 simply because the securities traded in them were closer substitutes for the securities actually being purchased. Second, QE1 took place during a time of severe financial and economic stress, and the program may have been perceived by markets as substantially diminishing the probability of a second Great Depression, which could have been associated with widespread defaults by Baa- and even Aaa-rated

49. The serial correlation of Treasury yield changes was also about zero in 1962. The lower standard deviation of Moody's indexes relative to Treasuries does not necessarily imply that the yields diverge over time. In 1962 both Treasury yields and Moody's indexes declined by about 20 bp, so the average daily yield change was about the same, but the volatility of the Moody's indexes around that average was lower.

50. Gagnon and others (2011) find a cumulative response of 10-year Treasuries of 91 bp to their five baseline QE1 events; 10-year agency yields fell 156 bp, and Moody's corporate Baa index fell 67 bp.

corporations. If the markets viewed QE1 as markedly reducing the probability of investment-grade corporate bond defaults, then one would expect to see corporate bond yields fall more sharply than otherwise.

This is not to say that low liquidity is necessarily unrelated to the small estimated response of corporate bond yields to Operation Twist. The unconditional standard deviation of those bond indexes in 1962 was surprisingly small, and their standard deviation has steadily increased relative to that of the 10-year Treasury yield over time.[51] But the evidence presented above suggests that some features of the data are not well explained by liquidity alone. Meanwhile, the fact that Baa- and even Aaa-rated corporate bonds are imperfect substitutes for Treasuries is consistent with all of the observations in this paper.

VI. Conclusions

For more than forty years, the conventional wisdom regarding Operation Twist has been driven by the results of low-frequency time-series studies, particularly Modigliani and Sutch (1966, 1967). However, these lower-frequency methods have inherent problems, such as unobserved expectational variables, large standard errors, and in particular the possibility of endogeneity if the Federal Reserve increased its purchases of longer-term Treasury securities in response to upward pressure on longer-term interest rates.

The present paper has reexamined Operation Twist using a modern, high-frequency event-study approach, which avoids the problems with lower-frequency methods just mentioned. In contrast to Modigliani and Sutch, this paper finds that Operation Twist had a highly statistically significant impact on longer-term Treasury yields. However, consistent with those authors' results, the paper also finds that the effect was moderate in size, amounting to about 15 basis points. This estimate is also consistent with the lower end of the range of estimates of Treasury supply effects in the literature.

Operation Twist appears to have had diminishing effects as one moves from long-term Treasuries toward private sector credit instruments. To some extent this may reflect a slower response of non-Treasury securities to

51. In 1962 the daily standard deviation of the Aaa and Baa indexes was about one-third the daily standard deviation of the 10-year Treasury yield (table 4). In 1986, the first year for which Moody's daily data are available electronically, the relative standard deviation was 0.5. By the late 1990s it had risen to 0.8, and by the late 2000s it was up to 1.0.

Operation Twist announcements, perhaps in part because of lower liquidity, but low liquidity alone seems insufficient to explain all the features of the data. Part of the difference in responses may simply reflect the fact that purchases of Treasuries have the greatest effect on the Treasury market itself and affect other markets only to the extent that the securities in those markets are substitutes for Treasuries.

Because Operation Twist and QE2 are similar in many important respects, it seems reasonable to expect the effects of QE2 to be similar to those of Operation Twist, reducing longer-term Treasury yields by about 15 bp and Aaa- and Baa-rated corporate bonds by only a few basis points. Thus, if the goal of quantitative programs such as QE2 is to reduce interest rates for private sector borrowers, purchases of Treasury securities may not be the most effective means of attaining that goal. Instead, purchases of mortgage-backed securities, or other securities more similar to private sector credit instruments, may reduce private sector borrowing rates more substantially and ultimately have a greater effect on macroeconomic variables.

Finally, the benefits of these programs in terms of lower interest rates must be weighed against their costs when assessing their overall desirability. Although this paper has not attempted to estimate the costs of Operation Twist or QE2, those costs are as important as the benefits for policy analysis, and thus future work on the nature and size of such costs would be welcome.

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