Liquidity Effects in the Bond Market

Boyan Jovanovic and Peter L. Rousseau*

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Abstract

At monthly frequencies, a one standard deviation shock to the surprise component of T-bills raises short-term interest rates by three to five basis points. In the U.S. economy T-bill supply risk now matters as much as price-level risk in determining the real return on bonds. On the other hand, the return on T-bills seems to be unrelated to the return on stocks. We explain these patterns in a model of an economy in which stocks and bonds trade in separate markets.

1 Introduction

Liquidity effects of money injections have been hard to find in the U.S. data. There seems no common view on how strong they are and, indeed, whether they are there at all. What one can infer from the way that money, interest rates and other variables move at high frequencies hinges on what we think the Fed is trying to accomplish, and which variables enter into its decision rule. In contrast, we show that it is easy to find liquidity effects of bond injections, that they are substantial, and that they have been with us for as long as we have the data to measure them.

From the earliest days of the Federal Reserve, ex-post real returns on marketable U.S. Treasury securities have been subject to two sources of risk. First, since Treasury securities are nominal assets, their real returns are uncertain if the future level of prices is unpredictable. Second, and less obvious, however, is that the real return on bonds is risky if the supply of securities that will end up in the hands of the public is uncertain. The Fed injects this uncertainty through its actions both in the primary market, where it acts as the Treasury’s agent in the regular Dutch (i.e., single-price) auctions for marketable government securities, and in secondary markets,

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where it conducts open market operations. Supply uncertainty in the auction phase also has immediate effects on action-price results and on the quantities that will become available in subsequent auctions. In this paper, we describe and quantify supply risk, and suggest that this little-studied source of risk has become increasingly important as Fed policy has rendered the price level more and more predictable.

When the Fed conducts open market operations, it either makes more bonds available to the public through a sale, or contracts the bond supply with a purchase. A sale makes bonds cheaper and lowers the resale value of all bonds, which in turn affects the returns of those who purchased bonds previously and need to sell them. Those who hold older bonds until maturity do so at high opportunity cost. Conversely, an open market purchase makes bonds more expensive and raises the resale value of all bonds, thus imparting a positive shock to the returns of existing bond holders. If these operations are fully anticipated, they will have less impact on resale values as the market will have factored these expectations into current prices by substituting away from other assets in the case of an upcoming bond sale, or toward them when faced with an upcoming bond-purchase. Thus, it is the unanticipated component of open market operations that should matter the most for holding period yields.

The lessons from the data that we highlight are the following:

1. *Surprise sales of T-bills raise real rates*: An unanticipated (month-to-month) shock in the supply of T-bills and Treasury securities has always had a large positive effect on the ex-post real returns earned by these instruments. Further, the relative importance of supply shocks has risen over the past eighty years to now exceed that of price level risk.

2. *Bond-supply risk and stock prices*: Overall, T-bill rates are negatively correlated with stock-returns, but this relationship has never been strong and appears to have broken down in the three decades immediately following the Second World War.

3. *The decline of Treasury finance*: The supply of T-bills has decreased steadily over time, but this has been neutral in its effect on asset prices, including bond prices. This confirms the notion that foreseen supply shifts will be accommodated by adjustments of agents in other assets markets. Over the postwar period the share of bonds in the market portfolio has declined, yet real bond prices, though also trending downward, have not fallen nearly as much.

4. *Lessons for policy*: As the Federal debt continues its decline, it is harder to expand T-bill issues to meet large rollover demands from foreign sources. As long as the Fed uses the secondary market for T-bills to conduct its open market operations, supply-risk will persist. If the decline in outstanding Treasury securities indeed does continue, a rise in the use of other debt instruments for open market operations will reduce the supply-risk for the group of short term
assets as a whole and will, thereby, enable Treasury securities to remain what they have been thus far – highly liquid and yet nominally riskless.

The next section discusses some details about how T-bills are sold and how open market operations work. Section 3 examines empirically the effect of bond-supply risk on bond rates, and section 4 documents its effect on stock returns. Section 5 introduces a segmented markets model that explains some of the facts, and sections 6, 7, and 8 carry out some tests of the model. Section 9 briefly concludes, and some technical details are in the appendices.

2 What is bond-supply risk?

Bond-supply risk arises when agents are to some extent committed to trade in bonds before they know the price at which they can execute the trade. Such risk arises because asset markets are incomplete and, in the sense of Grossman and Weiss (1983), segmented. Some agents and some fraction of their resources are ready to trade in the bond market and this exposes them to risk that comes from randomness in the supply of bonds. Agents who seek to buy bonds are lucky when a bond-supply shock is positive because bond prices are lower than expected and the rate of return is higher than expected. These agents get a good deal, and any real consequences of this shock are distributional because the shock has favored one subset of agents at the expense of others. The fact that non-competitive bids at T-bill auctions, which are currently limited to $1 million per account, have accounted for only 10.4 percent of total auction sales since July 1998 suggests that the market is indeed segmented, with the remainder going to large banks and financial institutions.  

To participate in the first place, large financial institutions must have some liquid assets to commit to the new-issue and secondary markets. Primary dealers, who make competitive bids due to their direct interaction with the New York Fed in the conduct of its open market operations, pay for their winning bids when bills are issued on the Thursday following the Monday auctions. Secondary dealers and their customers presumably pay for bonds acquired from primary dealers upon delivery, though the bonds trade actively prior to their issue in a “when-issued” market. Non-competitive tenders are paid for up-front by noon of the auction day. Even though many bidders can thus delay payment until issue, they must be ready to purchase their entire bid if won, and, in the event of an unsuccessful bid, must act quickly to reinvest liquid assets that had been set aside. A closer look at how these markets work shows how the winning bid prices and quantities can become quite uncertain.

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1We compute this figure as the average share of accepted non-competitive bids in the total face value of T-bills sold at each weekly auction of 13-week and 26-week T-bills from July 30, 1998 through April 5, 2001. Press releases of auction results are available at the Bureau of the Public Debt’s web site http://www.publicdebt.treas.gov.

2Non-competitive bidders who specify a bank account for direct debit through the Treasury Direct investment plan also do not pay for their bills until the issue date.
By “supply risk” we shall, for some purposes, mean “residual-supply risk.” This is because a large chunk of demand for T-bills comes from the decisions of the Fed regarding whether or not to roll over their substantial and various holdings of government securities, and these rollover decisions affect the residual supply that will become available to the remaining traders either at the current auction or subsequent ones. Thus, supply risk arises at the auction stage even though the Treasury announces the number of T-bills that it intends to issue. When the Fed makes these rollovers, either for its own account or as an agent for foreign financial institutions and international monetary authorities, it does so at the single auction price as a non-competitive bidder. As noted above, individuals also bid non-competitively, but the quantities of such bids are restricted and thus more predictable. When the Fed executes rollovers for foreign institutions, these securities become unavailable to the public. Since the public knows only the maturing quantity and not the rollover plans, randomness in these plans, from the perspective of the dealer, directly generates uncertainty about the final auction price. The securities that the Fed rolls over for itself do not count against the total offered to the public in that week’s auction, but will affect the size of subsequent auctions. For example, if the Fed rolls over only half of the bills that it could have, to maintain a constant debt level the Treasury would need to arrange a larger issue for the next week.

The Treasury has changed its normal procedures twice recently with regard to foreign rollovers, and the nature of these changes suggest that it also may be aware of supply risk. As late as early 1999, auction announcements specified that the Treasury could, at its discretion, issue additional amounts for foreign accounts whenever the total of new bids from these sources exceeded their total holdings of maturing bills. Beginning with the March 29, 1999 T-bill auctions, however, the Treasury often placed an explicit limit of $3 billion on the amount of foreign rollovers that would be counted against the public’s total, agreeing to make additional issues automatically if rollover bids were to exceed this amount. This practice became more prevalent in 1999. The change signalled a more accommodative stance by the Treasury that would have reduced residual supply risk by limiting the degree to which unexpected non-competitive rollovers could affect the final auction price. As of February 1, 2001, the Treasury has allowed only $1 billion in foreign rollovers to count against the total public offering, and there is no longer a provision for increasing the issue if the limit is exceeded. This implies that foreign institutions must now compete for the issues

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3Before November 1998, marketable Treasury securities were auctioned in a discriminatory fashion, with the highest bidders receiving their full allocations at the tendered price subject to a maximum of 35 percent of the total quantity auctioned (the “35 percent rule” is still in effect). Non-competitive bidders received their full allocations at prices based upon the weighted average of accepted competitive bids. Supply risk is present even in the Dutch auction, as Fed actions will affect the final auction price in either the discriminatory or Dutch auction. It remains uncertain, however, how changes in bidding behavior caused by the new auction system has affected the terms on which the Federal government can raise funds.

4Foreign bids are now limited to $200 million per account, with the largest bids receiving the
as any other secondary dealer might. Even though this change might ameliorate disturbances that would impede the systematic paying down of the Federal debt, it is also likely to have an adverse effect on residual supply risk.

Cammack (1991, p. 110) reports that the Fed bought 43 percent of all T-bills that were sold at auction between 1973 and 1984. By examining the press releases of auction results, we have found that this portion has risen to 44.8 percent since mid-1998. The risk associated with rollover decisions exceeds the spread in the distribution of bids and it also exceeds the time-series variation of the winning bids, because the losing bidders (of which there are more either now or subsequently when the Fed absorbs its limit) must end up holding cash or a lower-return substitute.

3 Bond-supply risk and interest rates

The next order of business is to quantify the variability in bond supplies. Figure 1 shows the standard deviation of the monthly growth rates of the monetary base, T-bills and T-notes, and all marketable Treasury securities (T-secs), including bills, notes, long-term bonds, and certificates of indebtedness. All quantities are expressed in real per capita terms, and the Treasury quantities reflect securities that are outstanding and in the hands of the public (i.e., excluding the Fed’s holdings). The standard deviations were computed using a 12-month rolling window, and all three series were HP filtered prior to plotting.

The striking feature of Figure 1 is the high month-to-month variability of Treasury instruments in the hands of the public. This variability was particularly high in the early 1940’s due to large issues of securities of all maturities to finance the Second World War. Since T-bills and T-notes had not been used much before 1930, their increased issue in the midst of the Depression and retirement in the late 1930’s, which was followed by another round of even sharper issues and retirements between 1942 and 1947, account for the particularly large rolling standard deviations that we observe over these years. It is also striking that the variability of the supply of T-secs is much larger than that of the monetary base itself, which suggests that a considerable portion of what we call supply risk may be aimed at stabilizing money growth.

5 The quantities of outstanding marketable Treasury securities used in this study are end of month observations from individual issues of the Annual Report of the Secretary of the Treasury for 1920-31, the Federal Reserve Board’s Banking and Monetary Statistics (1976b, pp. 509-11; 1976a, pp. 868-73) for 1932-70, and individual issues of the Treasury Department’s Monthly Statement of the Public Debt of the United States thereafter. To compute the quantity in the hands of the public we subtract the Fed’s holdings from Banking and Monetary Statistics (1976b, pp. 485-7; 1976a, p. 343) for 1932-70, and from individual issues of the Federal Reserve Bulletin for 1920-31 and 1971-99. The monetary base from is from the FRED database of the Federal Reserve Bank of St. Louis for 1934-2000, with M1 from Friedman and Schwartz (1970, Table 1, pp. 4-58) ratio spliced to the M0 aggregate for 1920-33.
Figure 1: Rolling standard deviations of monthly growth rates of real per capita supplies of Treasury securities and the narrow money, 1920-99.

Having quantified the variability in bond supplies, we now ask how much of this variability is unforeseen and how much supply risk affects the real return on T-bills. One way to judge this is by comparing supply risk to the better-understood price-level risk. Because the Fed’s policies have shifted over time, we shall compare the two kinds of risk first for the entire period 1920-99, and then for three of its subperiods. The size of the effect should depend not so much on how volatile the supply of bonds is but, rather, on the volatility of their surprise component. We now outline the method we use, and later we shall elaborate on the details and define variables as we discuss each case. We estimate separately two equations

\[ r_t = a_0 + a_1 \Delta \ln x_t^e + a_2 \Delta \ln x_t^u \]  
and

\[ r_t = b_0 + b_1 \Delta \ln P_t^e + a_2 \Delta \ln P_t^u \]

where \( r_t \) is a real rate of return, \( \Delta \ln x_t^e \) is the expected growth of bonds, and \( \Delta \ln x_t^u \) is the surprise component in their growth. Similarly, \( \Delta \ln P_t^e \) is expected inflation, and \( \Delta \ln P_t^u \) is the inflation surprise. The two expected growth rates and the two surprises are obtained from a vector autoregression of variable length (as we shall later explain) that included bond-quantities, \( x \), the price-level, \( P \), and \( r \) itself.
Should we expect the Fisher equation logic to hold in (2) and some similar argument to hold for (1) so that $a_1$ and $b_1$ should both equal zero? In other words, should expected shifts in $x$ and $P$ leave $r$ unaffected, and should only surprises in $x$ and in $P$ matter? This is what we would expect in these monthly data if we were dealing with one-month T-bills. We deal, however, with annualized real interest rates on three-month T-bills on the one hand, and with monthly series for $P$ and $x$ on the other, which means that the real rate of return on a T-bill with, say, two months remaining until maturity can and is affected by shifts in expected inflation. This is because at that point the T-bill is a month old, and an investor can not change the rate he locked in one month previously.

In contrast, only surprises in $x$ should affect $r$. Changes in $x$ can affect the rate on previously issued T-bills only if they were to change the realized price level during the remaining lifetime of the T-bills. Thus, $x^e_t$ could matter only if it is correlated with inflation during the remainder of the vintage T-bills’ lifetimes, and vintage T-bills have either one month or two months to go. It seems that this period is short enough that our estimates of $a_1$ do not end up being significantly different from zero for the period as a whole, but they do differ from zero in the two post-war periods. We now discuss the estimates in more detail.

3.1 Supply risk 1920-1999

Using monthly data from January 1920 through December 1999, Figure 2 shows the effects of one-standard deviation surprises in both the price level and the supply of marketable Treasury securities ($T$-secs) available to the public on the annualized ex-post real return on T-bills. Both sources of risk have always mattered, with price level risk at times quite large during the first 30 years of the sample, yet the relative importance of price-level risk has declined as prices have become more predictable. Now, about the same level of return risk appears to derive from each source.

The surprises in Figure 2 are one-step ahead forecast errors from a rolling 48-month tri-variate vector autoregression (VAR) with six lags. The three variables in the VAR are:

1. real per capita log levels of T-secs in the hands of the public,
2. the ex-post real interest rate on T-bills,\(^7\) and

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\(^6\)As we show in Section 5, the government’s maturity preferences have shifted considerably over time, but these shifts in themselves did not introduce risk in the total supply of securities available to the public. Thus, focusing on supply shocks to a single instrument such as T-bill quantities over eighty years of Fed history would necessarily analyze variations in a component of government finance that were not “shocks” but rather just a shifts in the relative use of a particular instrument. For this reason, we work primarily with the total of marketable Treasury securities, which include bills, notes and bonds.

\(^7\)The ex-post real rates are daily averages of nominal monthly rates on three-month (91 day)
Figure 2: Effects, in percentage points, of one standard deviation surprises in the price level and the supply of marketable T-secs on the ex-post annualized real return on T-bills, 1920-99.

3. log of the deflator for consumption of non-durable goods and services.\(^8\)

Since T-secs in the hands of the public are available at the start of each month while the consumption deflator, and population are computed as annualized monthly averages, we deflate Treasury securities at the start of month \(t\) with the average of the consumption deflator for month \(t-1\) and month \(t\), and convert to per capita terms using the average population across these same months. The monthly frequency of T-bills from which we subtract the monthly-compounded inflation rate given by the consumer price index over the next three months. Nominal secondary market interest rates on three-month T-bills are from the \textit{FRED} database of the Federal Reserve Bank of St. Louis for 1934-99 and \textit{Banking and Monetary Statistics} (1976a) for earlier years. The consumer price index is that for all urban consumers from \textit{FRED} for 1947-99, from the \textit{National Income and Product Accounts} of the Bureau of Economic Analysis for 1929-46.

\(^8\)We obtain monthly consumption of non-durables and services for 1959-99 from the \textit{FRED} database of the Federal Reserve Bank of St. Louis. Since this source includes real consumption in chained 1996 dollars from 1967 only, we obtain a deflator by dividing nominal consumption by real consumption for 1967-1999 and then by using the percentage changes in the consumer price index (CPI, also from \textit{FRED}) to interpolate between the quarterly estimates of the consumption deflator from the \textit{National Income and Product Accounts} (Table 1 quantities divided by Table 2B quantities) for earlier years.
the analysis is the highest possible due to the availability of data on government debt and Fed holdings thereof over the past eighty years. We seasonally adjust all three series in the VAR by OLS regression on monthly dummy variables and a sixth-order polynomial in time,\(^9\) and then compute the standard deviations of the forecast errors for the T-sec and price level equations using a rolling 12-month estimation window.

The VAR forecasts are then used to estimate the response of real T-bill returns to surprises to the supply of T-secs with the regression

\[
rt = .0003 + .0155 (\ln b_{t+1} - \ln x_t) + .0383 (\ln x_{t+1} - \ln b_{t+1}) + e_t
\]

where \(r_t\) is the ex-post real return on a three-month T-bill with term starting at time \(t\), \(\ln b_{t+1} - \ln x_t\) is the predicted growth in the T-bill supply, and \(\ln x_{t+1} - \ln b_{t+1}\) is the forecast error. T-statistics are in parentheses. It is interesting that only the forecast error, or surprise component of T-sec supply, has a statistically significant effect on ex-post real rates. Similarly, we compute the elasticity of the real T-bill return with respect to inflation surprises with the regression

\[
rt = .0017 - .5674 (\ln b_{t+1} - \ln p_t) - .4452 (\ln p_{t+1} - \ln b_{t+1}) + e_t,
\]

where \(\ln b_{t+1} - \ln p_t\) is predicted inflation in consumer non-durables and services, and \(\ln p_{t+1} - \ln b_{t+1}\) is the forecast error.

Finally, we multiply the coefficients on the surprises by the centered values of their rolling standard deviations to obtain the effects on the time series of monthly ex-post T-bill returns, and compound the result for 12 months to annualize. Figure 2, which shows these responses, does not span the full 1920-99 sample period due to the loss of observations needed to accommodate the lag length of the VARs, to construct the initial 48-month estimation window, and to compute the initial and final rolling standard deviations of the forecast errors.

### 3.2 The effect of supply risk in three subperiods

The method used to construct Figure 2 imposes potentially limiting homogeneity restrictions on both the monthly seasonal adjustment parameters for the underlying series and the elasticities of the interest rate responses to price and T-sec shocks over time. One way to examine the robustness of the figure to these restrictions is to compute the effects of price and supply risk over subperiods, deseasonalizing and computing return elasticities over only the subperiod of interest. We do this for 1920-46, 1947-79, and 1980-99, and display the results in Figures 3-5. We split the postwar

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\(^9\)Regressing on an adequately high-order polynomial in time reduces the degree to which the estimates of the monthly effects reflect cyclical and trend components. After substracting the coefficients on the monthly dummy variables from the raw series, we add the mean of the de-trended series back in to complete the seasonal adjustment. See Johnston (1984, pp. 234-9) for a clear exposition of this method along with its advantages and drawbacks.
period into pre-1980 and post-1979 segments because of the widely acknowledged shift in Fed targeting policy that occurred in 1979. To accommodate the shorter sample periods and as a robustness check, we limit the underlying VAR models to a 24-month rolling window with four lags. Tables 1A and 1B include the regression results for the analog of equations 1 and 2 for each subperiod.

Figure 3 reaffirms the importance of price risk in the pre-1947 period, and particularly in the years surrounding the trough of the Great Depression and those immediately following the end of the War. Supply risk rises at these same times and averages 0.9 percent over the 1920-46 period, but is always less important than price level risk, which averages nearly 2.3 percent. The narrower scaling of Figure 4 reflects the overall decline in price level risk that occurred from 1947-79, during which it averaged 0.95 percent. Even though supply risk also fell to 0.45 percent over this same period, the decline is considerably less than that observed for price level risk. Supply risk even exceeded price level risk a few times in the 1950’s. Figure 5, on the other hand, shows that supply risk has not changed much over the past 20 years, averaging 0.47 percent, and has regularly exceeded price level risk, which averaged only 0.35 percent. As such, supply risk has become the more important determinant of real holding period yields for investors in T-bills.
Figure 4: Effects, in percentage points, of one standard deviation surprises in the price level and the supply of marketable T-secs on the ex-post annualized real return on T-bills, 1947-79.

Table 1A–Dependent Variable: Ex-Post Real T-Bill Rate ($r_t$)

<table>
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<th>$x = \text{Marketable T-Seccs}$</th>
<th>$x = \text{T-Bills}$ &amp; Notes</th>
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<td>constant</td>
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<td>(1.34)</td>
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<td>(1.28)</td>
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<td>$\ln x_{t+1} - \ln b_{t+1}$</td>
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<td>(4.52)</td>
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<tr>
<td>$N$</td>
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Note: The table presents coefficient estimates for Eq. 3 in the text over the subperiods included in Figs. 1-5, with T-statistics in parentheses.
Figure 5: Effects, in percentage points, of one standard deviation surprises in the price level and the supply of marketable T-secs on the ex-post annualized real return on T-bills, 1982-99.

Table 1B–Dependent Variable: Ex-Post Real T-Bill Rate \( (r_t) \)

<table>
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</tr>
<tr>
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<tr>
<td>( 1920-46 )</td>
<td>( 1920-46 )</td>
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<td>constant</td>
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<td>(12.51)</td>
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<td>( \ln \left( a_{t+1} / p_t \right) )</td>
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<tr>
<td></td>
<td>(-24.09)</td>
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<tr>
<td>( \ln \left( b_{t+1} / b_p \right) )</td>
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<td></td>
<td>(-9.30)</td>
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<td>( R^2 )</td>
<td>.398</td>
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<td>( N )</td>
<td>900</td>
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Note: The table presents coefficient estimates for Eq. 4 in the text over the subperiods included in Figs. 1-5, with T-statistics in parentheses.

By the early 1980’s, the Treasury had completed a long-term shift in financing away from long-term instruments (T-bonds) and into short and medium-term instruments (T-bills and T-notes). For this reason, it is possible that fluctuations in the
quantity of T-bills and T-notes are more precise measures of supply risk for the post 1980 period than the total of outstanding marketable securities. To allow for this possibility, we compute supply shocks to T-bills and T-notes only after 1980 and display their effects on real T-bill returns in Figure 6. The result are qualitatively similar to those that we observe for all T-secs.

4 Bond-supply risk and stock prices

As we shall document in the next section, the size of the stock market has been on a non-monotonic yet dramatic upward path since the turn of the 20th century, and has grown by leaps and bounds in the 1990’s. A result of this rise, which comes on the heels of increased participation since the 1950’s, stocks have come to dominate the portfolio of the average investor. Some economists believe that such widespread participation is making Fed policy increasingly sensitive to its potential impact on stock prices. This section analyzes the potential link between bond supplies and stock prices as they are summarized by the S&P 500 index.
Table 2 – Correlations of Stock Returns with Interest Rates and Asset Quantities

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<th>T-Sec</th>
<th>M Base</th>
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<td>Real return on S&amp;P 500</td>
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<td>Real T-bill return</td>
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<td>Growth in real T-secs</td>
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<td>0.056</td>
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<td>Growth in real monetary base</td>
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<td>0.137</td>
<td>0.177</td>
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<td>1920-46</td>
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<td>Growth in real T-secs</td>
<td>0.059</td>
<td>0.418</td>
<td>0.176</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Growth in real monetary base</td>
<td>0.098</td>
<td>0.085</td>
<td>0.183</td>
<td>0.166</td>
<td>1</td>
</tr>
<tr>
<td>1947-79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real return on S&amp;P 500</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real T-bill return</td>
<td>0.041</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growth in real T-bills &amp; notes</td>
<td>0.051</td>
<td>0.050</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growth in real T-secs</td>
<td>0.064</td>
<td>0.160</td>
<td>0.037</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Growth in real monetary base</td>
<td>0.072</td>
<td>0.358</td>
<td>0.051</td>
<td>0.148</td>
<td>1</td>
</tr>
<tr>
<td>1980-99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real return on S&amp;P 500</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real T-bill return</td>
<td>-0.066</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growth in real T-bills and notes</td>
<td>0.102</td>
<td>0.145</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growth in real T-secs</td>
<td>-0.035</td>
<td>0.187</td>
<td>-0.042</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Growth in real monetary base</td>
<td>0.151</td>
<td>-0.104</td>
<td>0.173</td>
<td>-0.034</td>
<td>1</td>
</tr>
</tbody>
</table>

In a standard model, the supply of bonds can affect stock prices only if it changes real quantities. That is, if \( D_t \) are dividends on a security, and if \( c_t \) is consumption at date \( t \), theory predicts that the price of that security should equal

\[
p_t = E \left( \sum_{j=1}^{\infty} \beta^j \frac{U'(c_{t+j})}{U'(c_t)} D_{t+j} \right),
\]

where \( \beta \) is the discount factor and \( U() \) is the period utility function. According to this model, policy can affect real stock prices only if it affects consumption or dividends. To examine this implication, we compute cross-correlations from monthly data from 1920-99 between the ex-post real returns on T-bills and the S&P 500, and the per capita real growth rates of Treasury bills and notes in the hands of the public (TBN), marketable Treasury securities in the hands of the public (TSEC), and the monetary base (M0).\(^{10}\) Table 2 presents the correlations for 1920-99 and for subperiods covering

\(^{10}\) The nominal return on the S&P 500 (from Wilson and Jones, 2001) covers an actual calendar
The strongest and most consistent correlation is that between growth in the quantities of short-term Government securities (T-bills and notes) on the one hand, and stock returns and T-bill rates on the other. This relationship holds over the entire 1920-99 period, and it shows up in each subperiod too. The effect is weaker in the middle period (1947-79), but it is significant nonetheless. Since a rise in T-bills and T-notes in the hands of the public is usually the result of a bond-sale and, hence, a monetary tightening, it is surprising that the growth in the monetary base – a monetary loosening – seems to go hand in hand with bond sales as well as higher stock-returns. This may be because the money stocks are measured as monthly averages and the supply of T-secs are end-of-month quantities so that more precisely-timed or higher frequency data might be negatively correlated.

5 Model –

We assume a representative agent who assembles his portfolio sequentially. Initial asset choices are irreversible, and bonds are added to the portfolio at the end. There is one good. A stock market opens in the morning where agents can trade a single risky asset, and a bond market opens in the afternoon where agents can trade one-period bonds. Each T-bill promises 1 unit of consumption the following day. The government finances these payments with lump-sum taxes and with further issues of bonds. There is no money; the agent can give up goods in exchange for stocks in the morning, and only goods in exchange for bonds in the afternoon.

Preferences are

\[
E \left( \sum_{t=0}^{\infty} \beta^t U (c_t) \right)
\]

Stocks pay dividends \( y \) which obey the Markov transition law

\[
Pr \{ y_{t+1} \leq y' \mid y_t = y \} = F (y', y)
\]

Total supply is 1. Let \( z \) be the number of shares an agent carries into the current period, \( z' \) the number of shares he carries into the next period, and \( p \) the price of a share. Let \( m \geq 0 \) denote the agent’s savings after the morning’s trading in the stock market. As such, we compute the real return as the nominal return in month \( t \) less the average of the percentage change in the CPI from month \( t-1 \) to month \( t \) and from month \( t \) to month \( t+1 \). This provides an approximation of the inflation rate over the actual holding period. See footnotes 5, 7, and 8 for descriptions of the other variables.

\(^{11}\)Since an adequate breakdown of Treasury securities into its T-bill and T-note components is not available on a monthly basis prior to 1932, the correlations that include T-bills and T-notes in the two upper panels of Table 3 begin in 1932 rather than in 1920.
market. The agent will spend all of these savings on bonds in the afternoon. In the morning, the agent’s budget constraint is

\[ c + p(z' - z) + m \leq x + yz - \tau. \] (5)

Let \( x \) denote the number of bonds carried into (and cashed in) the current period, and let \( x' \) denote the number of new bonds issued. Let \( r \) denote the one-period rate of interest. An agent cannot exchange shares for bonds in the afternoon, nor can he borrow using shares as collateral. All uninvested savings would perish and so the agent exchanges them all for bonds regardless of the prevailing rate of interest. All of \( m \) will be exchanged for bonds. Then, bond-market equilibrium implies that

\[ m = \frac{1}{1 + r'} x'. \] (6)

**Government:** Let

\[ \text{Pr}\{x_{t+1} \leq x', y_{t+1} \leq y' \mid x_t = x \text{ and } y_t = y\} = G(x', y', x, y) \]

be the Markov transition law describing the bond-policy. Finally, let \( \tau \) denote the lump-sum tax levied in the morning needed to balance the budget, and let \( m \) be the goods that the government collects from agents in the afternoon in exchange for the bonds that it issues. Its receipts are then \( m + \tau \), and its outlays are \( x \). Thus its budget constraint is

\[ \tau + m = x. \] (7)

### 5.1 Equilibrium

We take the aggregate state to be the pair \((x, y)\), and the personal states to be \(\tilde{x}\) and \(z\). We first show that equilibrium can entail aggregate laws of the form

\[ p = P(y), \]
\[ \tau = T(x, y), \text{ and } \]
\[ 1 + r' = R(x, x', y) \]

**Individual agent’s problem:**

\[
v(x, y, \tilde{x}, z) = \max_{c, z', m'}^{1/2} U(\tilde{x} + yz - T[x, y] - P[y][z' - z] - m) ^{3/4} \beta \int v(x', y', mR[x, x', y], z') dG(x', y', x, y),
\]
EQUILIBRIUM: The decision rules are of the form \( z' = Z(x, y, \tilde{x}, z) \), and \( m = M(x, y, \tilde{x}, z) \). If the agent starts off with equilibrium quantities \((\tilde{x}, z) = (x, 1)\), prices must induce him to continue to hold the equilibrium quantities \((x', 1)\) in the following period, and so on. In other words, \( P, R, \) and \( T \) must be such that \( Z \) and \( M \) are optimal decision rules and such that
\[
Z(x, y, x, 1) = 1, \\
R(x, x', y) = \frac{x'}{M(x, y, x, 1)}, \text{ and} \\
T(x, y) + M(x, y, x, 1) = x
\]
The first and third of these conditions ensure that an agent who holds the representative portfolio \( z = 1 \) will consume the dividend, \( y \): That is, \( c = y \).

6 Implications and further evidence

Evaluated at the equilibrium choices, the first-order conditions are
\[
P(y) U'(y) = \beta E \{ U'(y') [y' + P(y')] \mid y \}
\]
and
\[
U'(y) = \beta E \{ U'(y') [R(x', x, y)] \mid x, y \}.
\]
Letting
\[
\mu(y, y') \equiv \beta \frac{U'(y')}{U'(y)}
\]
and taking conditional expectations in the two equations, the expected return to equity in state \((x, y)\) is
\[
E \left[ \frac{y' + P(y')}{P(y)} \right] \mid x, y = \frac{1 - \text{Cov} \left\{ \mu R(x', x, y) \mid x, y \right\}}{E \{ \mu \mid y \}}, \tag{8}
\]
and the expected return to bonds in state \((x, y)\) is
\[
E \{ R(x', x, y) \mid x, y \} = \frac{1 - \text{Cov} \left\{ \mu R(x', x, y) \mid x, y \right\}}{E \{ \mu \mid y \}}. \tag{9}
\]
The Mehra-Prescott formula for the pricing of the T-bill emerges here under two special sets of circumstances.

1. No market segmentation. If bonds and stocks were to trade in the same market at the same time, the gross return on T-bills would be
\[
R(y) = \beta \frac{E \{ U'(y') \mid y \}}{U'(y)},
\]
which is Mehra and Prescott’s formula. T-bill policy would then have no effect on bond-interest rates at all.
2. Predictable T-bill policy: If \( x \) were a constant (a Friedman type of rule), or perfectly predictable as in the more general case in Proposition 1, the savings rate would depend only on \( y \), say \( M(y) \), and so would the rate of interest via 
\[
1 + r \equiv R(y) = \frac{x}{M(y)}.
\]
A unit of consumption saved would then guarantee \( R(y) \) units in the next period, and the \( T \)-bill would then be a riskless asset.

In the general case, one could hope – although in section 4 these hopes will be dashed – that the model would help with both the equity premium and the risk-free rate puzzles if \( \mu \) and \( R \) are positively correlated. By (6), the return on \( T \)-bills is positively related to \( x \). This can happen only if more bonds \( x' \) are sold when \( y' \) is low.\(^{12}\) The premium on bonds, however, depends on the \( T \)-bill policy. If \( x \) is negatively correlated with \( y \) (and, hence, with consumption) the return to \( T \)-bills will be high when consumption is growing.

6.0.1 Estimating the policy rule

We shall test our proposition by (i) Estimating a policy rule and then (ii) decomposing growth in the supply of marketable Treasury securities held by the public into predicted and non-predicted components, and then examining their relative importance in explaining the ex-post real return on T-bills.

We examine these implications by estimating a policy rule of the form:
\[
x' = Bx^\gamma y^\delta (y')^\phi,
\]
where \( x \) is marketable Treasury securities in the hands of the public and \( y \) is consumption of non-durables and services, all in real per capita terms.\(^{13}\) Taking logs, the corresponding regression model is
\[
\ln x_{t+1} = B + \gamma \ln x_t + \delta \ln y_t + \phi \ln y_{t+1} + \lambda t,
\]
where \( t \) is a linear time trend that we include to account for the long-run upward drift in our quantity measures. We also examine the effects of anticipated consumption on \( T \)-bill rates by holding the design matrix constant and allowing the ex-post real \( T \)-bill rate to enter as the dependent variable
\[
r_t = B + \gamma \ln x_t + \delta \ln y_t + \phi \ln y_{t+1} + \lambda t.
\]

\(^{12}\) This sort of correlation would arise in fact if the Fed tries to increase \( y \) by purchasing bonds in order to expand the money supply.

\(^{13}\) Since Treasury securities in the hands of the public are reported as start of month totals while consumption, its deflator, and population are computed as annualized monthly averages, we deflate Treasury securities at the start of month \( t \) with the average of the deflators for month \( t - 1 \) and month \( t \), and convert to per capita terms using the average population across these same months. The timing assumptions imply that our measure of consumption for a given month is centered two weeks ahead of T-bill quantities. This timing is precisely what we would prefer when measuring the response of Treasury securities to changes in consumption that are anticipated over the near term.
### Table 3A—Dependent Variable: Marketable $T$–secs held by public (ln $x_{t+1}$)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$</td>
<td>0.874</td>
<td>0.827</td>
<td>1.209</td>
</tr>
<tr>
<td></td>
<td>(2.68)</td>
<td>(2.54)</td>
<td>(2.40)</td>
</tr>
<tr>
<td>ln $x_t$</td>
<td>0.989</td>
<td>0.989</td>
<td>1.008</td>
</tr>
<tr>
<td></td>
<td>(264.8)</td>
<td>(265.4)</td>
<td>(157.5)</td>
</tr>
<tr>
<td>ln $c_t$</td>
<td>-0.088</td>
<td>-0.395</td>
<td>-0.134</td>
</tr>
<tr>
<td></td>
<td>(-2.59)</td>
<td>(-2.34)</td>
<td>(-1.05)</td>
</tr>
<tr>
<td>ln $c_{t+1}$</td>
<td>0.312</td>
<td>0.447</td>
<td>0.123</td>
</tr>
<tr>
<td></td>
<td>(1.86)</td>
<td>(2.03)</td>
<td>(0.51)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(2.84)</td>
<td>(3.47)</td>
<td>(1.40)</td>
</tr>
<tr>
<td>$N$</td>
<td>491</td>
<td>491</td>
<td>239</td>
</tr>
</tbody>
</table>

Note: T-statistics in parentheses.

### Table 3B—Dependent Variable: Marketable $T$–secs held by public (ln $x_{t+1}$)

<table>
<thead>
<tr>
<th></th>
<th>1933-99</th>
<th>1933-46</th>
<th>1947-79</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$</td>
<td>-0.125</td>
<td>-0.134</td>
<td>0.475</td>
</tr>
<tr>
<td></td>
<td>(-2.38)</td>
<td>(-2.54)</td>
<td>(3.71)</td>
</tr>
<tr>
<td>ln $x_t$</td>
<td>0.998</td>
<td>0.998</td>
<td>0.990</td>
</tr>
<tr>
<td></td>
<td>(523.8)</td>
<td>(524.8)</td>
<td>(126.7)</td>
</tr>
<tr>
<td>ln $y_t$</td>
<td>0.017</td>
<td>-0.074</td>
<td>-0.045</td>
</tr>
<tr>
<td></td>
<td>(2.95)</td>
<td>(-1.79)</td>
<td>(-2.84)</td>
</tr>
<tr>
<td>ln $y_{t+1}$</td>
<td>0.092</td>
<td>-0.004</td>
<td>0.428</td>
</tr>
<tr>
<td></td>
<td>(2.23)</td>
<td>(-0.06)</td>
<td>(3.60)</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.0001</td>
<td>-0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(-2.59)</td>
<td>(-2.77)</td>
<td>(2.44)</td>
</tr>
<tr>
<td>$N$</td>
<td>803</td>
<td>803</td>
<td>395</td>
</tr>
</tbody>
</table>

Note: T-statistics in parentheses.

Tables 3A and 3B present estimates for equation 10 using monthly data from January 1933 to December 1999, and for subperiods covering 1933-46, 1947-79, 1959-99, 1959-1979 and 1980-1999. We present the results for the 1959-99 data and its subperiods first because our consumption measure is more reliable for this period than for earlier years.\(^\text{14}\) The regression reported in the first column for each period

\(^{14}\)We do not have monthly consumption data of non-durables and services for 1933-58, but we do have a nominal monthly indexes of the non-durable component of consumer-goods production from the Federal Reserve Board for 1939-1958 and the production of consumer goods less automobiles from the NBER’s *Macro-History Database* for 1933-39. We use these series to backcast the consumption series by ratio splicing them to the series for 1959-1999 (from the *FRED* database). We build a deflator by ratio splicing the general CPI for 1933-59 to our more precise deflator for 1959-99. We use this deflator to convert our composite monthly consumption series to real terms, and divide by total population as reported by the Bureau of the Census.
does not include contemporaneous consumption, and shows a negative and statistically significant relationship between lagged consumption ($y_t$) and the quantity of Treasury securities ($x_t$) in every sub-period. This is consistent with a Fed that accommodates increases in consumption by purchasing bonds. To examine the model’s more precise prediction of the Fed accommodating expected consumption, which only it can observe, we include $y_{t+1}$ in the second regression. This specification yields an unexpected positive sign on future consumption in all cases where the coefficient is statistically significant.

Table 4A–Dependent Variable: Ex-Post Real T-Bill Rate ($r_t$)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$</td>
<td>265.2</td>
<td>-9.34</td>
<td>346.1</td>
</tr>
<tr>
<td></td>
<td>(3.79)</td>
<td>(-0.08)</td>
<td>(3.01)</td>
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<tr>
<td>$x_t$</td>
<td>0.62</td>
<td>1.03</td>
<td>-1.19</td>
</tr>
<tr>
<td></td>
<td>(0.77)</td>
<td>(0.57)</td>
<td>(-0.82)</td>
</tr>
<tr>
<td>$y_t$</td>
<td>-30.06</td>
<td>0.38</td>
<td>-35.09</td>
</tr>
<tr>
<td></td>
<td>(-5.26)</td>
<td>(-5.38)</td>
<td>(-2.80)</td>
</tr>
<tr>
<td>$y_{t+1}$</td>
<td>160.2</td>
<td>218.4</td>
<td>150.9</td>
</tr>
<tr>
<td></td>
<td>(4.51)</td>
<td>(5.64)</td>
<td>(2.78)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>(3.83)</td>
<td>(-0.67)</td>
<td>(2.61)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.114</td>
<td>.182</td>
<td>.107</td>
</tr>
<tr>
<td>$N$</td>
<td>491</td>
<td>251</td>
<td>239</td>
</tr>
</tbody>
</table>

Note: T-statistics in parentheses. The $x$ variable is outstanding Treasury securities in the hands of the public.

Table 4B–Dependent Variable: Ex-Post Real T-Bill Rate ($r_t$)

<table>
<thead>
<tr>
<th></th>
<th>1933-99</th>
<th>1933-46</th>
<th>1947-79</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$</td>
<td>95.82</td>
<td>446.0</td>
<td>295.2</td>
</tr>
<tr>
<td></td>
<td>(6.40)</td>
<td>(4.51)</td>
<td>(8.61)</td>
</tr>
<tr>
<td>$x_t$</td>
<td>-1.84</td>
<td>-6.65</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(-3.39)</td>
<td>(-1.95)</td>
<td>(-0.01)</td>
</tr>
<tr>
<td>$y_t$</td>
<td>-9.71</td>
<td>-44.61</td>
<td>-33.80</td>
</tr>
<tr>
<td></td>
<td>(-5.93)</td>
<td>(-4.76)</td>
<td>(-8.03)</td>
</tr>
<tr>
<td>$y_{t+1}$</td>
<td>61.84</td>
<td>27.01</td>
<td>224.5</td>
</tr>
<tr>
<td></td>
<td>(11.56)</td>
<td>(1.39)</td>
<td>(7.41)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.02</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(9.71)</td>
<td>(1.16)</td>
<td>(6.74)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.150</td>
<td>.181</td>
<td>.163</td>
</tr>
<tr>
<td>$N$</td>
<td>803</td>
<td>167</td>
<td>395</td>
</tr>
</tbody>
</table>

Note: T-statistics in parentheses. The $x$ variable is outstanding Treasury securities in the hands of the public.
Tables 4A and 4B present results for equation 11. In this case, the first column for each subperiod again shows a strong negative relationship between lagged consumption and the real $T$–bill rate. Nevertheless, $y_{t+1}$ enters with an unexpected positive sign for each period that is significant in all but the 1933-46 period. Since the model requires that $y_{t+1}$ and $r_t$ be negatively correlated to help explain the risk-free rate puzzle, the data do not offer much hope for making progress on this dimension.

### 7 The effects of foreseen policy changes: The secular decline of Treasury finance

T-bills and other marketable Treasury securities have declined in relative importance over the postwar period. This should not matter for the real interest rates if only the surprises in bond supplies matter. The size of the bond market can be measured by the share of these securities in the aggregate portfolio. This share will decline if, because of a policy change, the quantity of Treasury securities made available to the public begins to shrink. The share will also decline as more individuals gain access to instruments other than bank deposits for lodging their surplus balances. Figures 7 and 8, which include Federal debt, commercial and corporate debt, and corporate equities as HP-filtered shares of gross domestic product and the aggregate portfolio, respectively, indeed show substantial declines in the share of marketable Federal debt from its postwar high in 1945. The growing importance of financial assets in the U.S. economy and the rapidly rising share of equity in total finance are also apparent. In contrast, the share of business debt has not changed much (with the exception of the 1980s) since the 1930s. Figure 9 provides additional detail on the rising share of equity in total business finance, with both the corporate bond and bank lending components of business debt falling to their lowest levels in recent years. The market for commercial paper has also grown rapidly over the past three decades, but remains a small part of total finance. See the appendices for descriptions of how we constructed the series for outstanding corporate equities and the components of outstanding debt that are presented in these figures.

Figure 10, which provides a breakdown of marketable Treasury securities by type, shows that long-term bonds dominated government finance between 1915 and 1960, but that medium-term T-notes and short term T-bills have risen to pre-eminence more recently. These shifts suggest that a broad measure of government bond activity, such as the sum of all marketable Treasury securities in the hands of the public, may be best one for evaluating the effects of supply shocks related to the Fed’s open market policies over the long term, but that the quantities of T-bills and T-notes might be more relevant in recent years. These considerations more precisely explain our choices of variables for quantifying supply risk that appear in earlier sections.

Figures 7 and 8, when combined with the effects of changes in the supply of Treasury securities presented in Figure 2, suggest that the decline in the share of
these securities in the aggregate portfolio has had little effect on the distribution of $R$. This stands in sharp contrast to the implications that such a decline would have in the limited participation model of Alvarez et al. (2001) in which the interest-rate effects of monetary injections depend inversely on the fraction of agents that take part in the bond market. Let us see how the decline in Treasury finance works in our model.

In our model, the size of the bond market can be measured by the share of these securities in the aggregate portfolio: Write $M(x, y, x, 1)$ as $M(x, y)$ for short. Then

$$\frac{m}{m + p} = \frac{M(x, y)}{M(x, y) + P(y)}.$$ 

This fraction will decline if, because of a policy change, $x$ declines over time. As long as the public expected it, however, our model predicts that the decline in $m/(m + p)$ of itself should have no implications for the distribution of $R$. In this sense, our model is more like Lucas (1990) where only policy surprises matter, than Alvarez et al (2001), where, more in the spirit of the original models of Grossman and Weiss (1993) and others, the fraction of agents that take part in the bond market is exogenous, and where, as a result, even foreseen movements in bond sales can matter.

Let us look more closely at how policy works in our model. Suppose that the
T-bill policy is of the form
\[ x' = \phi(x, y, y', \eta), \]
where \( \eta \) is a random variable drawn independently each period. Then by (6), the equilibrium T-bill investment decision is
\[
M(x, y, x, 1) = \beta E \left( \frac{U'(y')}{U'(y)} \right)^{\frac{3}{2}} \phi(x, y, y', \eta) \cdot \frac{U_0(y_0)}{U_0(y)} | x, y \tag{12}
\]
and the following result is immediate:

**Proposition 1** If
\[
\phi(x, y, y', \eta) = \phi^1(x, y) \phi^2(y', \eta),
\]
then
\[
M(x, y, x, 1) = \phi^1(x, y) \beta E \left( \frac{U'(y')}{U'(y)} \right)^{\frac{3}{2}} \frac{\phi^2(y', \eta)}{U_0(y)} | x, y.
\]

While
\[
R(x, x', y) = \frac{\phi^2(y', \eta)}{\beta E \left( \frac{U'(y')}{U'(y)} \right)^{\frac{3}{2}} U_0(y)} | x, y
\]
is not affected by shifts in the function \( \phi^1(\cdot) \), \( M(x, y, x, 1) \) and is proportional to it.
Thus the public saves in proportion to the foreseen component of the policy \( \phi^1(x, y) \). Therefore one explanation for the decline in T-bills is that the component of the policy which governs their expected supply – which is proportional to \( \phi^1(x, y) \) – has declined. This explains how the relative importance of T-bills has declined without seeming to affect the distribution of the T-bill yield. The public has reduced its investment proportionally so as to keep the distribution of \( R \) unchanged.

**Corollary 2** Unless \( \frac{U'(y_{t+1})}{U(y_t)} \) is a constant for all \( t \), the government is unable to stabilize the rate of interest.

**Proof:** Suppose it could do so. The rate of return on the T-bill would then be safe and the Mehra-Prescott formula would apply. Since the government is not able to alter the consumption sequence, the rate of return on T-bills, as given in (9) would have to fluctuate. ¥

The tendency of bond-market investment to track the bond-supply policy is clearest in the special case in which \( y \) is a constant, say \( y^* \). Then

\[
P(y^*) = \frac{\beta y^*}{1 - \beta},
\]

and, therefore,

\[
\frac{m}{m + p} = \frac{\phi^1(x, y) E_{\mathbf{\phi}^1(y^*, \eta) \mid x, y} \mathbf{\phi}^2(y^*, \eta) \mid x, y}{\phi^1(x, y) E_{\mathbf{\phi}^2(y^*, \eta) \mid x, y} \mathbf{\phi}^2(y^*, \eta) \mid x, y + (1 - \beta)^{-1} / y^*}
\]

24
\[
\text{E} (x' \mid x, y) = \frac{\text{E} (x' \mid x, y)}{\text{E} (x' \mid x, y) + (1 - \beta)^{-1} y^*}.
\]

8 The persistence of liquidity effects

We saw in equation (3) that for the sample as a whole, surprises in both the price level and bond supplies have significant effects on real rates while foreseen changes in bond supplies do not. But then in Table 1 we also saw this evidence was really dominated by the pre-war epoch and that, since the war, the effect of expected shifts is at least as strong as that of surprises, and this is not consistent with our model in which only surprises matter.

Our model also predicts that there should be no persistence in the effects of surprises. To examine this prediction, we compute the impulse responses for the tri-variate systems that we have considered in Section 3 over the 1920-46, 1947-79, and 1980-99 subperiods. Recall that the variables in the systems are the log quantity of real per capita marketable Treasury securities in the hands of the public, the ex-post real return on T-bills, and the deflator for consumption. This is also the placement ordering for the variables in the VAR.
Figure 11. Impulse response functions.
Figure 11 presents the responses of the annualized T-bill return to 1% shocks to the supply of T-secs and to the price level in the left and right panels, respectively, with one standard error bands derived using Monte Carlo integration. The responses show that surprises to the price level are accompanied by declines in bond returns that are actually quite persistent in the 1920-46 and 1947-79 subperiods, with both standard error bands beneath the zero-line for nine months after the shock. Conversely, the T-bill return is not responsive to T-sec supply shocks in the 1920-46 period. This, of course, may be due to the limiting assumption of stability of the underlying VAR process over the rather tumultuous 1920-46 period. T-sec supply shocks do have larger effects on T-bill returns for the 1947-79 period, though they manifest only after two months and persist for five months, which is long given the model’s prediction. For reasons discussed in Section 3, however, it is possible that the differential timing of the 3-month T-bill term versus the monthly supply and price shocks could generate some persistence that is not inconsistent with our model.

In the 1980-99 period, we find large but short lived effects of both supply surprises and price level shocks on T-bill returns, with both responses decaying within three months of the shock. This is better news for our model.

9 Conclusion

Bond-supply risk normally contributes between a quarter and three-quarters of a percentage point to movements in the real annualized rate of interest on three-month T-bills. The effect seems substantial and has shown no tendency to decline over the past half century. The Fed seems to be trying to keep this risk to a minimum, but is not able to push it to zero because the gradual paying down of the Federal debt has meant that it has become harder to expand T-bill issues to accommodate unexpectedly large rollover demands from foreign sources. Further, so long as the Fed uses the secondary market for Treasury securities as its chief means of conducting open market operations, shocks to the supply of these securities to the public will persist. If the supply of outstanding Treasury securities indeed does continue its decline, an increase in the use of other debt instruments for open market operations will reduce the supply-risk for the group as a whole and will, thereby, enable Treasury securities to remain what they have been thus far – highly liquid and yet nominally riskless.

APPENDIX A: Estimating the market value of outstanding corporate equity

To estimate the market value of outstanding corporate equity, we extend the Flow of Funds series (Table L.4) backward using the available data on capitalization for the NYSE, the regional exchanges, and over-the-counter (OTC) markets. We work backward not from 1945 (which is when the Flow of Funds begin) but, rather, in 1949 because the closest overlapping observations of OTC activity are for 1949.
The *Flow of Funds* reports $117 billion for outstanding corporate equities in 1949, which we divide into the value of NYSE-listed firms, the value of firms listed exclusively on AMEX and the regional exchanges, and the value of firms traded exclusively in OTC markets. Friend (1958) estimates the sum of NYSE and regional capital in 1949 at $95 billion. We know from CRSP that NYSE capitalization was $68 billion. This implies a regional capitalization of $27 billion and OTC capital of $22 billion in 1949. Assuming that the capitalizations of NYSE and regionally-listed firms are proportional to their transaction values, which are available from various issues of the *Annual Report of the Securities and Exchange Commission*, for 1935-49, we multiply NYSE capital by the ratio of regional to NYSE transactions to approximate movements in capitalization on the regional exchanges. We then adjust the resulting regional series to match the $27 billion that we estimate for 1949. To estimate regional capital for 1920-34, we observe that the ratio of regional to NYSE transaction value was steady at 0.18 for 1935-50, and again use NYSE capital to derive regional capital from 1920.

The OTC market presents a double-counting problem. Friend estimates that, in 1949, 25% of quoted OTC issues were also listed on a registered exchange. Our measure of OTC capital must exclude such firms. To derive estimates for 1920-49, we use Friend’s counts of the number of OTC-quoted firms over a 3-month window surrounding three benchmark dates in 1949, 1939 and 1929. There were 5300 such
OTC firms in 1949, of which 75% were not listed on registered exchanges. The median market value of these unlisted firms was $2.4 million. Therefore, we approximate exclusive OTC capital at $9.54 million (.75*5300*$2.4) in 1949. Assuming that the real median size of unlisted OTC firms did not change over 1920-49, we next use the GDP deflator to convert the median size into nominal terms at the other benchmark dates. Next, we observe that the $9.47 million for 1949 is too small by a factor of 2.3 given our comparable estimate from the Flow of Funds, and adjust the OTC benchmark estimates by this factor. Finally, we interpolate between the benchmarks to obtain an annual OTC series for 1929-49.

To obtain OTC capital for 1920-28, we continue to assume that capital on the exchanges is proportional to relative transaction values. Since we know NYSE capitalization and now have estimates for the regional and OTC markets in 1929, we can estimate of the share of the OTC in total market value in 1929. Since Friend (1958, p. 109) provides us with this share for 1926, and 1920, we can use them to estimate OTC capital for these years given the values of NYSE capitalization from CRSP and our earlier estimates of regional capital. We interpolate between the benchmarks once again to obtain OTC capital for 1920-29.

By adding NYSE, regional and OTC capitalizations, we obtain a series for total market value for 1920-49 that is consistent with the Flow of Funds in the sense that the two segments coincide in 1949. Our final estimates of equity capital outstanding, displayed in the figure below, are obtained by splicing our series with the Flow of Funds in 1945. The figure also includes the series for equity capital that would result from the use of CRSP (1925-99) and our NYSE listings (1900-1924) data alone. The importance of equities that were not listed on the NYSE from the end of the First World War to the start of Nasdaq in 1971, as depicted by the vertical distance between the red and blue lines in the figure, is considerable. Since we wish to use market value from 1900 in Figures 7 and 8, for the purpose of computing equity’s share in total finance, we ratio splice the value of NYSE capital from 1900-1920 (obtained from individual issues of the The Annalist, The Commercial and Financial Chronicle, The New York Times, and Bradstreet’s) to our result for 1920-99.

APPENDIX B: Estimating the market value of business debt

We define U.S. business debt as the value of outstanding commercial and industrial bank loans, corporate bonds, and commercial paper. For 1945-1999, book values for loans and corporate bonds are from the Flow of Funds (Table L.4 lines 5, and 6 respectively). For 1900-1944, the book value of outstanding corporate bonds is from W. Braddock Hickman (1952), and that of bank loans is from All Bank Statistics. Since bank loans are reported in the latter source as June 30 figures, we average across years for consistency with the calendar-year basis of the Flow of Funds.

For commercial paper, the outstanding amount for 1970-1993 is available from the FRED database of the Federal Reserve Bank of St. Louis. We carry this series to
the present using the quantity of open market paper from the *Flow of Funds* (Table L.4 line 2). We extend the series backward to 1959 using the Federal Reserve Board’s *Banking and Monetary Statistics* (1976b, pp. 717-719). These quantities include paper placed both directly (i.e. finance company) and by dealers. For 1919-1958, we have a continuous series for dealer-placed paper only, again from *Banking and Monetary Statistics* (1976b, pp. 714-717; 1976a, pp. 465-467), which we ratio-splice to the later series. The splice leads to what is likely to be an over-estimate of outstanding commercial paper by 1918 due to the rapid growth of directly-placed paper between the mid-1920s and 1941. For example, Greef (1937, p. 118), presents a figure of $874 million for outstanding commercial paper in 1918, while the spliced series would imply a total of $4.2. Since we do not have the data on finance paper that would be required to reconcile these series, we have chosen to simply use Greef’s figures before 1931, the point at which the outstanding totals from both series differ the least in percentage terms. Prior to 1918, Greef (1937, pp. 57-59) provides estimates of the volume of commercial paper trading in 1907 and 1912-1916. Assuming 4-6 month maturities, we then estimate the amount of commercial paper outstanding at 5/12 of the trading volume, and assume constant growth between the benchmarks of 1907 and 1912. We apply the same growth rate to 1900-1906 to complete the series. From the above, it should be clear that the commercial paper series is not very reliable prior to 1931. Since we do not perform any econometric analysis with this series, however, and it turns out to be a small portion of total debt finance in any case during this period, we consider the inclusion of the totals in Figures 1 and 3 to be useful.

To build a market value series, we include both commercial paper and bank loans, due to their short maturities, at their book values. We then convert outstanding corporate bonds from par values to market values using the average annual yields on Moody’s AAA-rated corporate bonds (from *Moody’s Investors Service*) for 1919-98 and Hickman’s “high grade” bond yields, which line up precisely with Moody’s, for 1900-18. To determine market value, we let \( r_t \) be the bond interest rate and compute the weighted average

\[
r_t^* = \frac{1}{P_t} \sum_{i=1885}^{1918} (1 - \delta)^{t-i} r_{t-i} X_t
\]

We choose \( \delta = 10\% \) to approximate the growth of new debt plus retirements of old debt, and multiply the book value of outstanding corporate bonds by the ratio \( \frac{r_t^*}{r_t} \) to obtain their market value.
References


