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LIQUIDITY EFFECTS IN THE BOND MARKET

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ABSTRACT

Our paper reports the following two findings:

1) In monthly data, bond purchases by the Fed raise bond prices and reduce bond yields. The residual bond-supply to traders is not fully predictable, and this supply-risk adds between 10 and 40 basis points to the standard deviation of the real interest rate on T-bills.

2) The Fed's open market purchases do not raise stock prices or reduce stock returns. If anything, they raise stock returns. More generally, bonds and stocks do not co-move at high frequencies.

To explain these two facts, we model the bond and stock markets as spatially separate or 'segmented'. In the model, bond purchases lower bond rates, but they do not affect stock returns, and this is consistent with both facts.

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Liquidity Effects in the Bond Market

Boyan Jovanovic and Peter L. Rousseau*

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1 Introduction

Monthly data show that surprise bond purchases by the Fed raise bond prices and reduce bond yields. Surprisingly, such injections do not raise stock prices or reduce stock returns. If anything, they *raise* stock returns. In other words, the two markets show a lack of comovement at high frequencies. This goes against the common view that liquidity is good for bonds and stocks alike – it is commonly argued, for instance, that a discount-rate cut raises both bond prices and stock prices. Barsky (1989) had argued that the prices of stocks and bonds will move in opposite directions if risk-aversion changes, and this may well explain some of the decade-to-decade changes or even changes that occur at business-cycle frequencies (Bernanke, Gertler and Gilchrist, 1996, fig. 1), but it is less compelling an explanation for monthly data.

We quantify the liquidity effect on interest rates caused by supply-risk in the bond market. This risk adds somewhere between 10 and 40 basis points to the standard deviation of the real rate of interest on T-bills. The risk may well increase unless the Fed expands the set of assets that it uses to conduct open market operations.

To explain these findings, we present a model that has a liquidity effect in the bond market, but not in the stock market. We extend Lucas's (1990) shopper-trader paradigm by having the trader first visit the stock market and then a separate bond-market in which he is surprised by the injection of bonds. The bond injection has no effect on stock prices because it is "sterilized" by lump-sum taxes. Expected policy actions have no effect in the model, and this is consistent with the fact that the long run relative decline in bond finance does not seem to have raised interest-rate volatility as some other models would have predicted. We do show, however, that the Fed will find it harder and harder to keep bond-supply risk low because the gradual

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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.

T-bills vs. non-borrowed reserves Since the 1970s, the Phillips-curve relation seems to have broken down, and money seems to have no clear effect on real interest rates either. Only if we assume that some part of money responds to real variables can we conclude that the exogenous part of money does move interest rates. Evans and Marshall (1998), for example, describe several scenarios–identifying assumptions–under which some part of the money supply can plausibly be said to move real interest rates. In other words, what we infer about a liquidity effect on interest rates depends on what we believe the Fed reacts to when it sets the money supply.

But, if we wish to estimate the liquidity effect on interest rates, or even if we wish to study the interest rate channel of monetary policy, is money the right measure of policy? The rate of interest is the return on bonds, which depends most directly not on the supply of money but on the supply of *bonds*. Using the quantity of bonds , one can find a liquidity effect without introducing a host of other variables.

Whether we measure money by non-borrowed reserves or more broadly, injections of money are *not* the same as withdrawals of, say, Treasury bills (T-bills). This is because the Fed sometimes injects money by buying long-term bonds, and this will affect short-term rates less than would a purchase of T-bills. Indeed, table 1 shows that, since 1961, the correlation between monthly growth in the real per capita supply of outstanding Treasury securities (T-secs) and non-borrowed reserves (NBR), which one might expect to be negative, has been slightly positive at .048.[1] The table also shows that, at least since 1980, growth in non-borrowed reserves has reduced short-term rates, but not as strongly as a contraction of T-secs. Over the whole period, however, growth in both non-borrowed reserves and T-secs is positively correlated with short-term rates–which, for non-borrowed reserves, is the wrong sign.

Table 1 – Correlations among monthly growth-rates

Variable	Period	
	1961-99	1980-99
$\text{corr}(r_{t,t+1}, g^{NBR}_{t-1,t})$	.046	-.063
$\text{corr}(r_{t,t+1}, g^{T-\text{secs}}_{t-1,t})$	.137	.107
corr(NBR,T-secs)	.048	-.007

[1] Tables 1 and 2 both deal with *ex-post* real returns of investors who purchase three-month U.S. Treasury bills in the secondary market with two months remaining until maturity and sell them a month later. In the tables, $r_{t,t+1}$ is the return obtained from purchasing the T-bill in month t and selling in month $t+1$. The $g^{NBR}_{t-1,t}$ and $g^{T-\sec s}_{t-1,t}$ terms denote growth in the per capita real supplies of non-borrowed reserves and marketable T-secs in the hands of the public (excluding the Fed's holdings) over the previous month (i.e., from month $t-1$ to month t). We obtain monthly nonborrowed reserves from the FRED database of the Federal Reserve Bank of St. Louis, and describe other data sources in the text and in footnote 8.

These conclusions do not change if we look instead at surprises, as in models like Lucas (1990) and Christiano and Eichenbaum (1995). Table 2 presents the correlations of interest rates with surprises in the growth of NBR and T-secs.[2] For the 1980-99 period, surprises to non-borrowed reserves come in with the wrong sign, whereas T-sec surprises have the positive correlation that a liquidity effect implies. Both correlations have the wrong sign for the 1961-99 period, but that between surprises to growth in the bond supply and real rates is tiny.

Table 2–Correlations among growth-rate surprises

Variable	Period	
	1961-99	1980-99
corr$(r_{t,t+1}, g_{t-1,t}^{NBR})$	.056	.138
corr$(r_{t,t+1}, g_{t-1,t}^{T-\text{secs}})$	-.008	.142
corr(NBR,T-secs)	-.060	-.118

The lessons from the data can be summarized as follows:

1. *T-bills vs non-borrowed reserves.* Short-term interest rates respond more strongly to changes in T-bills than they do to changes in the money supply or non-borrowed reserves,

2. *Interest rates and stock returns*: T-bill rates are uncorrelated or negatively correlated with stock returns, and surprise bond purchases do not raise stock prices – all this at monthly frequencies, and

3. *Risk and the decline of Treasury finance*: The quantities of outstanding T-securities have steadily declined relative to the unpredictable rollover demands for them at auction by foreign monetary authorities and financial institutions. This raises supply risk to bond traders. Including a broader range of short-term securities in the Fed's portfolio would stabilize the growth rate of T-secs, as the risk would be spread across a wider range of assets.

Section 2 assesses the effects that bond-supply risk has had over the past 80 years on the ex-post real returns obtained by purchasing a new three-month T-bill and holding it until maturity and compares them to the effects of bond-supply risk on real stock returns. We then document the role of supply risk under an investment strategy of purchasing a seasoned three-month T-bill with two months until maturity and selling it one month later. Section 3 documents the recent decline of Treasury finance and shows that, while supply risk has so far been unrelated to this decline, further declines will raise supply risk unless the Fed broadens its asset base. Section 4 describes the model, and Section 5 concludes the paper. Appendix A provides more detail on how T-bills are sold and how open market operations work.

[2] We compute surprises to T-secs and nonborrowed reserves as one-step ahead forecast errors from a series of rolling bi-variate VARs with four lags and a 30-month estimation window.

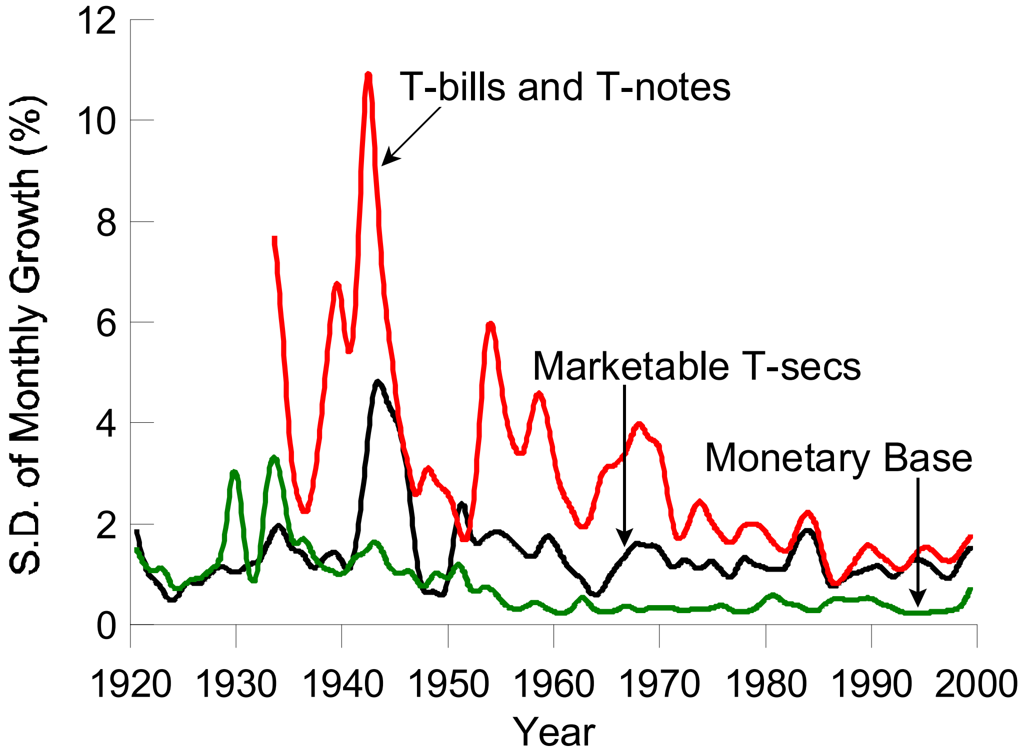

Figure 1: Rolling standard deviations of monthly growth rates of real per capita supplies of T-secs and the monetary base, 1920-99.

2 Bond-supply risk and interest rates

How much do bond supplies vary from month to month? Figure 1 shows the standard deviation of the monthly per capita real growth of the monetary base, T-bills and T-notes, and all marketable T-secs, including bills, notes, bonds, and certificates of indebtedness since 1920.[3] The Treasury quantities reflect securities that are outstanding and in the hands of the public (that is, excluding the Fed's holdings).[4]

[3]We compute the standard deviations using a 12-month rolling window and then apply the Hodrick-Prescott filter to each series before plotting.

[4]The quantities of outstanding marketable Treasury securities 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* (1976a, pp. 868-73; 1976b, pp. 509-11) 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* (1976a, p. 343; 1976b, pp. 485-7) for 1932-70, and from individual issues of the *Federal Reserve Bulletin* for 1920-31 and 1971-99. The monetary base is from the *FRED* database for 1936-99, with M1 from the Friedman and Schwartz (1970, Table 1, pp. 4-58) ratio, spliced to the M0 aggregate for 1920-35.

The striking feature of Figure 1 is the high month-to-month variability of total T-secs 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. We also observe large rolling standard deviations for the T-bills and T-notes subset in the midst of the Depression and again from 1942-47. Interestingly, variability in 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 have served to stabilize money growth.

How strongly do bond-supply surprises affect the real rate of interest? We shall use the effects of inflation surprises as a standard of comparison and compare the two kinds of risk, first for the entire 1920-99 period, and then for three subperiods. Here is how we proceed:

The nominal return at date t on a one-period zero-coupon bond maturing at date $t+1$ is

$$R_{t,t+1} = \left(\frac{1}{P_t} - 1\right),$$

where P_t is the price of the bond at date t. The *ex-post* real return on this bond is

$$r_{t,t+1} = \left(\frac{1}{P_t}\left[\frac{1}{1+\pi_{t,t+1}}\right] - 1\right),$$

where $\pi_{t,t+1}$ is the rate of inflation of goods prices between dates t and $t+1$. Rearranging and taking logs,

$$\ln\left(1 + r_{t,t+1}\right) = -\ln P_t - \ln\left(1 + \pi_{t,t+1}\right).$$

For any small number ε, $\ln(1+\varepsilon) \approx \varepsilon$. Using this, we approximate the above equation by

$$r_{t,t+1} \approx i_{t,t+1} - \pi_{t,t+1},$$

where $i_{t,t+1} \equiv 1/P_t - 1$.

Let the superscript e denote an expected value given information from the previous period, which we shall denote I_{t-1}, so that, for instance, $r^e_{t,t+1} = E\left\{r_{t,t+1} \mid I_{t-1}\right\}$.[5]

Let the superscript u denote the surprise component of a random variable so that, for instance, $r_{t,t+1} = r^e_{t,t+1} + r^u_{t,t+1}$, and so on. Then to a first approximation,

$$r^u_{t,t+1} = i^u_{t,t+1} - \pi^u_{t,t+1}. \tag{1}$$

[5] The information set I_{t-1} consists of the realized inflation rate from $t-1$ to t (i.e., $\pi_{t-1,t}$), the real T-bill return from $t-1$ to t (i.e., $r_{t-1,t}$),the real return on the $S\&P$ 500 portfolio from $t-1$ to t, and the growth in the bond supply from $t-2$ to $t-1$ (i.e., $g_{t-2,t-1}$). In other words, thinking of date t as February and date $t-1$ as January, and so on, when we commit funds to the bond market before any February auction, we know the return on the S&P 500 and the inflation rate for January, and the growth of the bond-supply in December. We do not include the growth of bond-supply in January, however, because that would imply a knowledge of P_t and an absence bond-supply risk. Therefore, I_{t-1} contains insufficient information to forecast P_t perfectly.

The first term is the bond-supply risk and the second is inflation risk.

Now assume a liquidity effect of bond-supply surprises on the price of bonds as in, say, Lucas (1990). That is, assume that

$$i^u_{t,t+1} = \alpha g^u_{t-1,t}, \tag{2}$$

where, once again, $g^u_{t-1,t}$ is the surprise growth in number of bonds at t given I_{t-1}. Substituting into (1) leads to

$$r^u_{t,t+1} = \alpha g^u_{t-1,t} + \pi^u_{t,t+1}. \tag{3}$$

The notation may suggest that the surprises in the above three variables are formed at different dates and are based on different information sets, but this is in fact not the case. The dependent variable and the regressors all derive from the information set I_{t-1} that we described in the previous footnote. To reiterate, at the start of date t, agents know the realization of $\pi_{t-1,t}$. But the presence of bond-supply risk means that the agents do not know the date-t supply of bonds when they form their expectations of P_t and, hence, of $i_{t,t+1}$. This means that they cannot yet know $g_{t-1,t}$, since its realization comes too late to be included in the date t information set. Therefore, in spite of the dating differences in the subscripts, $\hat{r}^u_{t,t+1}$, $\hat{g}^u_{t-1,t}$, and $\hat{\pi}^u_{t,t+1}$, are surprises based on the same information set, I_{t-1}.

We shall estimate (3) with the regression

$$\hat{r}^u_{t,t+1} = a_0 + a_1 \hat{g}^u_{t-1,t} + a_2 \hat{\pi}^u_{t,t+1}, \tag{4}$$

where $\hat{r}^u_{t,t+1}$, $\hat{g}^u_{t-1,t}$ and $\hat{\pi}^u_{t,t+1}$ are surprises of the three variables. In practice, we obtain these surprises using de-seasonalized monthly observations as the one-step ahead forecast errors from a set of vector autoregressions (VARs) with a rolling estimation window. To be more precise, the variables in the forecasting equations are:

1. g – the growth rate of real per capita T-secs in the hands of the public,
2. r – the ex-post real return on T-bills,[6]
3. π – the rate of growth of the consumer price index,[7] and
4. the ex-post real return on the S&P 500.[8]

[6]Nominal secondary market interest rates on three-month T-bills are from the *FRED* database for 1934-99 and *Banking and Monetary Statistics* (1976a) for earlier years.

[7]The consumer price index, which we also use to deflate the T-sec quantities, is that for all urban consumers from the Bureau of Labor Statistics.

[8]Nominal calendar-month returns on the S&P 500 assume the reinvestment of dividends, and are from worksheets underlying Wilson and Jones (2001).

Thus, all four variables in the system are dimensionless. We then pool the forecasts and errors from the VARs over the sample period and use them to estimate Eq. (4).

The monthly data represent the highest frequency that is available continuously for the past eighty years of Fed history. The T-bill return is the monthly average of daily rates for the current (i.e., "on the run") three-month T-bill, from which we subtract realized inflation over the next three months. The returns that we consider first, and the only ones that can be constructed going back to 1920, correspond to an investment strategy of buying the current 3-month T-bill and holding it until maturity. Later we consider one-month holding period returns on seasoned T-bills since 1961. Appendix B is a detailed description of the methods that we used to prepare the data for analysis and to compute the surprises.

2.1 Supply risk 1920-1999

Using monthly data from January 1920 through December 1999 and forecasting equations with a 36-month rolling window and three lags, Figure 2 shows the effects of one-standard deviation surprises to both the price level and the supply of marketable T-secs available to the public on the annualized ex-post real return on T-bills.[9] Pooling the surprises across periods, we obtain the following estimates for Eq. (4) with t-statistics in parentheses:

$$\hat{r}^u_{t,t+1} = \underset{(0.60)}{.0001} + \underset{(7.45)}{.0274}\, \hat{g}^u_{t-1,t} - \underset{(-17.31)}{1.082}\, \hat{\pi}^u_{t,t+1} + e_t. \quad (5)$$

The superscript u in Eq. (5) denotes a variable's deviation from its one-step ahead forecast from the rolling VAR.

As limited participation models would suggest, $\hat{g}^u_{t-1,t}$ raises ex-post real T-bill returns because a release of T-bills lowers T-bill prices. This in turn contributes to better-than-expected returns for those who have committed funds to the T-bill market. Unanticipated inflation enters with, essentially, a unit coefficient, which suggests that $\hat{\pi}^u_{t,t+1}$ is indeed a true surprise.

To obtain the series plotted in Figure 2, we multiply the coefficients on $\hat{g}^u_{t-1,t}$ and $\hat{\pi}^u_{t,t+1}$ by the centered values of their rolling 12-month standard deviations, and compound the result over 12 months to annualize. This measures the effects of the

[9] As we show in Section 4, 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-bills over the long term would over-emphasize variations in the maturity structure of government finance that were not "shocks" but rather just substitutions of one maturity for another. For this reason, we work primarily with the total of marketable Treasury securities in the hands of the public rather than a narrower quantity measure such as T-bills alone.

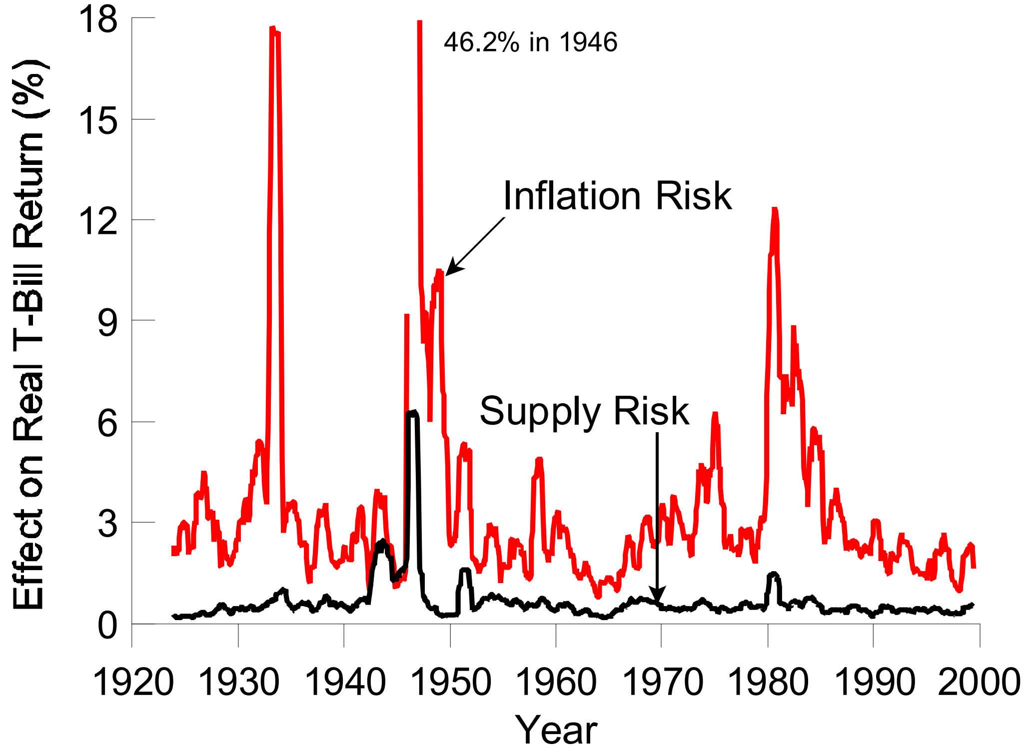

Figure 2: Effects, in percentage points, of one standard deviation surprises in inflation and growth in the supply of T-secs on annualized real T-bill returns, 1920-99.

surprises on annualized real T-bill returns.[10] The figure indicates that both sources of risk have always mattered, with inflation risk at times quite large, especially at the height of the Great Depression in 1933 and in the year immediately following the end of the Second World War. The relative importance of inflation risk has declined dramatically over the past two decades, however, as the price level has stabilized.

2.2 The effect of supply risk in three subperiods

The method used to construct Figure 2 assumes that the seasonal adjustment coefficients applied to the raw data and the responses of the T-bill rate to unexpected inflation and T-sec growth are stable across the 1920-99 period. One way to examine the robustness of our results to these assumptions is to repeat the analysis over subperiods. We do this for 1920-46, 1947-79, and 1980-99, and display the results in

[10]Figure 2 does not span the full 1920-99 period because observations are lost in accommodating the lag length of the VAR, in constructing the initial estimation window, and in computing the initial and final rolling standard deviations of the forecast errors.

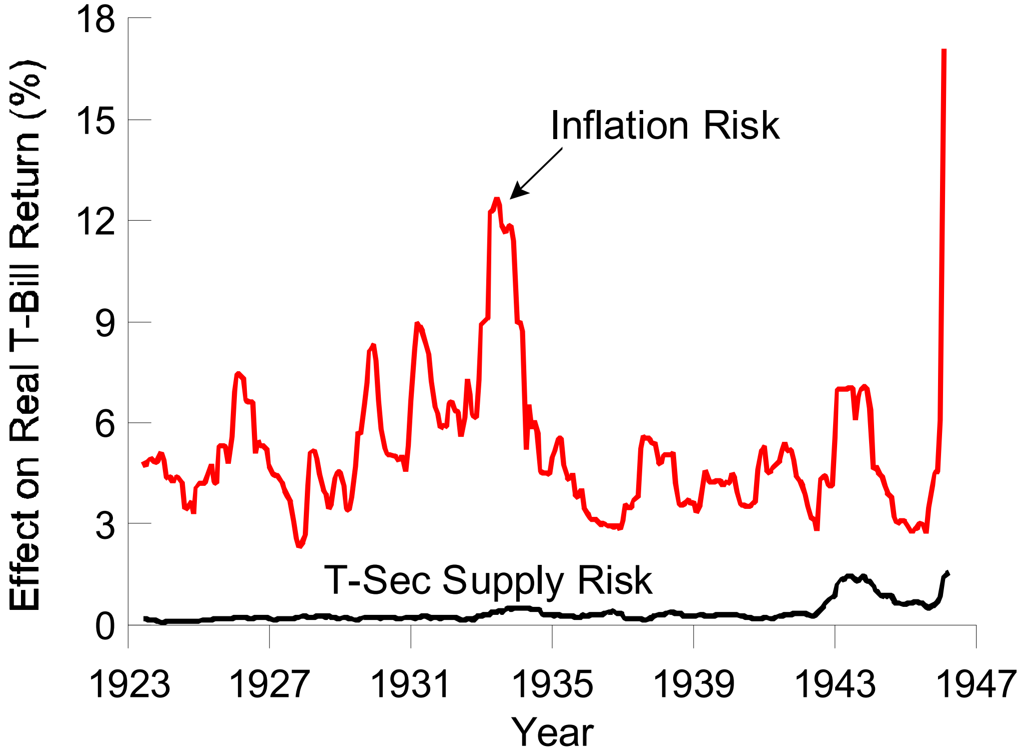

Figure 3: Effects, in percentage points, of one standard deviation surprises in inflation and growth in the supply of T-secs on annualized real T-bill returns, 1920-46.

Table 3-Interest rate regressions for "buy-and-hold" strategy
Dependent variable: unanticipated real return on 3-month T-bill, $\hat{r}^u_{t,t+1}$

	g = Marketable T-Secs				g = T-Bills & Notes
	1920-99	1920-46	1947-79	1980-99	1980-99
constant	.0001	.0002	.0000	-.0000	-.0000
	(0.60)	(1.04)	(0.01)	(-0.24)	(-0.29)
$\hat{g}^u_{t-1,t}$	.0274	.0140	.0069	.0100	.0104
	(7.45)	(1.97)	(1.42)	(2.37)	(2.66)
$\hat{\pi}^u_{t,t+1}$	-1.082	-.9963	-.3837	-.3446	-.3537
	(-17.31)	(-9.43)	(-6.04)	(-6.54)	(-6.79)
$R^2/(DW)$	.361	.255	.092	.206	.216
	(1.98)	(1.19)	(1.70)	(1.81)	(1.77)
N	919	290	370	205	205

Note: The table presents coefficient estimates for Eq. 5 over the subperiods included in Figs. 2-6, with T-statistics in parentheses. The R^2 and Durbin-Watson (DW) statistics, and number of observations (N) for each regression appear in the final two rows.

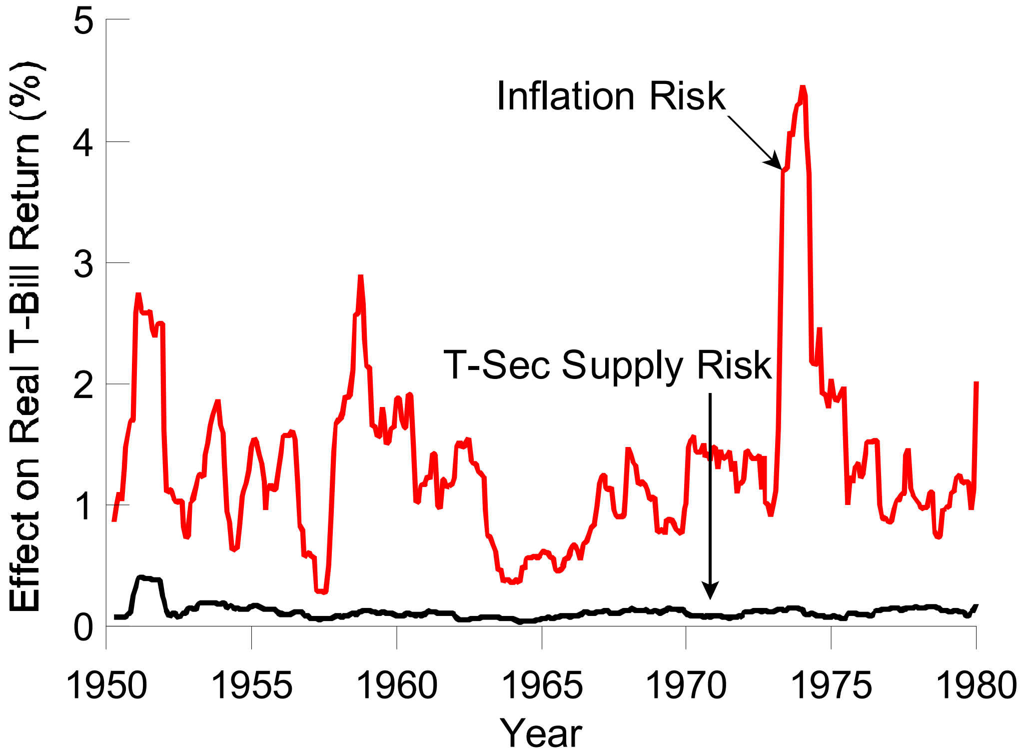

Figure 4: Effects, in percentage points, of one standard deviation surprises in inflation and growth in the supply of T-secs on annualized real T-bill returns, 1947-79.

Figures 3-5. We split the postwar period into pre-1980 and post-1979 segments because of the shift in Fed targeting policy that occurred in 1979. To accommodate the shorter sample periods, we limit the underlying VAR models to two lags and shorten the length of the estimation periods to 30 months. Table 3 includes regression results for Eq. (5).

Figure 3 reaffirms the importance of inflation risk in the pre-1947 period, including the 1933 and 1946 episodes. The effects of supply risk on T-bill returns rise at these same times and average 0.36 percent over the 1920-46 period, but are always less important than the effects of inflation risk, which averages 5.31 percent. In Figure 4, the narrower scaling reflects the overall decline in inflation risk that occurred from 1947-79, during which it averaged only 1.35 percent. Even though supply risk also fell to 0.12 percent over this same period, the decline is considerably less in percentage terms than that of inflation risk. Figure 5, on the other hand, shows that supply risk has if anything become more important over the past 20 years, averaging to 0.14 percent, while inflation risk continued to decline, averaging 0.99 percent.

By 1980, the Treasury had completed a long-term shift in financing away from

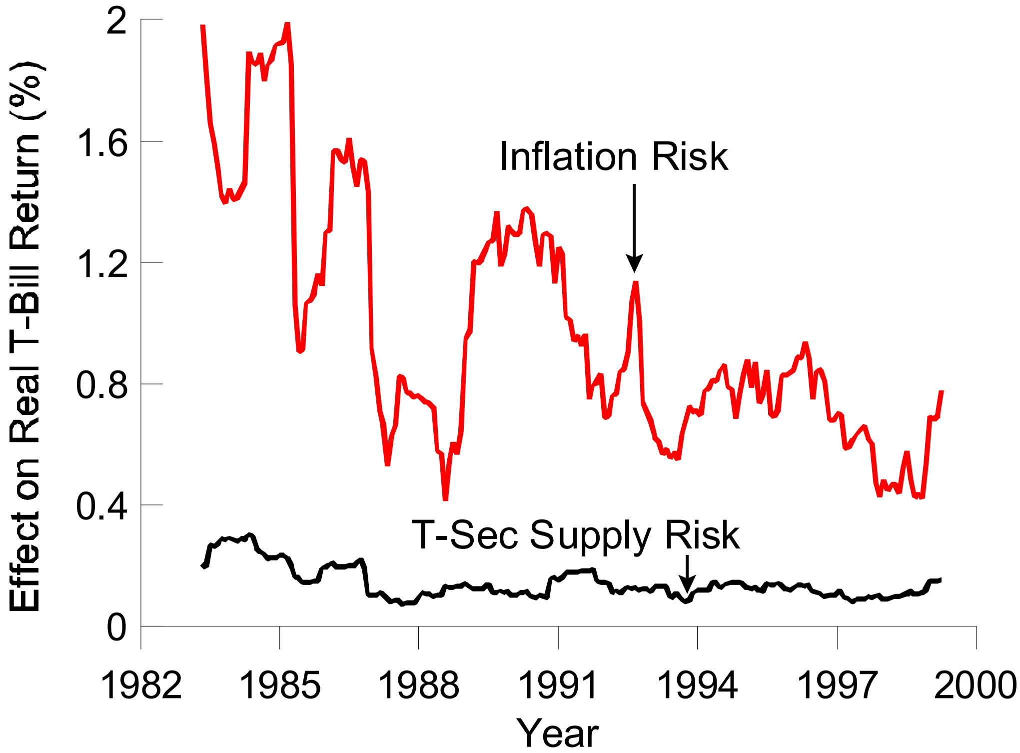

Figure 5: Effects, in percentage points, of one standard deviation surprises in the price level and T-sec supply on annualized real T-bill returns, 1980-99.

T-bonds and into shorter-term T-bills and T-notes (see Figure 14 in Section 4 below). It is therefore 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 T-secs. To see if this preference shift has influenced our results, we compute supply shocks to T-bills and T-notes only after 1980, and in Figure 6 once again display their effects on real T-bill returns. The results are similar to those observed for all T-secs, with average real effects of 0.16 percent and 1.0 percent respectively. Once again, supply risk grows in relative importance over time.

That bond-supply risk, which arises from committing funds to the T-bill market before supply is revealed, should even approach inflation risk in importance is quite striking. After all, if inflation surprises are measured over the entire term of the T-bill, they should affect ex-post yields virtually point-for-point.[11] To generate bond-supply risk, however, it is necessary for open market operations or variations in auction

[11] In this section, however, we measure inflation over only the first month of the T-bill term and then assess its effect on the three-month real yield. Even here we obtain coefficients on the inflation surprises that are close to unity for the 1920-99 period and the 1920-46 subperiod, though the coefficients are considerably below unity for 1947-79 and 1980-99.

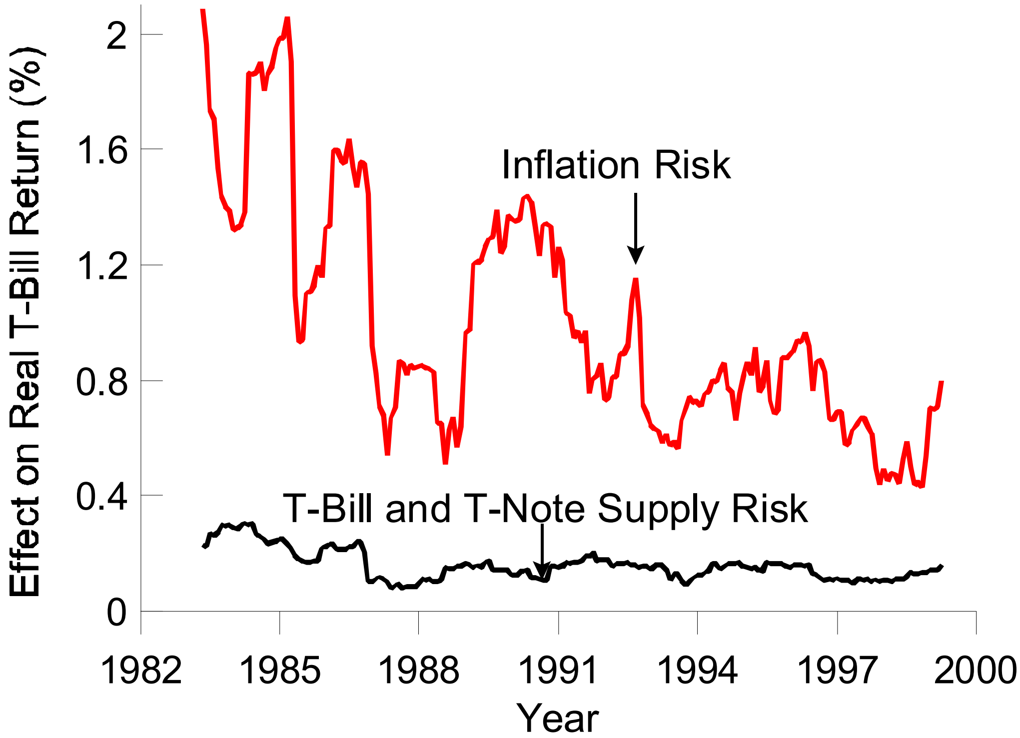

Figure 6: Effects, in percentage points, of one standard deviation surprises in inflation and growth in the supply of T-bills and T-notes on annualized real T-bill returns, 1980-99.

quantities to have large effects on interest rates, and this in turn suggests some degree of market segmentation. Otherwise, in the absence of segmentation, investors could offset T-sec supply shocks with transactions in the markets for substitute assets.

2.3 Bond-returns and stock returns

If stocks and bonds were perfect substitutes and if they traded in the same market, their real rates of return would always be equal. In such a world, an open market operation of the Fed or, indeed, any other event that changed the return on bonds would change the return on stocks by the same amount. For example a cut in the federal funds rate would cause bond prices and stock prices both to rise and the holding rate of return on each asset to fall. The presence of inflation risk on bonds and dividend risk on stocks would, perhaps, weaken the contemporaneous correlation between the ex-post real returns on the two assets, but would not eliminate it entirely.

One implication of this logic is that if the Fed's actions can affect the stock market, we should expect to find a positive correlation between bond returns and stock returns. Surprisingly, we find no evidence of a positive correlation between the two ex-post returns. We proceed as we did with T-bill returns, but now the dependent variable in Eq. (5) is the unanticipated component of the real return on the S&P 500, $\hat{s}^u$:

$$\hat{s}^u_{t,t+1} = a_0 + a_1 \hat{g}^u_{t-1,t} + a_2 \hat{\pi}^u_{t,t+1} + e_t \tag{6}$$

Table 4 presents our findings using surprises from the same VAR models that we used to examine T-bill returns. Interestingly, T-sec surprises never affect real stock returns. Inflation surprises, on the other hand, enter with the expected negative and significant coefficients in the 1947-79 and 1980-99 subperiods, but with a positive and significant coefficient for 1920-46. The latter result may be driven by a few extraordinary events, such as the sharp deflation and decline of equity values associated with the Great Depression and the inflation and rising market values of the immediate postwar period. In all, the evidence suggests that the stock market has been relatively unaffected by Fed policy.

In Table 5, we report contemporaneous correlations among the variables in our VARs (i.e., the variables themselves and not their surprises) and for the monetary

Table 4–Stock return regressions

Dependent variable: unanticipated real return on a 1-month investment in the S&P 500 portfolio, $\hat{s}^u_{t,t+1}$

	g = Marketable T-Secs				g = T-Bills & Notes
	1920-99	1920-46	1947-79	1980-99	1980-99
constant	-.0014	-.0033	.0014	-.0002	-.0008
	(-0.55)	(-0.50)	(0.57)	(-0.06)	(-0.19)
$\hat{g}^u_{t-1,t}$	.1085	-.0851	-.0558	-.2390	-.1476
	(1.20)	(-0.42)	(-0.36)	(-0.76)	(-0.503)
$\hat{\pi}^u_{t,t+1}$	0.2446	5.753	-5.571	-6.013	-6.296
	(0.16)	(1.92)	(-2.81)	(-1.53)	(-1.61)
$R^2/(DW)$	.002	.014	.022	.013	.014
	(1.76)	(1.96)	(1.84)	(1.78)	(1.77)
N	919	290	370	205	205

Note: The table presents coefficient estimates for Eq. (6), with T-statistics in parentheses. The R^2 and Durbin-Watson (DW) statistics, and number of observations (N) for each regression appear in the final two rows.

base over the 1920-99 period and the three subperiods.[12] Once again, links between stock returns and growth in bond supplies are weak and inconsistent across

[12] 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 5 begin in 1932 rather than in 1920.

Table 5–Correlations of real asset returns and real per capita quantities

	S&P	T-Bills	T-B/N	T-Sec	MBase
1920-99					
Real return on S&P 500	1				
Real return on T-bills	-.034	1			
Growth in real T-bills & notes	.046	.071	1		
Growth in real T-secs	.006	.110	.669	1	
Growth in real monetary base	.067	.235	.040	.142	1
1920-46					
Real return on S&P 500	1				
Real Return on T-bills	-.075	1			
Growth in real T-bills & notes	-.022	.108	1		
Growth in real T-secs	.040	.048	.680	1	
Growth in real monetary base	.064	.161	.067	.145	1
1947-79					
Real return on S&P 500	1				
Real return on T-bills	.028	1			
Growth in real T-bills & notes	.040	.096	1		
Growth in real T-secs	.003	.185	.575	1	
Growth in real monetary base	.011	.470	.017	.112	1
1980-99					
Real return on S&P 500	1				
Real return on T-bills	-.032	1			
Growth in real T-bills and notes	-.061	.188	1		
Growth in real T-secs	-.050	.208	.962	1	
Growth in real monetary base	.102	.064	-.065	-.003	

subperiods. For example, correlations between real growth in the T-sec supply and stock returns never exceed 0.05, and have the expected negative sign only for 1980-99. T-bill returns vary inversely with stock returns in all but the 1947-79 period, but in all cases the correlations are small. As it turns out, the most consistent correlations are positive ones between growth in T-sec quantities on the one hand and real T-bill returns on the other. This is true for the full 1920-99 sample period and for all of the subperiods. It is also as we might expect, since more T-secs in the hands of the public require higher interest rates to induce investors to hold them.

Since a rise in T-bills and T-notes in the hands of the public usually implies bond sales and, hence, a monetary tightening, it is surprising that growth in the real monetary base – a monetary loosening – seems to go hand in hand with bond sales (and the higher interest rates that they imply) in all but the 1980-99 period. To explore this further, we compute the correlations using growth in real per capita non-borrowed reserves, which is probably a closer indicator of policy stance than growth in the monetary base, for 1959-99 – the period over which we have a series for non-borrowed reserves. We find in this case that a monetary loosening, as measured by growth in non-borrowed reserves, also has an unexpected positive correlation with T-bill returns and T-sec growth, and that this result obtains for both the 1959-79 and 1980-99 subperiods.[13] This may again reflect important differences between indicators of policy stance that are based on monetary aggregates and our bond supply measures.

2.4 An alternative measure of real T-bill returns

Until now, we have considered the effects of bond-supply risk on T-bill returns under a buy-and-hold strategy. This, of course, is only one strategy that a T-bill investor might follow, as it is easy for an investor to liquidate a T-bill, and in particular after a supply or price shock has been realized. To analyze such a holding strategy, we now estimate Eq. (5) using surprises to the ex-post real one-month holding period return on a seasoned T-bill as the dependent variable.

The effects of supply risk should be different under this shorter-term strategy. This is because the investor now faces two sources of supply risk – one that occurs just before the bond is purchased, and another that occurs over the holding period. A positive shock after commitment but before purchase will lower the bond price and raise the real return, yet a similar shock over the holding period will lower the resale value of the bond. Thus, it is deviations of resale values from investor expectations that were formed prior to purchase that impart risk to the strategy.

To derive the equivalent of Eq. (4) for multi-period bonds, we again define the cost of such a bond at date t as $\frac{1}{P_t}$ units of real consumption. The bond's nominal return over the holding period is

$$i^*_{t,t+1} = \frac{P_{t+1} - P_t}{P_t},$$

where we introduce asterisks to reflect the change from the buy-and-hold investment strategy of Sections 3.1-3.3 to the seasoned one-month holding strategy considered here. The ex-post real return is again approximately, $r^*_{t,t+1} = i^*_{t,t+1} - \pi^*_{t,t+1}$ and, as in (1),

$$r^{u*}_{t,t+1} = i^{u*}_{t,t+1} - \pi^{u*}_{t,t+1}.$$

Now we need to be quite precise about the dating of information. Let

$${}_{t-1}z^u \equiv \text{ the surprise component of a random variable } z \text{ given } I_{t-1},$$

[13] The correlations of nonborrowed reserves for 1959-79 are .110 with the S&P, .216 with T-bill returns, .071 with T-bill and T-note quantities, and .091 with T-sec quantities. For 1980-99, the respective correlations are .104, .134, .068, and .087. Correlations of the real monetary base for 1959-79 are .096 with the S&P, .461 with T-bill returns, .010 with T-bill and T-note quantities, and .094 with T-sec quantities. The correlations of nonborrowed reserves with real T-bill returns differ from those reported in Table 1 because contemporaneous rather than leading relationships are considered here. In addition, the return measure in Table 1 reflects a one-month yield on a seasoned T-bill rather than the return to the "buy-and-hold" strategy considered here.

and suppose that

$$i^{u*}_{t,t+1} =_{t-1} \left(\frac{P_{t+1}}{P_t}\right)^u - 1 = \alpha\left({}_{t-1}g^{u*}_{t-1,t}\right) + b^*\left({}_{t-1}g^{u*}_{t,t+1}\right). \qquad (7)$$

The right-hand side of (7) is based on the logic behind (2). The first term deals with the denominator of the left-hand side; it is the one-step ahead surprise, and is the same as in (2). The second term deals with the numerator, P_{t+1}, and is a two-step-ahead surprise to growth in the bond supply. We shall compute this term as a VAR forecast using I^*_{t-1}. Isolating the return surprises on the left-hand side, we have the holding-period analog of (3):

$${}_{t-1}r^{*u}_{t,t+1} \approx \alpha\left({}_{t-1}g^{u*}_{t-1,t}\right) + b^*\left({}_{t-1}g^{u*}_{t,t+1}\right) - \left({}_{t-1}\pi^{u*}_{t,t+1}\right),$$

or, roughly, the linear relation that we shall estimate:

$${}_{t-1}\hat{r}^{*u}_{t,t+1} \approx a^*_1\left({}_{t-1}\hat{g}^{u*}_{t-1,t}\right) + a^*_2\left({}_{t-1}\hat{g}^{u*}_{t,t+1}\right) + a^*_3\left({}_{t-1}\hat{\pi}^{u*}_{t,t+1}\right). \qquad (8)$$

The final term in Eq. (8) is inflation risk over the holding period.

Under the buy-and-hold strategy that we considered earlier, we subtracted realized inflation over the three-month term of the T-bill and, assuming monthly compounding, and converted to a monthly return. The result there reflected an average of inflation over the next three months. Here we proceed slightly differently: For the one-month holding strategy, we subtract the one-month inflation rate that corresponds to the actual holding period.

Our analysis of one-month investments in seasoned three-month T-bills is limited to 1961 to 1999 – the period for which daily secondary market prices on U.S. Treasury securities are available from the New York Fed and the *Wall Street Journal*.[14] Using the composite "quote sheets," we collected the annualized yield-to-maturity on the final trading day of the month for the T-bill with closest to 60 days until maturity, and then recorded its yield on the final trading day of the next month. We then computed a synthetic annualized 30-day holding period yield as

$$R_{2,1} = \left[\frac{1 + \left(R_2 \frac{60}{365}\right)}{1 + \left(R_1 \frac{60}{365}\right)}\right] - 1,$$

where R_2 is the annualized yield-to-maturity on the reference T-bill with approximately 60 days until maturity, and R_1 is the annualized yield on the same T-bill a month later. Due to weekends, holidays, and the monthly calendar, we do not always observe prices 30 days apart, so our computation assumes that R_1, whenever

[14] We obtained the secondary market quotes for 1961-86 from the master microfilm reels that are on deposit at the New York Fed's Department of Public Information. Quote sheets for 1987-96 are available at their website (*http:www.ny.frb.org*). We collected quotes for 1997-99 from individual issues of the *Wall Street Journal*.

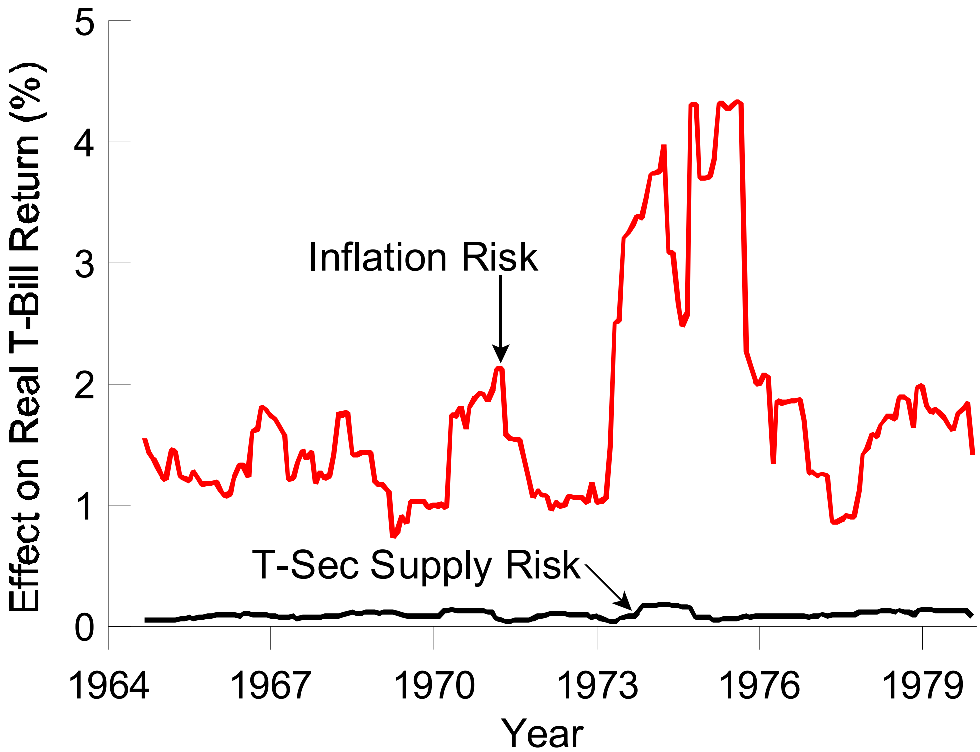

Figure 7: Effects, in percentage points, of one standard deviation surprises in inflation and growth in the supply of T-secs on the annualized real one-month return on T-bills, 1961-79.

observed, also applies on the 30th and final day of the holding period. This ignores changes in secondary market yields that might arise for a seasoned T-bill over at most a two-day period, but does not generate any systematic bias. We convert to real terms by subtracting CPI inflation.

After again obtaining surprises to T-bill returns, inflation, and growth of the T-sec supply from a series of 30-month rolling VARs with two lags and the S&P 500 return as a control, we use the coefficient estimates from Eq. (8) to compute the overall effects of supply risk over the course of a month (i.e., both pre-purchase and holding period risk) as the square root of

$$Var\left({}_{t-1}\hat{r}^{*u}_{t,t+1}\right) = (\hat{a}^*_1)^2\, Var\left({}_{t-1}\hat{g}^{u*}_{t-1,t}\right) + (\hat{a}^*_2)^2\, Var\left({}_{t-1}\hat{g}^{u*}_{t,t+1}\right) + 2\hat{a}^*_1\hat{a}^*_2 Cov\left({}_{t-1}\hat{g}^{u*}_{t-1,t}, {}_{t-1}\,\hat{g}^{u*}_{t,t+1}\right),$$

where the $Var(\cdot)$ terms are variances and $Cov(\cdot)$ the covariance. The effects of inflation risk are the product of a^*_3 and the standard deviation of the forecast errors for inflation. The series of variance-covariance matrices were obtained from 12-month rolling samples of the forecast errors. Figure 7 presents our results for the 1961-79

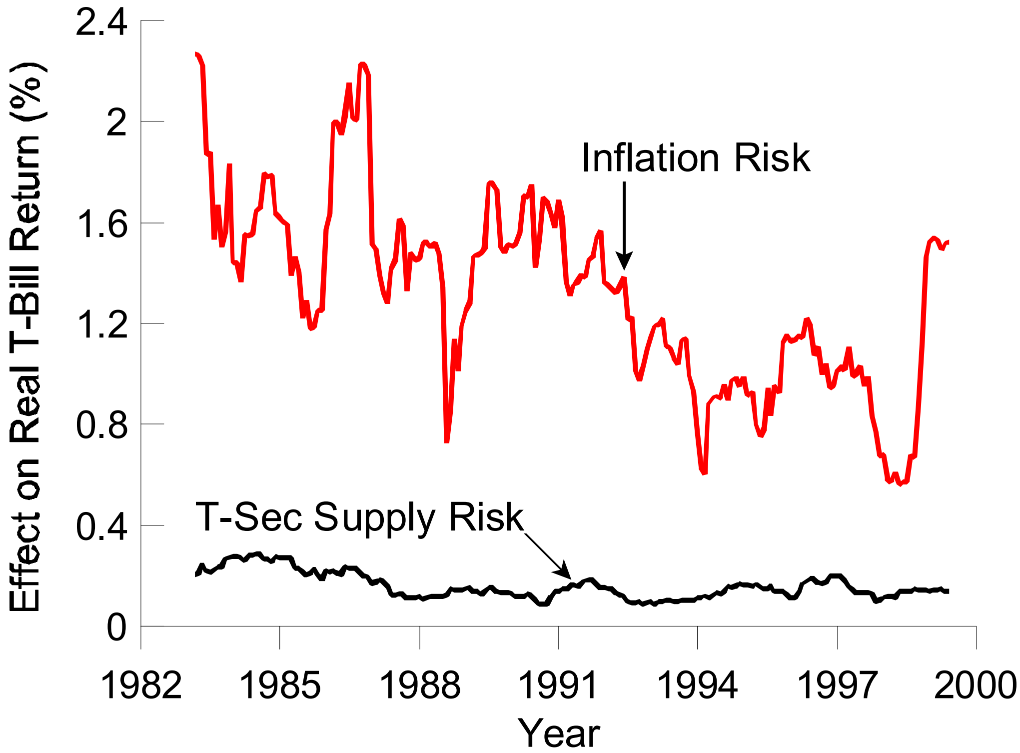

Figure 8: Effects, in percentage points, of one s.d. surprises in inflation and growth in the supply of T-secs on the annualized real one-month return on T-bills, 1980-99.

period, which have been annualized by compounding over 12 months. We report the corresponding estimates for Eq. (8) in Table 6.

In Figure 7, an inflation surprise of one standard deviation lowers the holding period yield by 1.77 percent on average. Like the results in Figures 2 and 5 for the "buy-and-hold" strategy, inflation risk rises to nearly 4.5 percent in the mid-1970's after fluctuating at about 1-2 percent throughout the 1960's. Supply risk, though not significant in Eq. (8), averages .10 percent, which is only slightly smaller than that observed under the buy-and-hold for 1947-79.

Figure 8 and two other columns of Table 6 cover the 1980-99 period, and offer a direct comparison with Figures 5 and 6. Whether we use all T-secs in the hands of the public (Figure 8) or only T-bills and T-notes (Figure 9) in forming $\hat{g}^{u*}$, the effects of supply risk on one-month yields are similar to those obtained under the 3-month buy-and-hold, averaging .16 percent and .21 percent in Figures 8 and 9, respectively. The coefficients on the pre- and post-purchase surprises to growth in the T-sec supply variables also have the expected and opposite signs, but are statistically significant only when T-bills and T-notes are included in $\hat{g}^{u*}_{t-1,t}$. This differs from the results

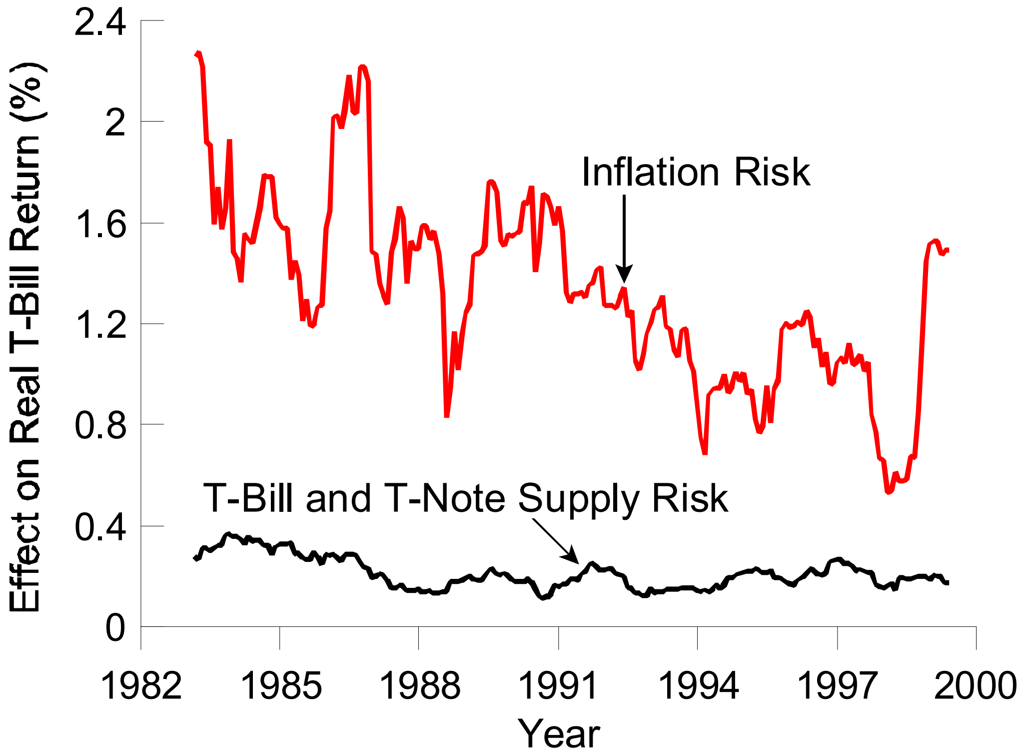

Figure 9: Effects, in percentage points, of one s.d. surprises in inflation and growth in the supply of T-bills and T-notes on the annualized real one-month return on T-bills, 1980-99.

Table 6–Interest rate regressions for 1-month holding strategy
Dependent var: unanticipated real return on T-bill ${}_{t-1}\hat{r}^{u*}_{t,t+1}$

	g = Marketable T-Secs		g = T-Bills & Notes
	1961-99	1980-99	1980-99
constant	.0000	.0001	.0001
	(0.17)	(1.12)	(1.03)
${}_{t-1}\hat{g}^{u*}_{t-1,t}$	.0046	.0061	.0075
	(1.02)	(1.28)	(1.77)
${}_{t-1}\hat{g}^{u*}_{t,t+1}$	-.0041	-.0064	-.0076
	(-0.83)	(-1.36)	(-1.76)
${}_{t-1}\hat{\pi}^{u*}_{t,t+1}$	-.9644	-.9370	-.9501
	(-27.10)	(-20.54)	(-21.32)
$R^2/(DW)$	.796	.683	.704
	(2.09)	(1.50)	(1.50)
N	196	205	205

Note: The table presents coefficient estimates for Eq. (8), with T-statistics in parentheses.

under the buy-and-hold, where our analysis of pre-purchase risk in isolation showed significant effects of supply surprises for total T-secs as well. Inflation risk is larger on average with the one-month holding strategy than with the buy-and-hold. The closeness of the coefficients on the inflation surprises to unity is also good news for our specification, as inflation should affect the real return point-for-point when the time periods for the inflation and return observations coincide.

Next, we again place the unanticipated component of the real S&P 500 return (s^{u*}) on the left hand side of Eq. (8) to obtain

$$_{t-1}\hat{s}^{u*}_{t,t+1} \approx a_1^* \left(_{t-1}\hat{g}^{u*}_{t-1,t} \right) + a_2^* \left(_{t-1}\hat{g}^{u*}_{t,t+1} \right) + a_3^* \left(_{t-1}\hat{\pi}^{u*}_{t,t+1} \right). \tag{9}$$

The results, which we report in Table 7, indicate that surprises to $\hat{g}$ do not generate substantive supply risk for investors who are about to buy the S&P portfolio, but that positive shocks after purchase *raise* one-month stock returns for the 1980-99 period. This runs counter to the standard view that stocks lose when the Fed tightens and gain when the Fed cuts rates.

Table 7–Stock return regressions for 1-month holding strategy
Dependent var: unanticipated real return on S&P 500, $_{t-1}\widehat{s}^{u*}_{t,t+1}$

	g = Marketable T-Secs		g = T-Bills & Notes
	1961-99	1980-99	1980-99
constant	-.0070	.0042	.0040
	(-1.89)	(1.12)	(1.07)
$_{t-1}\hat{g}^{u*}_{t-1,t}$	.1020	.3533	.3089
	(0.37)	(1.17)	(1.12)
$_{t-1}\hat{g}^{u*}_{t,t+1}$	.2447	.5797	.5693
	(0.81)	(1.93)	(2.03)
$_{t-1}\hat{\pi}^{u*}_{t,t+1}$	-4.153	.6752	.1401
	(-1.913)	(0.24)	(0.05)
$R^2/(DW)$	.023	.019	.020
	(1.93)	(1.71)	(1.73)
N	196	205	205

Note: The table presents coefficient estimates for Eq. (9), with T-statistics in parentheses. The R^2 and Durbin-Watson (DW) statistics, and the number of observations (N) for each regression appear in the final two rows.

The lack of significance on the coefficient for the pre-purchase surprise could simply suggest that the Fed cannot directly and consistently affect the stock market. The positive and significant coefficient on the holding period supply shock, on the other hand, is consistent with a policy of passive responses by the Fed to changing

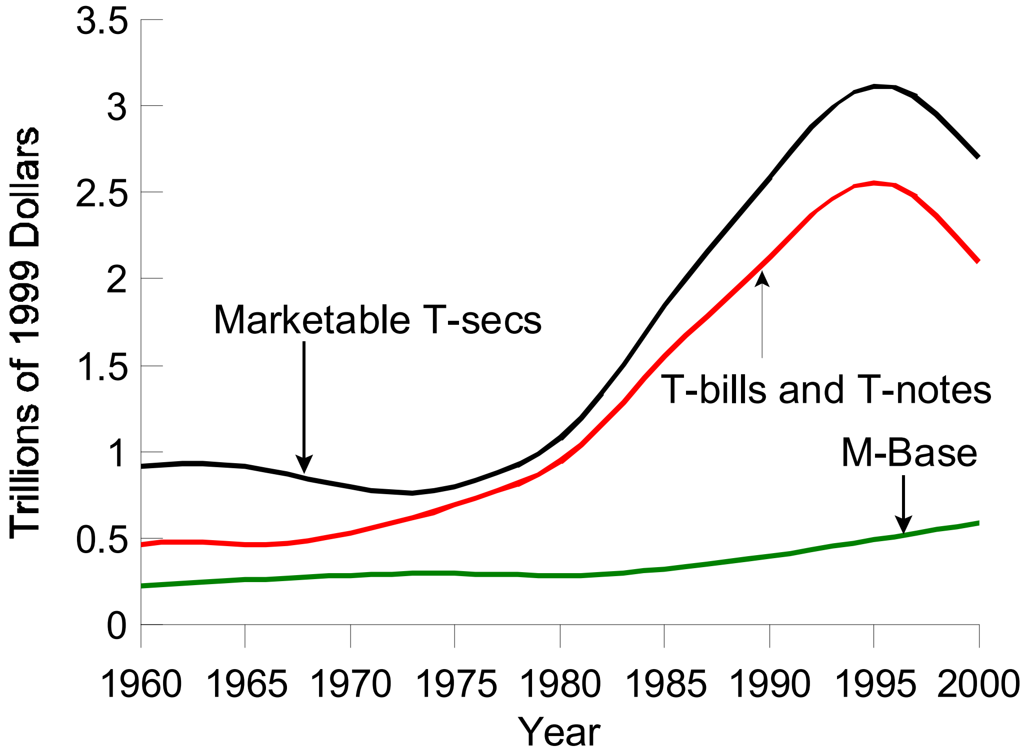

Figure 10: T-secs in the hands of the public and the monetary base, 1960-99.

conditions in other asset markets. For example, when the stock market is surging, the Fed may try to slow it down a bit by injecting bonds and raising interest rates. Since any relationship between Fed policy and the stock market is probably loose, however, the bond sale often seems to have little effect, and the market continues to push ahead.

3 The effects of foreseen policy changes: The secular decline of Treasury finance

The relative importance of T-bills and other marketable T-secs in the aggregate portfolio has declined over the postwar period. This should not matter for real interest rates if it is only surprises to the growth of bond supplies that matter. Indeed, most rational expectations models with money and no nominal rigidities specify no real effects for expected changes in the money or bond supplies. One such change is the gradual decline in outstanding T-secs, since this is probably well understood by agents in the bond and money markets. But this change may not be neutral, or at least may begin to matter soon if the trend continues. This is because fluctuations

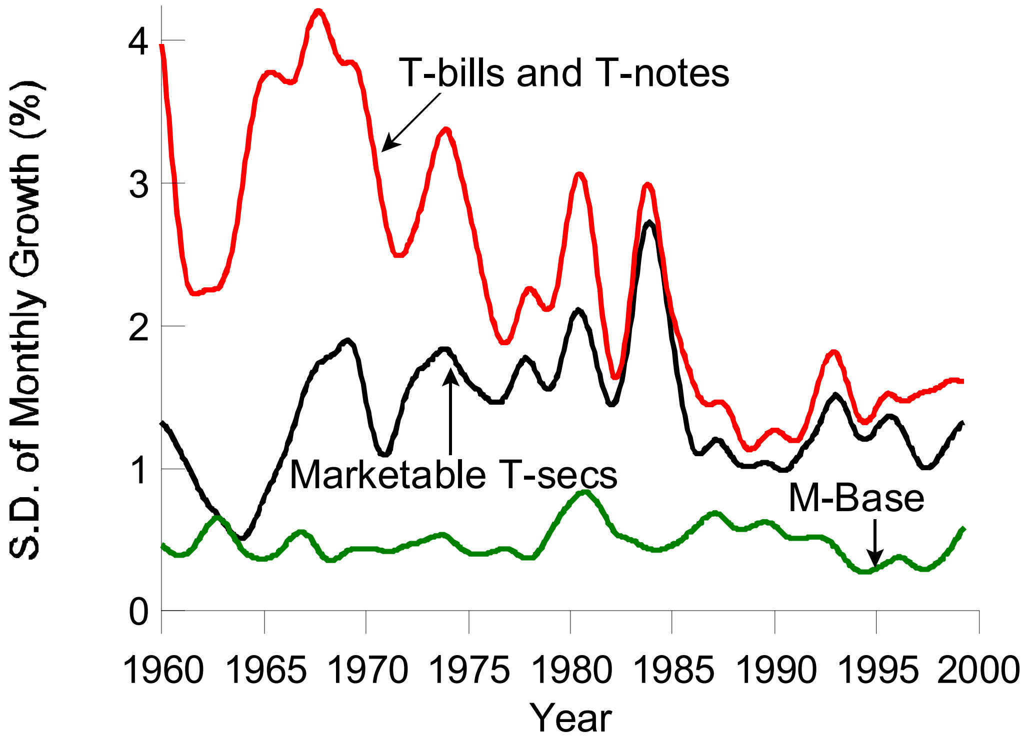

Figure 11: Rolling standard deviations of surprises to monthly growth rates of real per capita T-sec supplies and the monetary base, 1960-99.

in bond supplies stemming from rollover risk and other sources have become larger relative to the quantity of outstanding T-secs. Figures 10 and 11 suggest that such a trend may be emerging. Figure 10 shows that the amount of T-secs in the hands of the public has fallen since the mid-1990's. Figure 11, on the other hand, indicates that the standard deviation of the growth rate surprises (the cause of supply risk) has increased a little.[15] In this section, we document long-run trends in Treasury financing over the Fed's history and argue that their effects on supply risk up until now have probably been small.

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. Figure 12, which include the ratios of federal debt,

[15] We compute surprises to T-secs and the monetary base as one-step ahead forecast errors from a series of rolling bi-variate VARs with four lags and a 30-month estimation window.

In this figure and all others in this section, we apply the Hodrick-Prescott filter to our data series before plotting them.

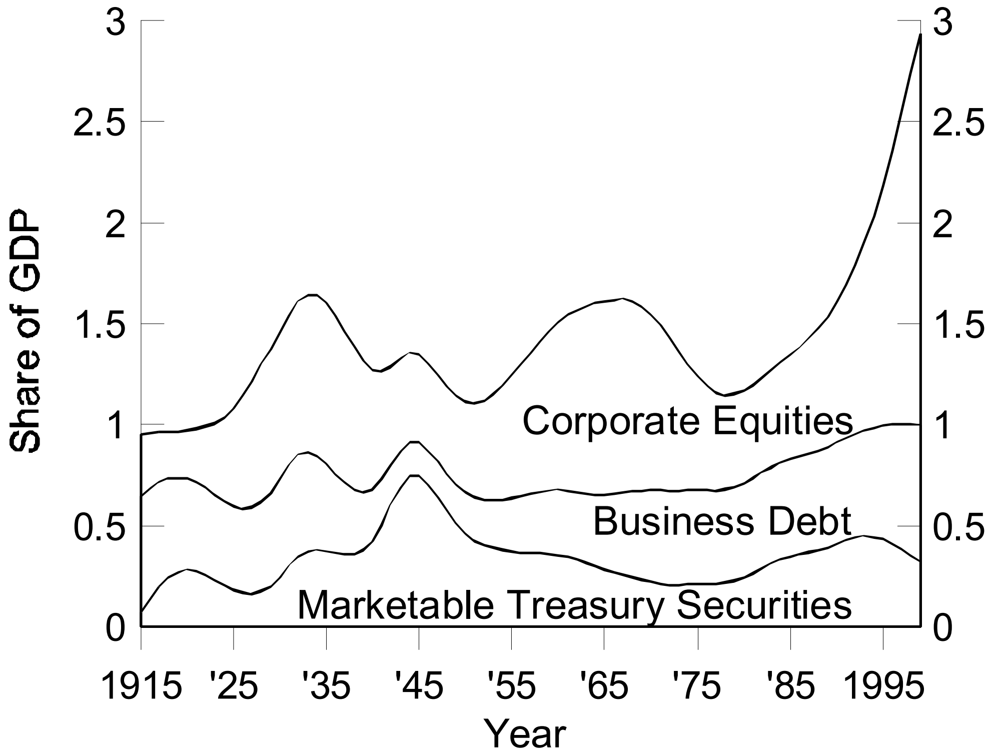

Figure 12: Outstanding Federal and business securities as shares of gross domestic product, 1915-99.

commercial and corporate debt, and corporate equities to gross domestic product, indeed shows 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. Figure 13 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 it remains a small part of total finance. (See Appendices C and D 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 14, 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 for evaluating the effects of supply shocks related to the Fed's open market

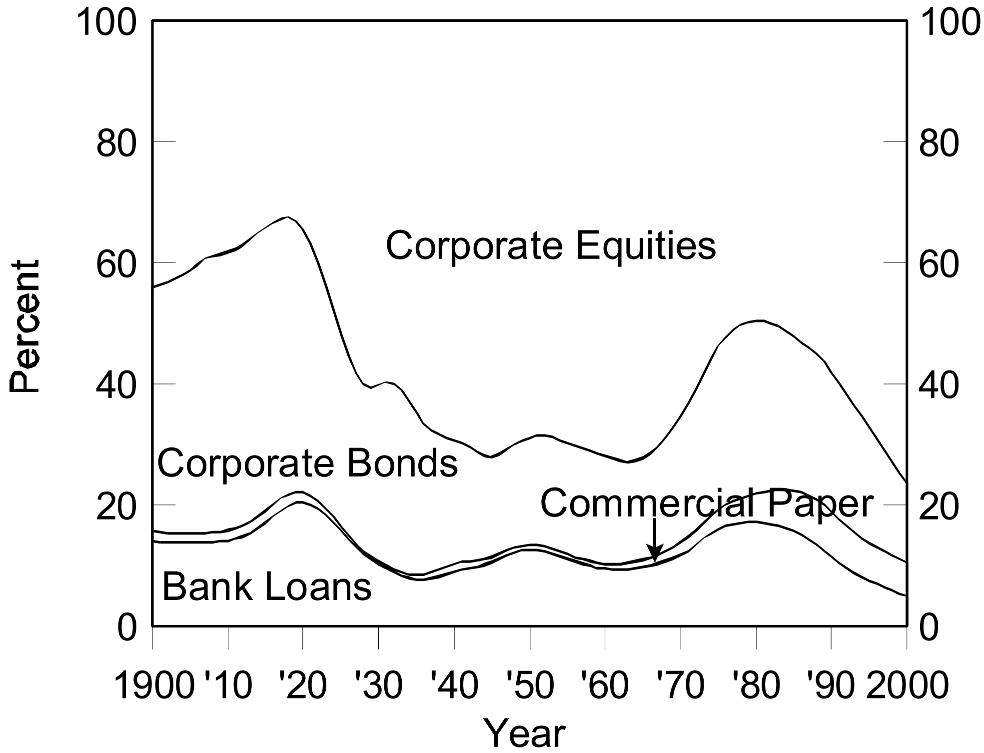

Figure 13: Corporate financing in the 20th century.

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 earlier in this paper. Interestingly, and in keeping with most rational expectations models, we found in most cases that the choice of supply variable did not matter.

Figure 12, when combined with the effects of changes in the supply of T-secs presented in Figure 2, suggests that the decline in the share of these securities in the aggregate portfolio has had little effect on the distribution of r_t – the real return on T-bills. 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.

4 Model

In this section, we present a segmented markets model that shows how policy can affect bond-rates but not stock prices. The model is also consistent with the non-effect

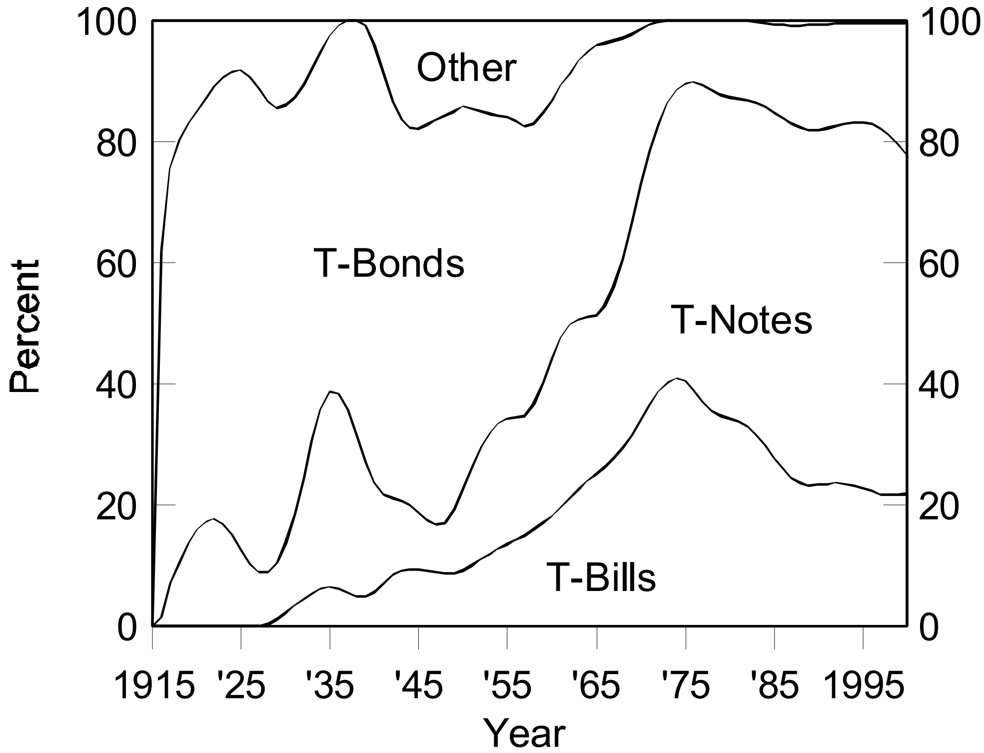

Figure 14: Marketable Treasury Financing, 1915-99.

of trends in policy that the previous section documents.

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 bond 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

$$E\left\{\sum_{0}^{\infty}\beta^{t}U\left(c_{t}\right)\right\}.$$

Stocks pay dividends y which obey the Markov transition law

$$\Pr\left\{y_{t+1}\leq y' \mid y_t = y\right\} = F\left(y', y\right).$$

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. The agent will spend all of these savings on bonds in the afternoon. In the morning, the agent's budget constraint is

$$c + p(z' - z) + m \leq x + yz - \tau. \tag{10}$$

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

$$m = \frac{1}{1+r} x'. \tag{11}$$

Government: Let

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

be the Markov transition law describing the bond-policy. Finally, let τ 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

$$\tau + m = x. \tag{12}$$

4.1 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 an equilibrium entails aggregate laws of the form

$$\begin{aligned} p &= P(y), \\ \tau &= T(x, y), \quad \text{and} \\ 1 + r' &= R(x, x', y) \end{aligned}$$

The agent's problem: We confront the agent with all possible pairs of personal and aggregate states, even those that will not arise in equilibrium, and derive his optimal behavior when faced with these hypothetical situations. The Bellman equation is

$$v(x, y, \tilde{x}, z) = \max_{c, z', m'} \left\{ \begin{array}{c} U(\tilde{x} + yz - T[x, y] - P[y][z' - z] - m) \\ \beta \int v(x', y', mR[x, x', y], z')\, dG(x', y', x, y) \end{array} \right\},$$

and the decision rules are of the form $z' = Z(x, y, \tilde{x}, z)$, and $m = M(x, y, \tilde{x}, z)$.

EQUILIBRIUM: 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

$$\begin{aligned} Z(x, y, x, 1) &= 1, & (13) \\ R(x, x', y) &= \frac{x'}{M(x, y, x, 1)}, \text{ and} & (14) \\ T(x, y) + M(x, y, x, 1) &= x & (15) \end{aligned}$$

Condition (13) ensures that an agent who holds the representative portfolio $z = 1$ will continue to hold it, and thereby willingly consume the dividend, y. Condition (14) re-states the bond market equilibrium condition (11). Finally, (15) ensures that the government's transfer, x, is covered by its lump-sum tax and bond issue.

4.2 Stock-returns, bond-returns, and their covariance

The equilibrium returns on stocks and on bonds are, respectively,

$$R_S \equiv \frac{[y' + P(y')]}{P(y)} \quad \text{and} \quad R_B \equiv R(x', x, y)$$

Evaluated at the equilibrium choices, the first-order conditions are

$$P(y) U'(y) = \beta E \{U'(y') [y' + P(y')] \mid y\} \tag{16}$$

and

$$U'(y) = \beta E \{U'(y') [R(x', x, y)] \mid x, y\}. \tag{17}$$

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

$$E\{R_S \mid x, y\} = \frac{1 - Cov\left\{\mu \frac{[y'+P(y')]}{P(y)}\right\}}{E\{\mu \mid y\}}, \tag{18}$$

and the expected return to bonds in state (x, y) is

$$E\{R_B \mid x, y\} = \frac{1 - Cov\{\mu R(x', x, y) \mid x, y\}}{E\{\mu \mid y\}}. \tag{19}$$

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 traded in the same market, the gross return on T-bills would be

$$R(y) = E\{\mu \mid y\},$$

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 $1 + r \equiv R(y) = x/M(y)$. A unit of consumption saved would then again guarantee $R(y)$ units in the next period, and the $T-$bill would then be a riskless asset.

In models like Lucas (1978) and Mehra and Prescott (1985), there is no role for Fed policy to affect the returns on either the risky or the safe security. We now derive the correlation of stock returns and bond returns and show that it does not depend on policy. Assume that the T-bill policy is of the form

$$x' = \phi(x, y, \eta), \tag{20}$$

where η is a random variable drawn independently each period. (If x' were to also depend on y', the Fed would be able to anticipate next period's output when setting this period's supply of bonds, and this it probably is not able to do). We can now precisely state a key consequence of the segmentation of the two markets: Neither the supply shock in the bond market, η, nor the dividend-shock in the bond market, can induce a correlation between the two variables.

Proposition 1

$$Cov(R_S, R_B \mid y) = 0.$$

Proof. PROOF: By (14),

$$R_B = \frac{\phi(x, y, \eta)}{M(x, y, x, 1)}.$$

Now, substituting from (20) into (17) and multiplying by $M(x, y, x, 1)/U'(y)$ leads to the librium T-bill investment decision,

$$M(x, y, x, 1) = \beta E\{\mu(y, y')\phi(x, y, \eta) \mid x, y\}, \tag{21}$$

and, hence to the equilibrium return on bonds:

$$R_B = \frac{\phi(x, y, \eta)}{\beta E\{\mu(y, y')\phi(x, y, \eta) \mid x, y\}},$$

and therefore

$$Cov\,(R_S, R_B) = Cov\left(\frac{[y' + P\,(y')]}{P\,(y)}, \frac{\phi\,(x, y, \eta)}{\beta E\,\{\mu\,(y, y')\,\phi\,(x, y, \eta) \mid x, y\}}\right) \tag{22}$$

Now, the only variable that affects both arguments on the right-hand side of (22) is y and the result follows. ■

In this model, then, the Fed influences the return on bonds, but it cannot affect the stock market price. The two returns could conceivably move together as y varies, but not because of a policy intervention.

4.3 Predictable policy shifts

In models like Alvarez *et al* (2001) and Grossman and Weiss (1983), the fraction of agents that take part in the bond market is exogenous, and even foreseen movements in bond sales can matter. Our model is, instead, like Lucas (1990), so that foreseen changes do not matter. We can now return to Figures 12 and the effects of changes in the supply of T-secs documented in Figure 2. Evidently, the relative decline in these securities has had little long run effect on the distribution of r_t.

The share of bonds in the aggregate portfolio is

$$S_B = \frac{M\,(x, y, x, 1)}{M\,(x, y, x, 1) + P\,(y)}.$$

Policy can reduce S_B by reducing x over time. But if the public expects it to occur, the decline in x will leave the distribution of R unaffected. Specifically, (and this will connect us to the material in section 3), we have

Proposition 2 *If $x' = \hat{\phi}\,(x, y)\,\eta$, where η is i.i.d., then*

$$M\,(x, y, x, 1) = \hat{\phi}\,(x, y)\,E\,\{\mu\,(y, y') \mid y\}\,E\,(\eta)\,.$$

is proportional to $\hat{\phi}\,(x, y)$, while

$$R_B = \frac{\eta}{E\,\{\mu\,(y, y') \mid y\}\,E\,(\eta)}$$

does not depend on the form of $\hat{\phi}$.

Proof. Substituting $\hat{\phi}\,(x, y)\,\eta$ for ϕ into (21) and using the independence of η leads to the first assertion. The second follows from (11). ■

The critical assumption here is that the distribution of η is fixed. As long as that distribution is indeed fixed, the public saves in proportion to the foreseen component of the policy $\hat{\phi}\,(x, y)$. Thus the relative importance of T-bills can decline and leave the distribution of the T-bill yield unchanged.

In the model, one can think of η as reflecting unpredictable rollover demands of foreign financial institutions and monetary authorities in the auction phase. Given current policy trends described in section 3, the distribution of η cannot remain fixed for much longer unless there is a change in the assets that the Fed uses to intervene in the money market. That is, this result presumes that the Fed will be able to meet its rollover demands with a constant variance of η, and yet this has become harder and harder to do because the gradual paying down of the federal debt has meant that the unpredictable component of T-bill growth will have to rise if the Fed is to meet the rollover demands from foreign sources. One way to avoid this is to expand the set of asset holdings that the Fed uses for this purpose.

5 Conclusion

If stocks and bonds trade in the same market, and if policy affects real-rates on bonds, then policy should also affect stock prices. Yet the bond and stock markets show a lack of comovement that is hard to explain unless one assumes that the markets are segmented. We presented a model in which stocks and bonds trade in separate markets, and in which unforeseen shocks to bond-supplies do affect short-term interest rates, but do not affect stock prices. Expected policy actions have no effect in the model; this is consistent with the non-effect of the long-run relative decline in bond-finance on the short-term interest rate.

We also found that bond-supply risk normally contributes between 10 and 40 basis points to the monthly movement in the real rate of interest on T-bills and that the effect has shown no tendency to decline over the past half century. Indeed, it will probably rise, as the gradual paying down of the federal debt has made it harder to expand T-bill issues to accommodate unexpectedly large rollover demands from foreign sources.

Appendix A: The nature of Bond-Supply risk in the U.S.

The Bond-supply risk arises when agents commit funds to the bond market before they know the price at which they will buy the bonds or the price at which they will be able to sell them afterwards. 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. Buyers are in luck when a bond-supply shock is positive because bond prices are then lower than expected and the rate of return is higher than expected. These agents get a good deal, and any real consequences are distributional because the shock has favored some agents at the expense of others.

To take part in the bond market, institutions must commit liquid assets to the new-issue and secondary markets. Primary dealers, who make competitive bids in the course of their direct interactions with the New York Fed in the conduct of Treasury auctions, pay for their winning bids when the new bonds are issued on the Thursday following the Monday auctions. Certain depository institutions and other broker/dealers may also pay for their winning bids on the date of issue. Other competitive bidders pay at the time of submission and are either refunded excess balances or called upon to remit additional funds based upon the final auction price and security allocations. A majority of secondary dealers, however, acquire new issues from primary dealers, and presumably pay for them upon delivery, though the bonds trade actively prior to their issue in a "when-issued" market. Noncompetitive tenders, or offers to purchase bonds at the final auction price, whatever that may be, are paid for up front on the auction day.[16] Noncompetitive bids at T-bill auctions are currently limited to $1 million per account, and they have accounted for only 10.4 percent of total auction sales since July 1998.[17] Thus, even though many bidders can 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 bids can become quite uncertain.

By "supply risk," in some cases, we mean "*residual*-supply risk." A large chunk of the demand for T-bills comes from the decisions of foreign financial institutions and international monetary authorities (FIMA) regarding whether to roll over their substantial and various holdings of bonds, and these rollover decisions affect the residual supply that will be available to the remaining traders because they count against the issue quantity stated in the auction announcement. Further, when FIMA make rollovers, they do so at the single auction price as noncompetitive bidders.[18] Many individuals also bid non-competitively, but, as mentioned above, the quantities of such bids are restricted and thus more predictable. All of this means that supply risk can arise at the auction stage, even though the Treasury announces the face value of the T-bills that it intends to issue. Since the public knows only the maturing quantity and not the rollover plans, randomness in these plans, from the perspective

[16] Noncompetitive bidders who specify a bank account for direct debit under the *Treasury Direct* investment plan also do not pay for their bills until the issue date.

[17] We 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.*

[18] Before November 1998, marketable Treasury securities were auctioned in a discriminatory fashion, with the highest bidders receiving their requested quantities in full at the tendered price subject to a maximum of 35 percent of the total quantity auctioned (this "35 percent rule" is still in effect). Noncompetitive bidders received their requests in full at prices based on a weighted average of accepted competitive bids. Both auction systems, discriminatory and single-price, generate some degree of supply risk.

of the dealer, makes the final auction price less predictable.

The Fed itself must also decide whether to roll over portions of its own portfolio of maturing bonds at the final noncompetitive price. The securities that the Fed rolls over do not count against the total offered to the public in that week's auction and, thus, have at best a minimal impact on the final auction price, but they will affect the size of subsequent auctions. For example, if the Fed rolls over only half of the bills that it could have in a given auction, to maintain a constant debt level the Treasury would need to arrange a larger issue for the next week. It seems, however, that the Fed's rollovers, at least in recent years, have been quite predictable – the Fed rolls over its entire holdings unless that would exceed its self-imposed limit on individual securities holdings, in which case it redeems enough to meet that limit.

The Treasury has changed its usual procedures twice recently with regard to foreign rollovers, and the nature of these changes suggests that it may be trying to reduce supply risk. In early 1999, auction announcements still specified that the Treasury could, at its discretion, issue additional securities for foreign accounts whenever the total of new bids from these sources exceeded their total holdings of maturing bills. Beginning with the T-bill auctions of March 29, 1999, however, the Treasury usually 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 common as 1999 progressed. The change signaled a more accommodative stance by the Treasury that would have reduced residual supply risk by limiting the degree to which unexpected noncompetitive rollover decisions could affect the final auction price. As of February 1, 2001, however, the Treasury has allowed only $1 billion in total foreign noncompetitive tenders, and that limit cannot be exceeded.[19] Foreign institutions seeking to purchase large amounts of T-secs at auctions must now bid competitively. Even though this change might ameliorate disturbances that would impede the systematic paying down of the federal debt, it is also likely to raise residual supply risk.

Cammack (1991, p. 110) reports that the Fed and FIMA combined to buy 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 the time-series variation of the winning bids, because losing bidders (of which there are more either immediately or in future auctions when the Fed absorbs its limit) must end up holding cash or a lower-return substitute.

[19] Foreign bids are now restricted to $200 million or less per account, and are filled from smallest to largest until the $1 billion total limit is reached. The size of foreign bids will be restricted to $100 million or less as of January 1, 2002.

Appendix B: Estimating the impact of price and T-sec supply risk on real T-bill returns

The methodology underlying Figures 2-9 begins with adjusting the raw data to make the timing of monthly observations consistent across variables. Since the nominal quantity of T-secs in the hands of the public (X_t) are available at the end of each month while the consumer price index (CPI_t) and population (pop_t) are computed as annualized monthly averages, we derive the real quantity of Treasury securities at the end of month t as:

$$x_t = 4 \times \frac{X_t}{(CPI_{t+1} + CPI_t) \times (pop_{t+1} + pop_t)},$$

which amounts to averaging the consumption deflator and population across periods to center them with X_t.

To approximate the ex-post real return on T-bills ($r_{t,t+1}$) associated with the buy-and-hold strategy (Sections 3.1-3.3), we start with the annualized yields to maturity on three month (91 day) T-bills that are computed by the Fed as averages of daily yields over the course of a calendar month (R_t), and subtract the annualized inflation rate implied by the change in the CPI over the next three months. Since the CPI is a monthly average and R_t is annualized, we have

$$r_{t,t+1} \approx \left[1 + \left(R_t - \left[\left(1 + \frac{CPI_{t+3} - CPI_t}{CPI_t}\right)^4 - 1\right]\right)\right]^{\frac{1}{12}} - 1.$$

This is the monthly real return that an investor would receive by buying a three-month T-bill and holding it until maturity, assuming that inflation rate is steady across the three months.

The nominal return on the S&P 500 (S_t) covers an actual calendar month, and so we derive an ex-post return by subtracting the growth rate of the consumer price index (CPI_t).

$$s_t = S_t - \left[\left(\frac{CPI_{t+1} - CPI_t}{CPI_t - CPI_{t-1}}\right) - 1\right],$$

which amounts to computing the growth in the CPI after averaging across periods.

Before using the series derived above (as well as CPI inflation itself), we de-seasonalize by regressing each on monthly dummy variables and an adequately high-order polynomial in time. We include the time polynomial to reduce the degree to which the estimates of the monthly effects reflect cyclical and trend components. After subtracting 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.

The VAR equations used to compute the surprises to growth in the supply of T-secs (g) and inflation (π) have the form

$$\begin{aligned} g_t &= \sum_{i=1}^{k} c_{1,k}\, g_{t-k} + \sum_{i=1}^{k} d_{1,k}\, \pi_{t-k} + \sum_{i=1}^{k} f_{1,k}\, r_{t-k} + \sum_{i=1}^{k} h_{1,k}\, s_{t-k} + t + e_{1,t} \\ \pi_t &= \sum_{i=1}^{k} c_{2,k}\, g_{t-k} + \sum_{i=1}^{k} d_{2,k}\, \pi_{t-k} + \sum_{i=1}^{k} f_{2,k}\, r_{t-k} + \sum_{i=1}^{k} h_{2,k}\, s_{t-k} + t + e_{2,t} \end{aligned}$$

where k is the lag length and t is a linear time trend. The time subscripts refer to the information sets I_{t-k} from which the variables derive To allow the forecasts to reflect recent economic conditions, we allow the VAR samples to roll with time, choosing estimation windows of 36 months (Figure 2) or 30 months (Figures 3-9). This implies that each successive one-step ahead forecast and forecast error is computed with a information set that overlaps the previous one in all but the latest and earliest periods. Using the coefficients from the time t regression, we compute the forecasts for time $t+1$ as fitted values obtained with the information set from time t.

In estimating 4, we pool the monthly surprises across the sample period to obtain a single set of regression coefficients.

Appendix C: 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.

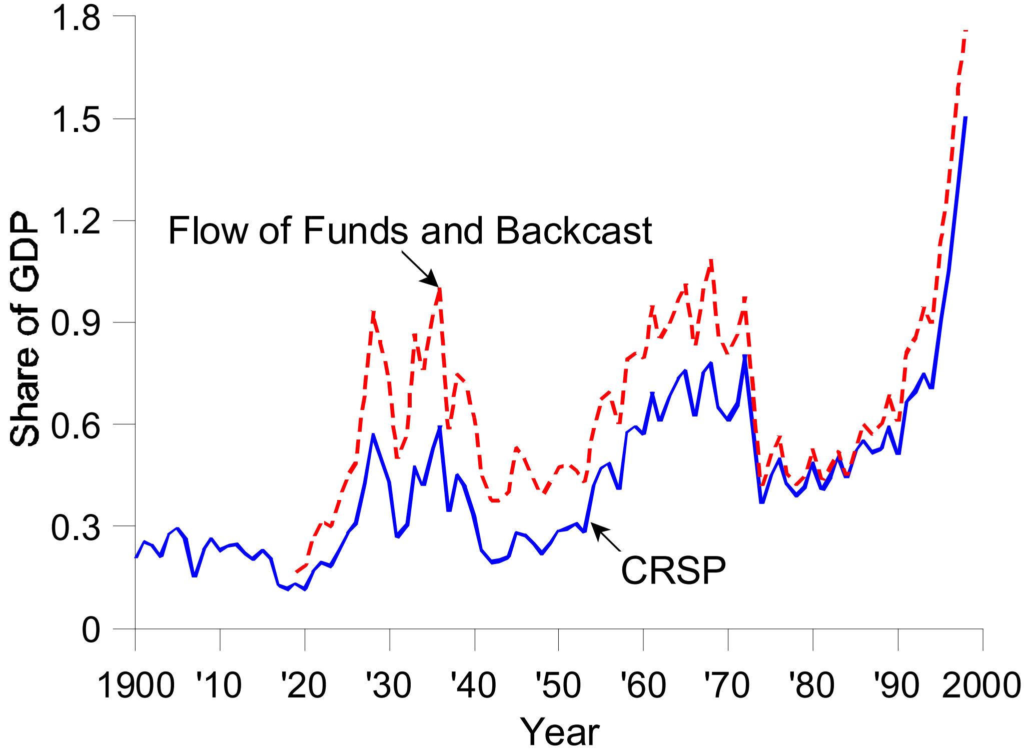

Figure 15: Estimates of Outstanding Equity, 1900-1999.

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 prior to 1920 in Figures 12-14, 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 D: 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

$$r_t^* = \frac{1}{\sum_{i=1885}^{t} (1-\delta)^{t-i}} \sum_{i=1885}^{t} (1-\delta)^{t-i} r_{t-i}.$$

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.

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