

Figure 9.1

a result of investor demands for a greater risk premium to compensate for the higher likelihood of default. If higher credit risk could not explain the movements of U.S. Treasuries at the time of the downgrade, what could?

In this chapter we examine the risk and return trade-offs of fixed income securities. We first assume that Treasuries are risk free and discuss the factors driving risk-free bond returns. We then consider corporate bonds, which add the dimension of credit risk, and other types of risks.

2. Monetary Policy and the Level Factor

Understanding the factors affecting bonds requires understanding the most important player in bond markets—the Federal Reserve, America's central bank, known as the Fed.

2.1. THE FEDERAL RESERVE

Monetary policy is one of the primary drivers behind interest rates because of the way monetary policy responds to macro factors. Monetary policy is officially set by the Federal Open Market Committee (FOMC), a Fed panel with membership comprising the Fed Chair, the seven members of the Federal Reserve Board, and five of the twelve regional Federal Reserve Bank presidents (the president of the Federal Reserve Bank of New York always sits on the committee, a “first among equals”).² The current Fed Chair, Janet Yellen, was appointed on February 1,

²The convoluted setup of the Fed was the result of a series of compromises between politicians in the rural and west versus the east and between politicians and businesses, as described at length

2014. The previous Fed Chair was Ben Bernanke who served from February 1, 2006 to January 31, 2014. Before Bernanke, Alan Greenspan was the Fed Chair from August 11, 1987 to January 31, 2006.

The Fed traditionally implements monetary policy by intervening in the Federal funds market. This is where banks (*depository institutions*) lend or borrow money (*Fed funds*) overnight through the Fed to maintain reserve requirements. Banks with *excess reserves* lend them to other banks that need money. This market is bilateral, meaning banks needing funds seek out banks willing to lend funds on a one-to-one basis, and banks pay different rates for funds depending on who is lending and who is borrowing. Each pair of banks, therefore, borrows or lends at a different *Fed funds rate*. The *effective Fed funds rate* is the volume-weighted average of these rates across the banks. The Fed intervenes in this market through *open market operations* (a fancy term for buying and selling bonds) so that the market rates bear some resemblance to the *target federal funds rate*, which is set by the FOMC. Since December 16, 2008, the Fed has specified a *range* for the target federal funds rate of 0% to 0.25%.

Monetary policy is conducted at the very shortest end of the yield curve—the overnight market—and only among banks. But the Fed ultimately wants to influence the long end of the yield curve, with maturities of ten to thirty years and also the prices of corporate and agency debt in addition to those of long-term Treasuries. The way short-end monetary policy ultimately affects the economy is through the *transmission mechanism*.³ Since the financial crisis, the Fed has conducted *nonconventional* monetary policy by directly buying or selling long-dated Treasuries and a large variety of (sometimes very) risky credit instruments. *Quantitative easing* falls in this series of nonconventional programs. Before the financial crisis, experts would have called you crazy if you had suggested that monetary policy would now be conducted by the direct purchase of commercial paper (CP), agency debt, and debt of government-sponsored enterprises (Fannie Mae, Freddie Mac, and the Federal Home Loan Banks), residential mortgage-backed securities, commercial mortgage-backed securities, collateralized debt obligations, and so on, plus direct loans to JP Morgan Chase (“Maiden Lane”), AIG (“Maiden

in Meltzer (2003). The locations of the Federal Reserve Banks largely correspond to the main areas of economic activity at the time of the creation of the Federal Reserve System in 1913: Atlanta, Boston, Chicago, Cleveland, Dallas, Kansas City, Minneapolis, New York City, Philadelphia, St. Louis, and San Francisco. The one exception is the former capital of the Confederacy, Richmond, which was selected largely because it was in the home constituency of Carter Glass, the Democratic congressman who helped write the Fed’s enabling legislation. The regional Federal Reserve Banks are owned by commercial banks, but the stock is not tradeable. The Federal Reserve Board of Governors is an independent federal agency. For more information on Fed governance, see Gerdesmeier, Mongelli, and Roffia (2007), who also compare the Fed with the European Central Bank and the Bank of Japan. Full disclosure: I have received consulting fees from the Federal Reserve Board of Governors and the Federal Reserve Bank of New York.

³The standard reference is actually by the former Fed Chair, Bernanke and Blinder (1988).

Lane II" and "Maiden Lane III"), Citigroup, and Bank of America. In my opinion, unconventional monetary policy is likely to become conventional, and interventions in the Fed funds market will be just one of many weapons in the Fed's arsenal.

For now, let's concentrate on conventional monetary policy. It may seem incredible that the Fed can affect the yields of thirty-year corporate bonds by influencing interest rates in a bank-to-bank market where funds are lent overnight, but these monetary policy actions turn out to be one of the most important drivers of all bond prices.

2.2. THE LEVEL FACTOR

Figure 9.2 plots the Fed funds rate in the solid line and the three-month T-bill rate in the dashed line from July 1954 to December 2011. The correlation between the two series is 0.99: whatever happens in the Fed funds market is mirrored in the T-bill market almost one for one. Since the 1950s, interest rates have a remarkable triangle-shaped pattern: they reached a maximum during the late 1970s and early 1980s when three-month T-bills topped 15%.⁴ During the 1970s, inflation soared

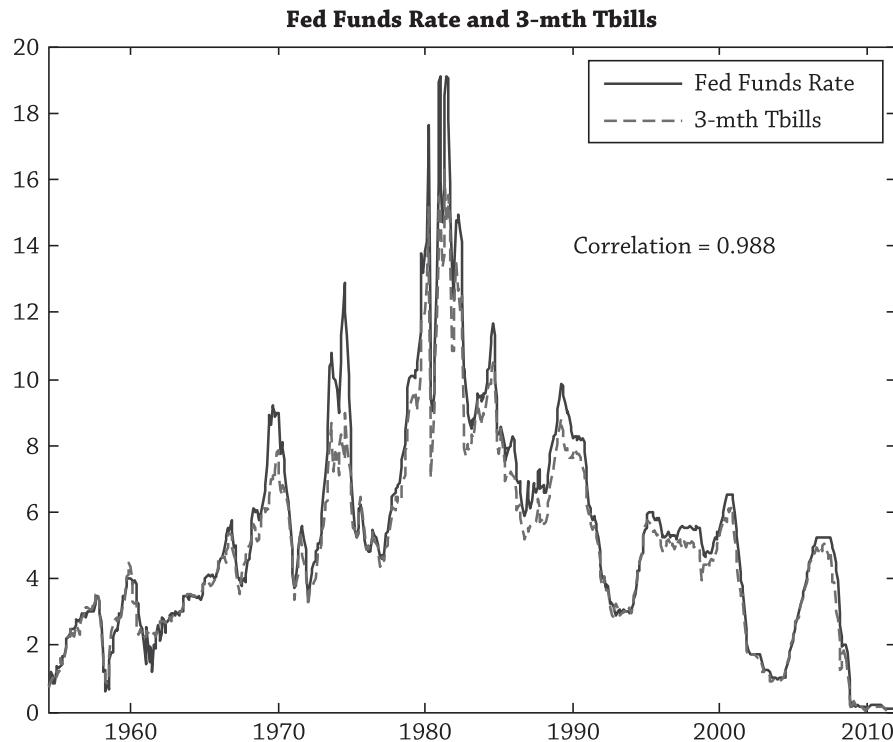


Figure 9.2

⁴On average, the T-bill yield has been *lower* than the Fed funds rate, as can be seen in Figure 9.2. This is partly because the Fed funds market, consisting of banks, has credit risk whereas the Treasury

(*the Great Inflation*) until Fed Chair Paul Volcker brought it under control in the 1980s. (I describe the inflation experience in more detail in chapter 11 where I discuss “real” assets.) There have been notable cycles around this broader up and down interest-rate trend. The Fed cut interest rates sharply after the 9/11 attacks, and the economy was in recession for most of 2001. The Fed held interest rates low for two years after these events, around 1%, and started to raise them again in 2003. Most recently, the Fed cut interest rates during the global financial crisis of 2008 and 2009, although interest rates already had begun to fall in 2007. They have remained almost zero (below 25 basis points) since, giving the Fed a *zero lower bound* problem: how do you conduct monetary policy when the policy rate cannot go any lower? This is one reason that quantitative easing and other nonconventional monetary policy programs have been introduced.⁵

Very often, long-term Treasuries move in tandem with short-term Treasuries. Figure 9.3 plots the Fed funds rate and the ten-year Treasury yield from July

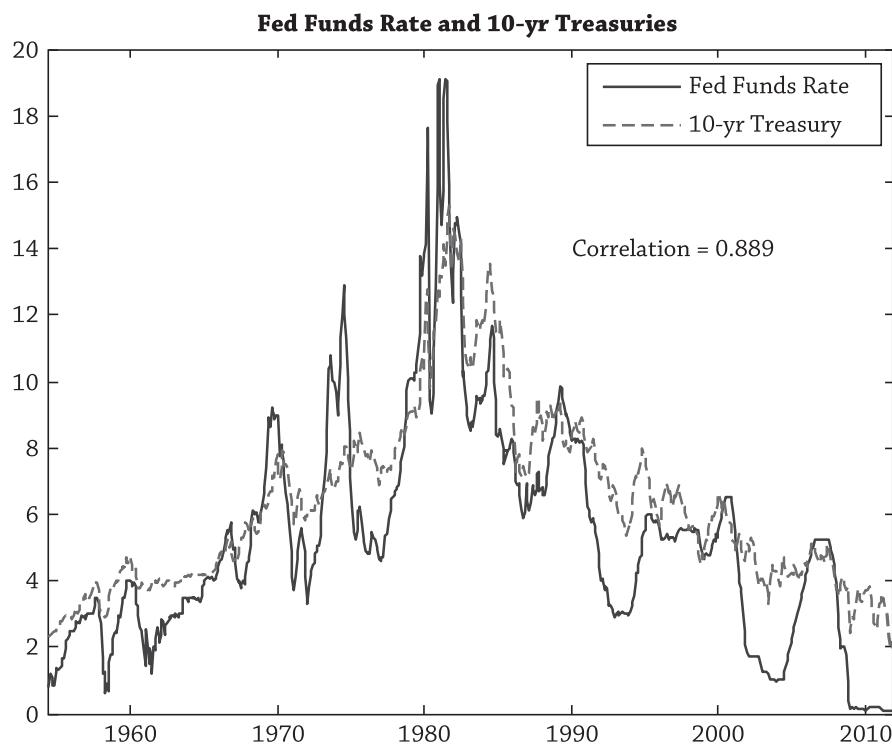


Figure 9.3

market is risk free, Standard & Poor’s opinion notwithstanding. Also, T-bills can be used as collateral, which increases T-bill prices and reduces T-bill yields, while Fed funds cannot. Finally, the T-bill market is much larger and more liquid than the Fed funds market.

⁵Conducting monetary policy when policy rates are at zero had been well studied before the financial crisis because the problem has afflicted Japan for the past twenty plus years. It is called *zero interest-rate policy*. One of the ways to conduct monetary policy in this environment is quantitative easing, which the Fed practiced during and after the financial crisis (see, e.g., Goodfriend (2000)).

1954 to December 2011. The correlation is 0.89, lower than the almost perfect correlation for the Fed funds rate and T-bills but still very high. Treasury yields have the same triangle pattern as the short end of the yield curve, but there are some periods of pronounced differences between the short and long ends of the curve. Below we discuss what drives this *term spread*, but notice that the whole yield curve displays a strong degree of commonality with the Fed funds rate.

The strong co-movement of the Fed funds rate and the entire Treasury yield curve is captured by a *level factor*. The level factor simply describes the tendency of all bond yields to move up and down together, largely in line with the Fed funds rate. Level factor movements constitute the vast majority—above 90%—of movements across all maturities in the yield curve (or the *term structure of interest rates*).⁶ The exposure to level is known as *duration*. This is analogous to beta in equity markets, which measures exposure to the market equity factor (see chapter 6). Duration is the beta of bonds with respect to level shifts of interest rates. Other factors influencing bond returns are *slope* or the *term spread*, which describes the movements of the long end of the yield curve relative to the short end, and *curvature*, which allows the middle of the yield curve to move independently of the level and term spread. But the most important factor is level.

Factors are extremely important in fixed income. It is instructive to compare fixed income with equities in this regard. In equities, idiosyncratic risk is large, constituting 80% to 90% of return variance, and systematic factor risk is small (10% to 20%). Intuitively, each company is different—firms have different managers, plants, employees, and production technologies even when they operate in the same sector. In fixed income, the idiosyncratic risk component is quite small—often less than 1% for risk-free Treasuries. Systematic factor risk, especially level, dominates.

Consider a five-year Treasury bond. This bond is highly correlated (approximately 98%) with the six-year bond, which is highly correlated (approximately 98%) with the seven-year bond. The risk-free cash flow streams of these bonds are fixed, as we assume that the Treasury will pay. Thus, the only uncertainty is the rate at which the cash flows are discounted. The seven-year bond is subject to the same discount rate as a one-year bond, plus a rate prevailing between years one and seven (this is called the *forward rate*). Similarly, the six-year bond is subject to the short-term one-year discount rate, plus a rate prevailing between years one and six. Thus, whatever affects the short-term rate gets propagated through the yield curve—each long-term bond moves in response to the one-year rate as well as shocks that affect longer maturities. The short, one-period rate affects *all* bond prices. This is why the level factor, or the level shift, is so important in fixed income.

Idiosyncratic risk does increase as you move through the risk spectrum of fixed income from sovereigns, to agencies, to investment grade corporate bonds, and

⁶See, among others, Litterman and Scheinkman (1991).

then to high-yield bonds, but for all of these bonds, the main effect is the level factor. To understand fixed income investments, therefore, investors have to understand the level factor. The level factor acts like the Fed funds rate, so we need to understand how the Fed sets monetary policy.

2.3. THE TAYLOR (1993) RULE

The current goals of the Fed are outlined in the 1977 Federal Reserve Reform Act. The Fed

shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of *maximum employment, stable prices, and moderate long-term interest rates*.

The italics are mine. The last of these three goals gets relatively little attention but, in my opinion, empowers the Fed to take actions that will reduce uncertainty. During the financial crisis, the Fed undertook *extraordinary measures* to stabilize the monetary system and the economy, which certainly reduced volatility. This was done under Section 13(3) of the 1913 Federal Reserve Act, which authorizes the Fed to lend money to anyone "in unusual and exigent circumstances." Prior to the financial crisis, it was last invoked during the Great Depression. The first two considerations of "maximum employment" and "stable prices" are called the *dual mandate*, which some scholars consider a contradiction (a "dueling mandate").⁷ Although "low inflation" is not necessarily "stable prices," the stable price mandate has been traditionally interpreted as a low inflation mandate.⁸ Many central banks, including the European Central Bank, do not have a mandate for economic growth and only have a mandate for price stability. Since the financial crisis, many central banks, including the Fed, have added a *financial stability* mandate.

We know a great deal but far from everything about the Fed's decision-making process. Minutes of FOMC meetings are made public three weeks later. But detailed transcripts along with other materials, which include detailed internal forecasts, are only available after a five-year lag. Even then, anyone who has served on committees knows that often the actual (often dirty) work happens before the committee meeting between select groups of people, so minutes or transcripts do not necessarily capture what is really going on. While some researchers have used

⁷ See, for example, the study of Labonte (2012) done for Congress, which criticizes the dual mandate. De Long and Summers (1988) make a case for the dual mandate.

⁸ See Goodfriend (1999). Since January 2012, the Fed considers that "inflation at the rate of 2 percent, as measured by the annual change in the price index for personal consumption expenditures, is most consistent over the longer run with the Federal Reserve's statutory mandate." See <http://www.federalreserve.gov/newssevents/press/monetary/20120125c.htm>.

these minutes, transcripts, and other materials to describe Fed behavior,⁹ an important alternative is a reduced-form model developed by the Stanford University economist John Taylor in 1993.

The famous *Taylor rule* states that the Fed funds rate should be set to move together with inflation and economic activity. Its original formulation was

$$FF_t = r^* + \pi_t + 0.5(\pi_t - \pi^*) + 0.5Gap_t, \quad (9.1)$$

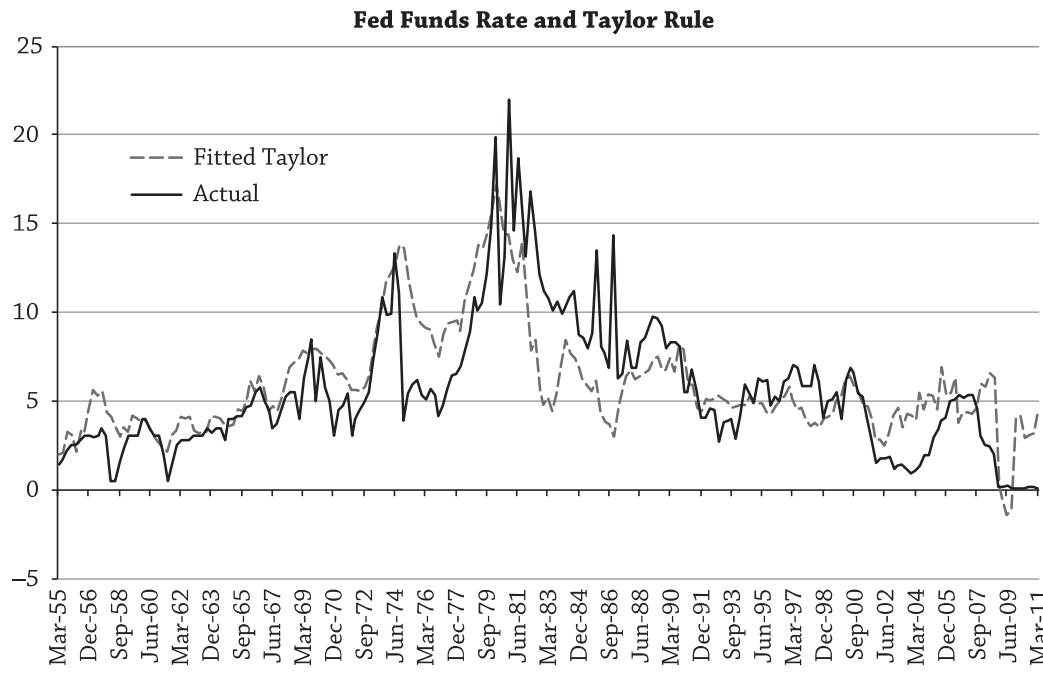
where FF denotes the Fed funds rate, r^* is the long-run real interest rate, π is the current inflation rate, and π^* is the target inflation rate. The output gap, which is the difference between real and potential GDP, is denoted as Gap . The Taylor rule is used both as a descriptive tool (what has the Fed done?) and a prescriptive tool (what should the Fed do?).

The Taylor rule captures the dual mandate of the Fed by describing how it moves the Fed funds rate in response to changes in the output gap and inflation. There is a positive coefficient of 0.5 (the coefficient differs in data and subsequent theories) on the output gap. As the output gap shrinks and economic activity slows, the Fed lowers the Fed funds rate to spur economic growth. The coefficient on inflation, π , in equation (9.1) is 1.5, but it is split up between the first term, $r^* + \pi$, and the second, $0.5(\pi - \pi^*)$. The first term is the sum of the real rate and inflation and should be the simple nominal short rate according to the *Fisher Hypothesis* (see below). The second term is the deviation of current inflation from its long-term target. As inflation increases, the Fed raises the Fed funds rate to rein in rising prices. As the total coefficient on inflation is greater than 1.0, when inflation increases, the Fed moves interest rates more than one for one. This means that the Fed raises *real rates* when inflation increases. This is called the *Taylor principle*.

Many versions of the Taylor rule describe the Fed's reaction to inflation and economic growth. These models can use different definitions of inflation (GDP deflator, CPI-All, core CPI, PPI, etc.) or of economic growth (GDP growth, output gap, industrial production growth, employment, etc.); the important concept in equation (9.1) is that the Fed responds to general movements in inflation and growth. Variants developed since Taylor (1993) can use forward-looking measures like surveys or agents' expectations (*forward-looking rules*) and past data beyond just current inflation and output (*backward-looking rules*). Versions of the rule can also account for occasions when the Fed partially adjusts to information (*partial adjustment rules*).¹⁰ The difference between the actual Fed funds rate and what the

⁹ See, for example, the recent study of Weise (2012), who examines the transcripts to characterize Fed behavior during the 1970s. Romer and Romer (2000) show that the Fed's internal forecasts are far superior to commercial forecasts.

¹⁰ There is an equivalence among some forms of these different basic Taylor rules, and the forward-looking, backward-looking, and partial adjustment versions, as Ang, Dong, and Piazzesi (2007) explore.

***Period: 1955Q1 - 2011Q1***

	Coeff	Std Error	t-stat
Const	0.97	0.06	15.51
GDP	0.26	0.07	3.58
CPI	1.09	0.41	2.66
R^2	0.52		

Figure 9.4

Fed is predicted to do according to the Taylor rule in equation (9.1) is referred to as a *monetary policy shock*. Thus, the monetary policy shock captures the discretion of the Fed in acting beyond what the Taylor rule prescribes in responding to movements in inflation and output.

Figure 9.4 graphs a version of the Taylor rule compared to the actual Fed funds rate from March 1951 to March 2011. Estimates of Taylor rule coefficients are also reported proxying economic growth with real GDP growth and inflation with CPI inflation, both defined as year-on-year changes. The coefficients on economic growth and inflation are both positive, consistent with the Taylor (1993) predictions, and the R^2 is over 50%, indicating a good fit. Figure 9.4 shows that monetary policy shocks can be large and persistent. The Taylor rule indicates that the Fed should have set interest rates to be much higher during the 1970s and reduced interest rates by more during the 1980s. Fed funds rates largely conformed to Taylor rule predictions during the 1990s. In the early 2000s, the Fed funds rate was much lower than predicted. During the financial crisis in 2009, the Taylor rule predicted that Fed funds rates should have been negative—precisely when the Fed embarked on its unconventional monetary policy programs. More recently, in

2011, the Taylor rule model advocated interest rates to be much higher than what they were (interest rates were effectively zero).

Because the Fed has such a big impact on bond prices and because the Taylor rule tells us (for the most part) what the Fed will do, bond investors should pay attention to the Taylor rule as it helps them get their arms around the impact of inflation and economic growth risks. The Fed also sets short-term interest rates to be higher or lower than predicted by a pure response to only macro variables, and this is monetary policy risk. Monetary policy risk is important for bond prices: Ang, Dong, and Piazzesi (2007) estimate that monetary policy risk accounts for 25% to 35% of the variance of yield levels.

2.4. CHANGING POLICY STANCES

The basic Taylor rule framework assumes that the Fed's *reaction function* is constant—that is, the way the Fed responds to a given output or inflation shock does not vary over time, although obviously the shocks vary in size. But what if the *stance* of the Fed toward output or inflation risk changes over time? In equation (9.1), this is captured by time-varying coefficients on growth and inflation, rather than constant coefficients of 0.5 and 1.5, respectively, in the benchmark Taylor (1993) model. In addition to potentially changing Fed stances with respect to macro risk, which of the Fed's dueling mandates—full employment or stable prices—has been given precedence by the Fed?

These are the questions that Ang et al. (2011) investigate. They find that the Fed policy stances—the policy coefficients on output and inflation in the Taylor rule—have evolved a great deal over time, mostly with respect to inflation rather than output. These changing policy stances also have a big impact on long-term bond prices.

Figure 9.5 estimated by Ang et al. (2011) shows that the monetary policy loading on output has not moved very much from around 0.4, whereas the inflation loading has changed substantially from close to zero in 2003 to approximately 2.4 in 1983. Figure 9.5 shows that during the 1960s and 1970s, the response to inflation was less than 1.0. According to the Taylor principle, the coefficient on inflation should be greater than 1.0, otherwise *multiple equilibria* occur. This is economist talk for very volatile and unfortunate macro outcomes—like the high inflation and low economic growth (*stagflation*) of the 1970s.¹¹ The Fed became much more aggressive in battling inflation during the 1980s, when Volcker brought the inflation beast under control. In the early 2000s, the inflation loading was again very low but rose quickly in the mid-2000s.

¹¹This view is argued by Taylor (1999) and Clarida, Gali, and Gertler (2000), among others. For a theory view of how multiple equilibria can arise and why this is bad, see Benhabib, Schmitt-Grohe, and Uribe (2001).

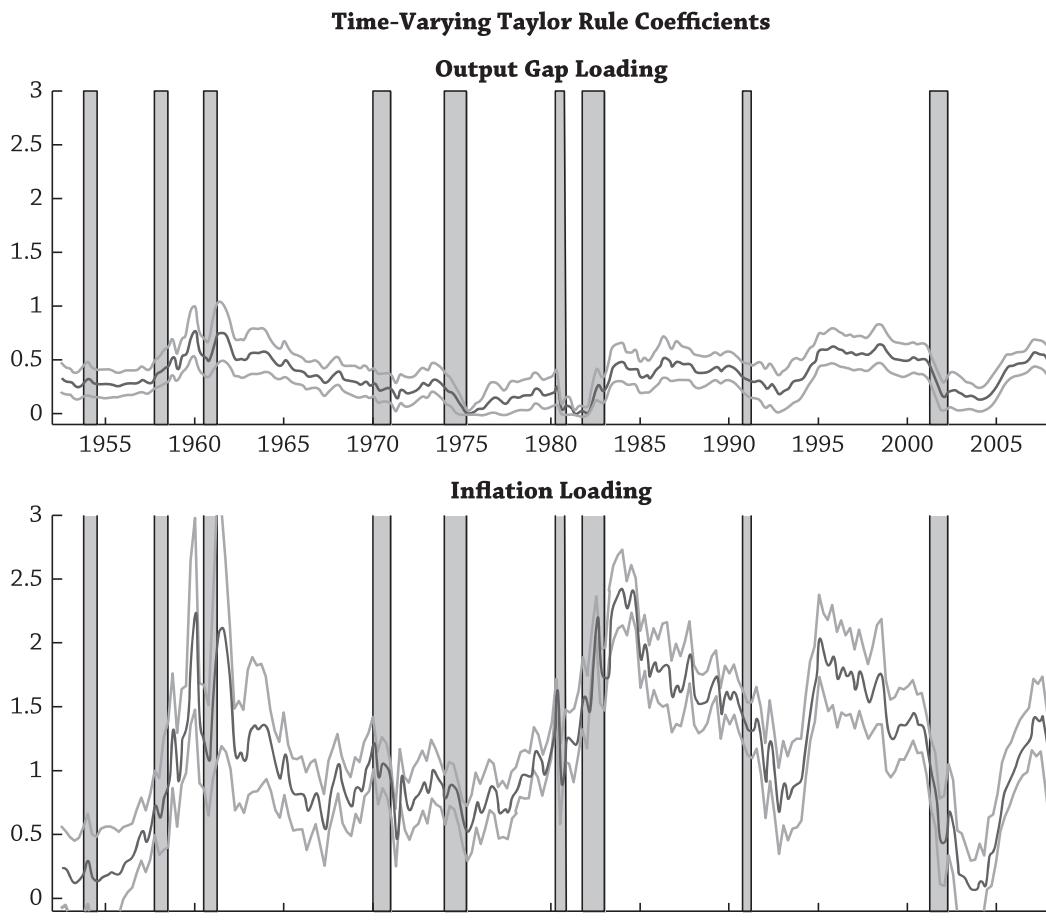


Figure 9.5

One question that Ang et al. can address is the existence of a *Greenspan put* (and after him a *Bernanke put*), which refers to the propensity of the Fed to open the spigots and provide liquidity whenever the economy experiences bad shocks—thereby, in the view of some critics, rescuing investors from their own risky decisions and encouraging ever-greater recklessness. Some commentators, including John Taylor, raised the possibility that short-term interest rates were held too low for too long after the Fed lowered interest rates in response to the 9/11 terrorist attacks and the 2001 recession.¹² Figure 9.6 from Ang et al. (2011) plots the path of the short rate after 2001 compared with what it would have been had the Fed maintained its output and inflation stances in 2000. The difference between the solid line (data) and the dashed line (which is the counterfactual) is a quantitative measure of the Greenspan put. Interest rates from 2002 to 2005 would

¹² See Taylor, J., "How Government Created the Financial Crisis," *Wall Street Journal* op-ed, Feb. 9, 2009.

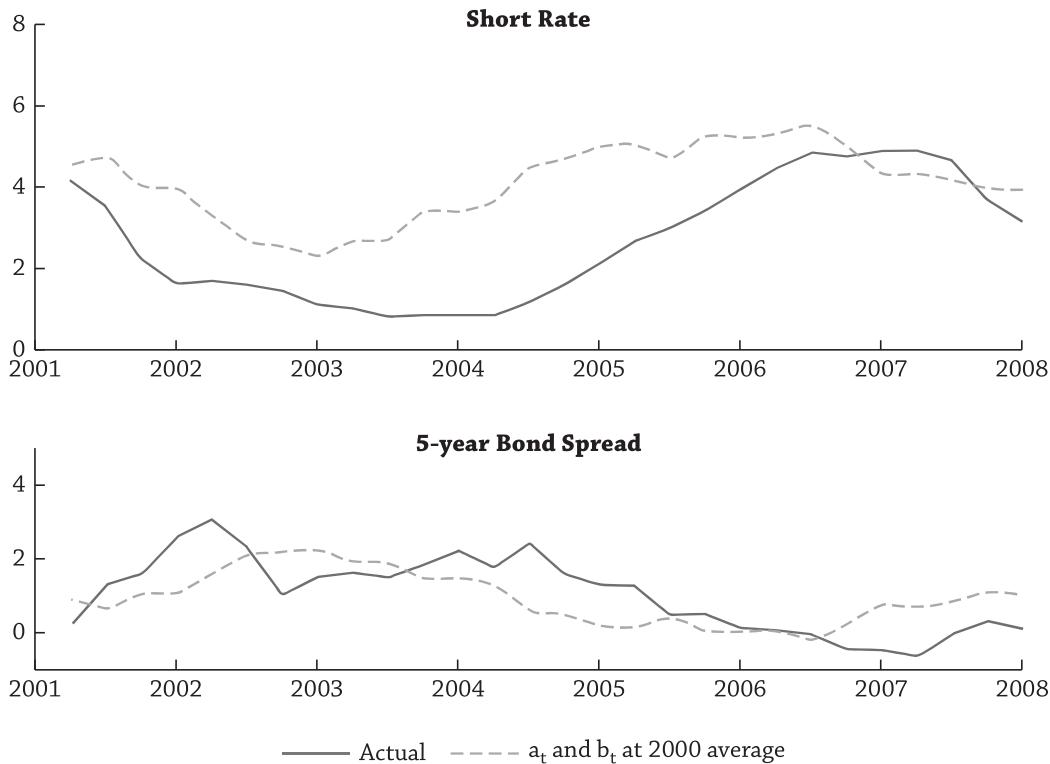


Figure 9.6

have been substantially higher if the Fed had not changed its inflation stance. For example, short rates reach 0.9% in June 2003, whereas at this time the short rate without any policy shifts would have been 2.7%. The bottom panel in Figure 9.6 plots the five-year bond spread, showing both the actual spread and the one predicted had the Fed not been so accommodating. They are very similar. Thus, the Greenspan put does not explain any part in the flattening of the yield curve in the early 2000s (the *Greenspan conundrum*).

The message for investors is that not only are macro risks, growth and inflation, important for bonds, but investors should take into consideration the actions of the Fed. Fed risk includes monetary policy shocks, which are deviations of Fed behavior from what would normally be expected of Fed policy with respect to output and inflation, and also changing policy stances, especially with regard to how the Fed responds to inflation risk.

2.5. NEW MONETARY POLICY

We live in the post-financial crisis world, and discussion of monetary policy risk for bond prices cannot be complete without discussing how an investor should react to the Fed's new unconventional monetary tools, which will in all likelihood become conventional. These programs have taken many forms in addition to quantitative easing and fall under an alphabet soup of acronyms, including the

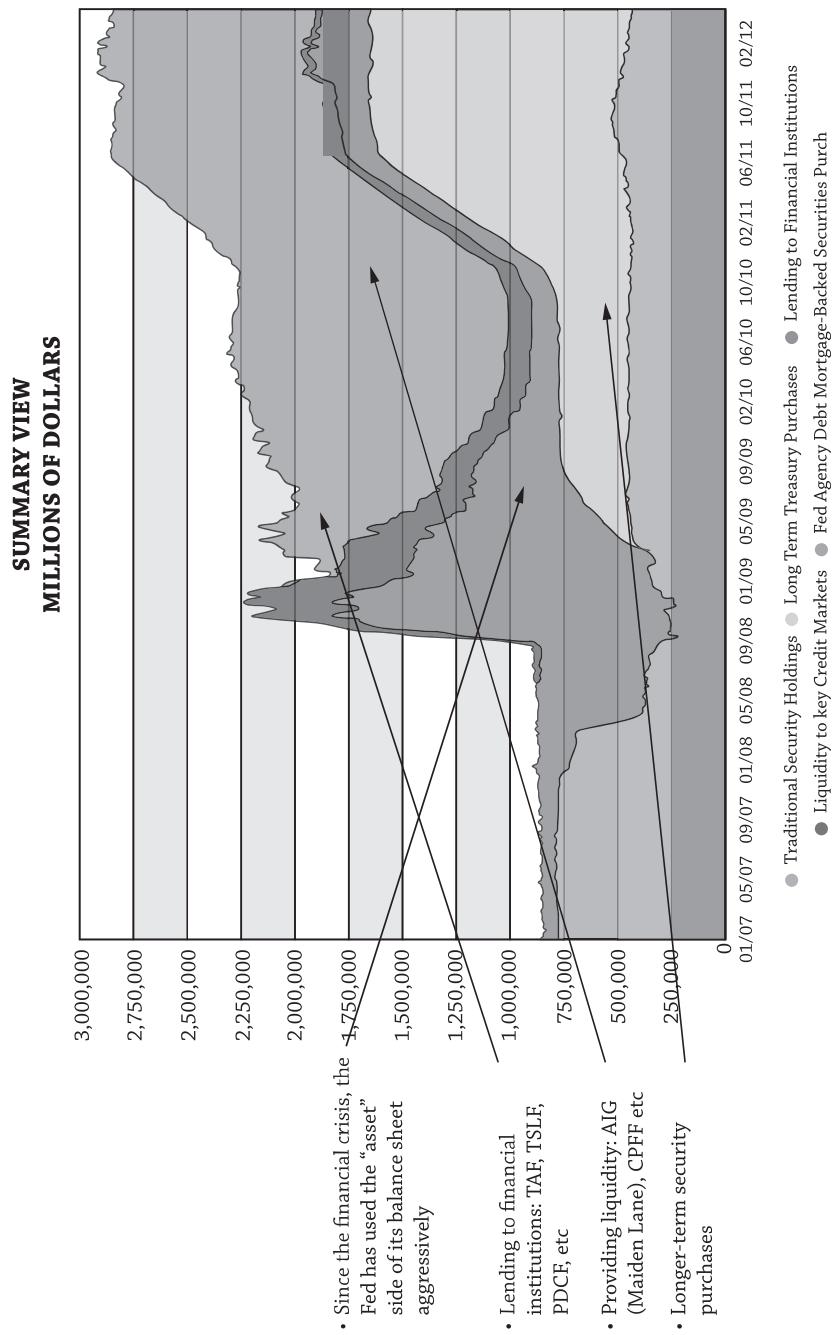


Figure 9.7

Money Market Investor Funding Facility (MMIFF), the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), the Commercial Paper Funding Facility (CPFF), the Primary Dealer Credit Facility (PDCF), the Term Securities Lending Facility (TSLF), and the Term Auction Facility (TAF). The Money Market Investor Funding Facility (MMIFF) was never used. Strangely, the MBS Purchase Program seemed not to get an acronym. And the Fed also loaned money to primary dealer affiliates and banks: JP Morgan, Citibank, and Bank of America.

Since the financial crisis, the Fed has expanded its balance sheet very aggressively and bought many risky assets. Figure 9.7 shows the explosion in the Fed balance sheet since September 2008, which at April 2012 is approaching \$3 trillion. Traditional “plain vanilla” Treasuries have declined and mortgage-backed securities now total almost \$1 trillion.

For unconventional monetary policy, defined here as the purchase of risky non-Treasury securities, to have a permanent effect after the Fed has ceased buying, the buying programs must have either altered investor expectations or risk premiums or there must be some segmentation in the market so that the Fed can change prices in one part of the market or yield curve without the other markets or parts of the yield curve fully adjusting to offset the Fed’s effects. The original version of segmented markets was the *preferred habitat theory* or clientele model developed by Culbertson (1957) and Modigliani and Sutch (1966a, 1996b). The most recent incarnation of this theory, which has spawned a new, resurgent literature, is Vayanos and Vila (2009).

In the Vayanos and Vila model, there are agents who are locked into, or prefer, bonds of a particular maturity. Think here of pension funds, say, which like long-dated Treasuries because they must hedge long-term liabilities. There are also arbitrageurs, who are able to take speculative positions across the yield curve. Think here of hedge funds or the (now-emasculated) proprietary trading desks of investment banks. While arbitrageurs can smooth the effects of shocks at a particular maturity induced, say, by the Fed purchasing long-term bonds, Fed actions have permanent effects across the yield curve because they change the supply of bonds available to those investors locked into long-term Treasuries of that maturity. Thus, asset owners investing in fixed income instruments might consider the effects of relative supply as a factor.

3. Term Spread (Long-Term Bonds)

3.1. RISK AND RETURNS OF LONG-TERM BONDS

Bond yields and prices are inversely related, so bond returns are high in times of falling yields, and vice versa. Since Figures 9.2 and 9.3 document the general pattern that interest rates rose until the early 1980s and then fell, it is not surprising that bonds generally did relatively poorly up until the early 1980s and then had

high returns since the early 1980s. Table 9.8 lists means, volatilities, and Sharpe ratios across maturities from January 1952 to December 2011 of excess bond returns, computing excess returns using the T-bill rate as the short rate. Like many researchers, I use the post-1951 sample because bond yields were pegged at artificially low yields by the Fed until the 1951 Treasury Accord between the U.S. Treasury and the Federal Reserve. This was a legacy of World War II when interest rates were held low so the government could borrow cheaply. The Treasury Accord freed the Fed from being forced to purchase bonds issued by the Treasury and gave the Fed independence.¹³ I split the sample at the end of 1982 because the Fed temporarily targeted monetary reserves in its conduct of monetary policy from October 6, 1979 to October 9, 1982.¹⁴

Table 9.8 shows that from 1952 to 1982, excess returns of bonds of five- to ten-year maturities were zero, on average, and excess returns of bonds with maturities greater than ten years were actually negative, at -0.62% . But since 1983, bonds have done very well as an asset class. Bonds with maturities of five to ten years and greater than ten years have returned 5.85% and 8.48% in excess of the T-bill rate from 1983 to 2011. Thus, the overall positive returns of these bonds of 1.91% and 2.97% , respectively, over the full sample are mostly due to the general decline in all interest rates post-1980. Over the full sample, bond returns increase, on average, with maturity: excess returns are 0.59% for bonds of less than one-year maturity and increase to 2.97% for bonds with maturities greater than ten years. Table 9.8 also separately breaks out 2000–2011, the Lost Decade for stock returns. (Stock returns are reported in the last column of Table 9.8.) Since 2000, bonds have been a terrific investment relative to stocks: bonds with maturities greater than ten years have returned 7.18% in excess of T-bills compared to -0.39% for U.S. equities.

The Sharpe ratios reported in Table 9.8 generally decrease across maturities starting from above 0.7 for bonds of maturities less than one year to around 0.3 for long-term bonds. Because average returns increase with maturities, the falling Sharpe ratios as maturities lengthen are due to the much greater volatility of long-term bond returns relative to short-term bond returns. This is in itself surprising—a ten-year bond should reflect the macro and financial environment over ten years, and given mean reversion of interest rates and the tendency of economic shocks to die out, this implies that long-term bonds should have significantly lower volatilities than short-term bonds. They don't. Volatilities of long-term bonds are only a little lower than short-term bonds. The large volatility of long-term bonds is indeed excessive compared to simple economic models

¹³ For an account of joint monetary and fiscal policy in the years after World War II, see Eichengreen and Garber (1991).

¹⁴ The Taylor rule is still appropriate over this sample, as Cook (1989) shows the short-term interest rate is a good instrument to proxy the Fed's actual monetary targeting operating procedure during this period.

Table 9.8

	Treasury Returns							
	1–12 months	1–2 years	2–3 Years	3–4 Years	4–5 Years	5–10 Years	> 10 Years*	Stocks
<i>Excess Returns</i>								
1952–1982	0.47%	0.56%	0.54%	0.36%	0.04%	-0.01%	-0.62%	5.93%
1983–2011	0.72%	1.58%	2.29%	2.93%	3.28%	3.96%	5.66%	7.00%
2000–2011	0.53%	1.45%	2.43%	3.30%	4.03%	4.59%	7.18%	-0.39%
1952–2011	0.59%	1.05%	1.39%	1.60%	1.61%	1.91%	2.97%	6.45%
<i>Volatilities</i>								
1952–1982	1.03%	2.50%	3.66%	4.36%	4.96%	5.85%	8.48%	14.09%
1983–2011	0.48%	1.50%	2.55%	3.54%	4.43%	5.71%	9.76%	15.45%
2000–2011	0.41%	1.31%	2.35%	3.37%	4.34%	5.27%	10.41%	16.36%
1952–2011	0.81%	2.08%	3.18%	4.00%	4.73%	5.81%	9.27%	14.76%
<i>Sharpe Ratios</i>								
1952–1982	0.46	0.22	0.15	0.08	0.01	0.00	-0.07	0.42
1983–2011	1.51	1.05	0.90	0.83	0.74	0.69	0.58	0.45
2000–2011	1.31	1.11	1.04	0.98	0.93	0.87	0.69	-0.02
1952–2011	0.73	0.51	0.44	0.40	0.34	0.33	0.32	0.44

Data: CRSP Fama bond total returns, S&P 500 total returns

*Data missing Sep 1962 to Nov 1971

with just mean-reverting short rates. This phenomenon is the *bond excess volatility puzzle* and was documented by the same economist, Robert Shiller (1979), who documented excess volatility in stock markets (See chapter 8).¹⁵ Long-term bond yields also exhibit large excess sensitivity to macroeconomic announcement shocks.¹⁶ Long-term bonds exhibit relatively large volatility and are sensitive to movements in macro and other factors because they exhibit large risk premiums. That is, long-term bonds are very sensitive to factor risk, and to adequately describe factor risk premiums for bonds, we need to explain how factor risk premiums are related across the yield curve.

3.2. MACRO-FACTOR TERM STRUCTURE MODELS

While conventional monetary policy operates on the short end of the yield curve, it influences the long end as well. Bond prices at the long end of the yield curve, however, are (largely but not completely now due to quantitative easing) set by markets, and thus the Fed has much less control of these long-term bonds than over the price of Fed funds. Figure 9.2 shows the three-month T-bill has almost identical movements with the Fed funds rate, which the Taylor rule tells us responds to macro factors. The same macro factors, or the level factor, will affect the entire yield curve through *no arbitrage*.

While prices of two different stocks can diverge wildly because they have different managers and operations, risk-free bonds with different maturities cannot have prices too far out of whack with each other. This is because bonds only differ in terms of their maturity since their cash flows are risk free. Bond markets are chock full of arbitrageurs who pounce on the slightest profitable opportunities when prices of bonds with a particular maturity move out of line with prices of bonds with similar maturities. While there are some limited arbitrage opportunities in bond markets (no one believes—not even ivory-tower academics—that markets are perfectly efficient; see chapter 6), bonds must move in a tight fashion with other bonds. Otherwise, the profit opportunities grow too big, and like in a game of whack-a-mole, smart investors quickly bash their mallets down to remove them. We capture this phenomenon with models where investors receive returns for holding bonds commensurate with their risk, and as a close approximation, we assume bond prices are determined by the *absence* of arbitrage. These are called *term structure models*. The key insight of this class of models is that bond yields are linked to each other—across maturities and across time.

Take, for example, a two-year Treasury note. Investing for a two-year period, we can just go and buy the two-year T-note. We can also invest our money over a

¹⁵ Early economic models with *constant* risk premiums were not only unable to explain excess volatilities of long-term bonds, they could not even explain why the yield curve sloped upward, on average (see Backus, Gregory, and Zin (1989) and den Haan (1995)).

¹⁶ See Gürkaynak, Sack and Swanson (2005).

two-year horizon by buying a three-month T-bill. In three months, the T-bill expires, but then we invest the proceeds in another three-month T-bill. If we *roll over* three-month T-bills over seven successive quarters, we will have reached the same horizon as directly investing in a two-year T-note. The two strategies are not identical—we are subject to roll-over risk when we invest in a series of T-bills, whereas we know the yield today on the two-year Treasury note. Nevertheless, the price of a three-month T-bill cannot move too far from the price of a two-year Treasury note. If the roll-over strategy is very cheap compared to the two-year Treasury note, arbitrageurs will buy T-bills and sell notes. Conversely, if T-bills are too expensive compared to notes, investors will sell T-bills and buy notes. Following this logic, the price of any long-term bond must be related to the price of any short-term bond.

Risk Premiums

We can decompose the movements of long-term yields into pure “expectations” components and components that embed risk premiums. According to the *Expectations Hypothesis* originally developed by one of the great economists of the early twentieth century, Irving Fisher (1896),

$$\text{Nominal long yield} = \underbrace{\text{average of expected short rates}}_{\text{Expectations Hypothesis}} + \text{risk premiums.} \quad (9.2)$$

If we interpret the three-month T-bill as the short rate, then the two-year Treasury note yield should be the average of eight three-month T-bill yields: the current three-month T-bill, the future three-month T-bill yield that will prevail in three months time, the future three-month T-bill yield that will start in six months time, and so on, up to the end of two years. This is the Expectations Hypothesis component. In the real world, this does not hold. One three-month T-bill today and seven future, roll-over three-month T-bill positions do not, on average, equal the two-year Treasury yield.¹⁷ There is risk in the rolled-over T-bill positions: the macro-economy may change and inflation may spike, volatility may change, or investors may become suddenly more risk averse. Not surprisingly, the risk premium components, especially in long-term Treasuries, can be quite large.

Another decomposition is based on the *Fisher Hypothesis*, also by Fisher (1930):

$$\text{Nominal long yield} = \underbrace{\text{real yield} + \text{expected inflation}}_{\text{Fisher Hypothesis}} + \text{risk premiums} \quad (9.3)$$

The pure Fisher Hypothesis states that the long yield is equal to the real yield and expected inflation and ignores the risk premium components. Like

¹⁷There is a very large literature testing the Expectations Hypothesis beginning with Fama and Bliss (1987) and rejecting it overwhelmingly for the United States.

the Expectations Hypothesis, the Fisher Hypothesis is rejected in the data. Nevertheless, the risk premiums, both relative to the Expectations Hypothesis and the Fisher Hypothesis, must be closely related across bonds of similar maturities; a ten-year bond must move, by our smart whack-a-mole investors, in a manner similar to a bond of maturity of nine years.

Term structure models specify the types of risk premiums and how they change. Thus, they capture how the two-year Treasury yield can deviate from an average of current and future T-bill rates (deviations from the Expectations Hypothesis), and how the long yield differs from the real rate and expected inflation (deviations from the Fisher Hypothesis). These models have three ingredients:

1. The underlying risk factors,
2. How the short rate moves, and
3. How the short rate and factor risk premiums affect long-term bonds.

The dynamics of the short rate in (2) can be interpreted as modeling how the Fed sets (or is implied to set) the interest rates at the shortest end of the yield curve in terms of risk factors (inflation and output according to the Taylor rule). The risk premiums specified in (3) compensate investors for maturity or duration risk, monetary policy risk, uncertainty, macro risk coming from inflation and growth shocks, and other risks. The key result is that the risk premiums differ across maturities and across time.¹⁸ The workhorse models of today are the class of *affine term structure models*, which embody time-varying volatility, macro and latent factors, and what turns out to be very important to match the dynamics of yields in data—time-varying risk premiums.¹⁹

Term structure models derive both the dynamics of the entire cross section of bonds across maturities relative to each other, that is, the term structure of interest rates at a given point in time and specify how the term structure of interest rates evolves across time. In the context of equations (9.2) and (9.3), term structure models specify how risk premiums change across maturities. In a term structure model, the ten-year risk premium and, hence, yield is a function of the underlying factors and must move in such a way that it does not move “too much” (in a fashion consistent with no arbitrage) relative to the nine-year yield. The same must be true for the nine-year yield relative to the eight-year yield, and so on. Thus, the term structure model naturally picks up the notion of strong systematic

¹⁸ The no arbitrage assumption in term structure models implies that investors receive the same *risk-adjusted* compensation across all bonds.

¹⁹ The affine class of term structure models was formalized by Duffie and Kan (1996), but the first model was a pure Gaussian model developed by Vasicek (1977). Oldrich Vasicek played an important role in the development of the index fund industry (see chapter 17). A famous heteroskedastic model, also a special case of the affine framework, is Cox, Ingersoll, and Ross (1985). Time-varying risk premiums are essential in matching deviations from the Expectations Hypothesis, as Dai and Singleton (2002) show. For a summary of term structure models, see Piazzesi (2010).

factor dependence of yields so that yield dynamics at a particular maturity are tightly bound to other maturities. The affine term structure models do this in a very tractable way so that bond yields are affine (constant plus linear) functions of risk factors. This makes the models straightforward to use in many applications from asset allocation to derivative pricing. The risk premiums in these models change over time—so the shape of the yield curve can take different shapes in recessions and expansions or in times of low or high volatility.

The first generation of term structure models employed only latent variables. That is, they described the yield curve by using only variables that were not observable macro factors and were “filtered” out from the bond yields themselves. These models did provide interpretations for what these latent factors represented by their action on the yield curve: the level, slope, and curvature factors, with the most important of these being the level factor (see Figure 9.2 and 9.3).²⁰ A sizeable macro-finance literature now characterizes the movements of yields and risk premiums using macro factors, including economic growth and inflation, partly inspired by Ang and Piazzesi (2003).

Monika Piazzesi and I wrote the first draft of this paper in 1998 while we were PhD students at Stanford University. At the time, we could not foresee the big bump in our citation counts that it would generate (we got lucky). We brought together the Taylor policy rule and factor dynamics for inflation and output that were widely used in macro models, with time-varying risk premium models in finance that were able to closely match bond prices. An advantage of the model is that it explicitly showed how monetary policy risk was priced in the yield curve. We have since worked on other macro-finance term structure models together, with our students, and other co-authors.

3.3. MACRO RISK PREMIUMS IN LONG-TERM BONDS

The macro-finance literature shows that macro factors play a very important part in the dynamics of the yield curve and the excess returns of bonds. Ang and Piazzesi find that the variance of bond yields at various points on the yield curve has the following attributions to output, inflation, and other (including monetary policy) factors:

	Inflation	Output	Other Factors (Including Monetary Policy)
Short End	70%	13%	17%
Middle	62%	11%	27%
Long End	32%	6%	62%

²⁰ Other labels are, of course, used. The canonical study of Dai and Singleton (2000), for example, labels the three factors “level,” “central tendency,” and “volatility.” The third factor has slightly different dynamics depending on the particular affine specification employed.

At the short end of the yield curve, macro factors explain approximately 85% of the variation of yield levels decreasing to 40% of long-term bond yields. Of the macro factors, yield movements are most sensitive to inflation and inflation risk, which is not surprising because bonds are nominal securities. Monetary policy plays a large role in the “other factors,” and monetary policy risk is priced in long-term bonds, but Ang and Piazzesi use other latent factors that may represent other risk factors.

Ang, Bekaert, and Wei (2008) decompose yields into real yields, expected inflation, and risk premiums based on the Fisher decomposition in equation (9.3). In their sample, they find that the short rate is 5.4% and the long yield is 6.3%, which can be decomposed as:

	Real Rate	Expected Inflation	Risk Premium	Total
Short End	1.2%	3.9%	0.3%	5.4%
Long End	1.3%	3.9%	1.1%	6.3%

Thus, most of the upward-sloping nominal yield curve (going from 5.4% to 6.3% in the Ang–Piazzesi sample) is explained by risk premiums rather than by real rates. The variance of the long yield is 20% attributable to variations of real rates, 70% due to movements in expected inflation, and 10% due to changes in risk premiums. Thus, expected inflation and inflation risk are extremely important determinants of long-term bond prices.

The risk premiums on long-term bonds also vary through time. Risk premiums are *counter-cyclical*: long-term bond yields are high relative to short rates during recessions because agents demand large compensation for taking on risk. The short rate is *pro-cyclical* because of the Taylor rule; the Fed lowers short rates in recessions to stimulate economic activity. During expansions, the opposite relations hold. Bonds do badly during recessions, where they have low prices and high yields. Investors feel most risk averse during these times of high marginal utility (see chapter 6). They demand higher risk premiums, which are reflected in a steeper yield curve. We tend to see steeper yield curves during other hard times like periods of high inflation, which tend to coincide with times of low economic activity. Bad times are also times of low productivity, and they could be times when other supply shocks hit the economy, like oil price shocks.²¹

The counter-cyclical risk premiums of long-term bonds manifest themselves in the ability of the term spread to predict recessions. Recessions have upward-sloping yield curves when the risk premiums on bonds are the highest. Correspondingly, the peaks of expansions are when risk premiums are the lowest,

²¹See Piazzesi and Schneider (2006), Wachter (2006), and Rudebusch and Swanson (2012).

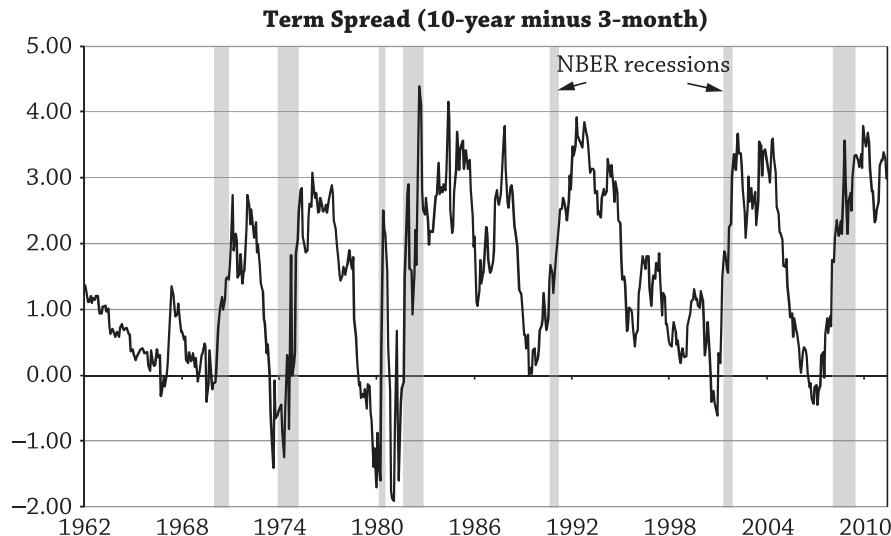


Figure 9.9

and the yield curve is downward sloping. Thus, the term spread is a counter-cyclical indicator of future economic activity, and low, especially negative, term spreads forecast economic slowdowns.²² Figure 9.9 plots the ten-year Treasury minus the three-month T-bill term spread and shades the National Bureau of Economic Research recessions. The term spread has been negative prior to every recession since the 1960s.²³

3.4. OTHER FACTORS

While macro factors and monetary policy account for a substantial part of yield curve movements, they do not explain everything. During the financial crisis of 2008–2009, there was a pronounced *flight to safety* as many investors moved into risk-free Treasuries and sold off risky assets including corporate bonds and equities. One measure of liquidity is the *on-the-run/off-the-run* spread. When Treasuries are newly issued, they are most liquid and called “on the run.” But as time passes and new Treasuries are issued, the old ones become “off the run.” On-the-run bonds are in higher demand by investors, so their yields are lower, on average, than off-the-run bonds. The on-the-run/off-the-run effect is a liquidity measure because it involves instruments with the same credit risk (zero, assuming

²² Some papers in this literature include Harvey (1988), Estrella and Mishkin (1998), and Ang, Piazzesi, and Wei (2006).

²³ At the time of writing, these are December 1969 to November 1970, November 1973 to March 1975, July 1981 to November 1982, July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009.

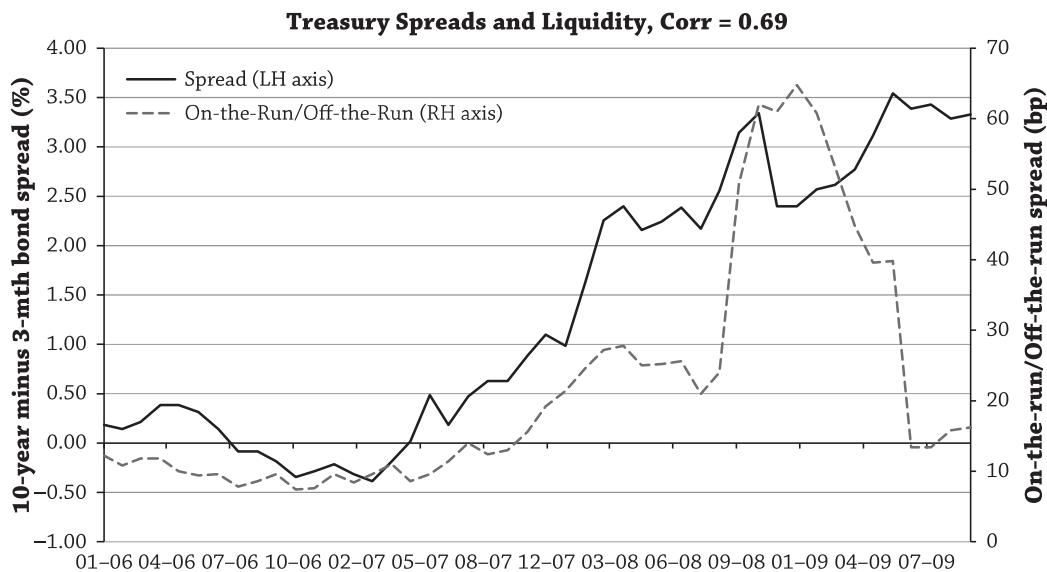


Figure 9.10

Treasuries are risk free) but different volumes and prices.²⁴ The effect is, however, influenced by how and when the Treasury brings to market new issues.

Figure 9.10 plots the ten-year Treasury minus three-month T-bill term spread (left-hand axis) with the on-the-run/off-the-run spread (on the right-hand axis) from January 2006 to October 2009. Higher on-the-run/off-the-run spreads indicate periods of greater illiquidity. During this sample, the correlation between the term spread and the illiquidity spread was a lofty 69%. Figure 9.10 shows that the term spread tracks the rise in illiquidity from 2007 to 2009. However, the term spread remains elevated after the economy stabilizes and the financial crisis passes post-2009, whereas the illiquidity spreads fall and the market recovers its liquidity. Nevertheless, the demand for Treasuries during times of illiquidity and high volatility, or the flight-to-safety effect, was an important factor driving Treasuries during the financial crisis.

Recently several researchers have focused on the effect of different investors, particularly foreign investors, on the dynamics of the yield curve. The top panel of Figure 9.11 graphs the proportion of Treasuries held by foreign investors (excluding official holdings in central banks), showing this has increased from below 10% during the 1960s to over 50% today. (The largest of these foreign positions is China's; see chapter 1.) The bottom panel of Figure 9.11 plots net new issues by the Treasury and foreign demand for Treasuries, both normalized by GDP. The panel shows that both are cyclical and the effects have been increasing over time. Foreign demand had a local peak in the mid-2000s and also during the financial crisis in 2008. Fed Chair Ben Bernanke himself suggested that these

²⁴ See Amihud and Mendelson (1991) and Krishnamurthy (2002).

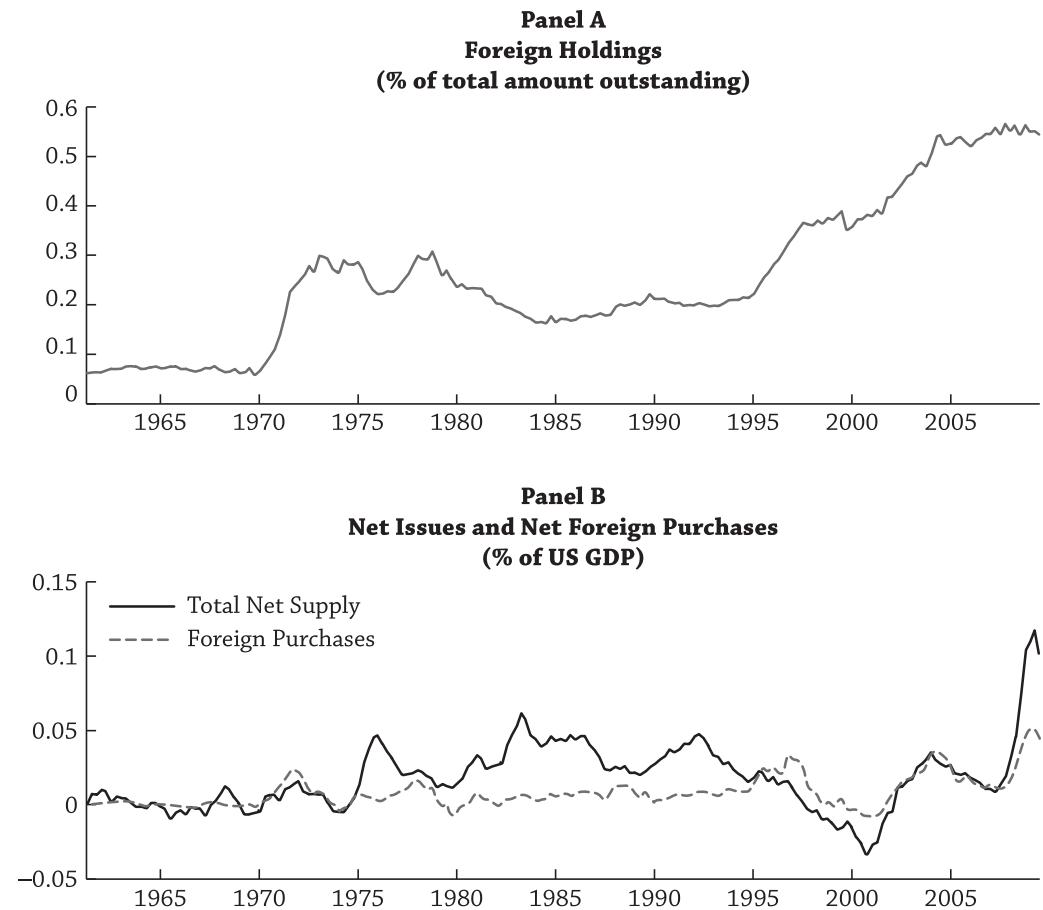


Figure 9.11

developments could be affecting bond prices, saying in 2007 that “strong foreign demand for U.S. long-term debt has been one factor tending to reduce the term premium.”²⁵

The modern clientele models based on Vayanos and Vila (2009) predict that the smaller the supply or the greater the demand, all else equal, the higher the prices of Treasuries and the lower their yields. The Vayanos–Vila framework would interpret certain classes of investors such as foreigners as demanding certain maturities for exogenous reasons—in China’s case, this could be to manage its exchange rate—and this foreign demand affects bond prices. Greenwood and Vayanos (2010), Hamilton and Wu (2012), and Krishnamurthy and Vissing-Jørgensen (2012) find supply effects in Treasuries consistent with the clientele model. Thus, actions by the Fed such as quantitative easing must be weighed along with demand from investors. This is related to how outstanding supply should affect optimal holdings of fixed income. We return to these topics in chapter 14 on factor investing.

²⁵ Speech by Fed Chair Ben Bernanke in 2007 at the Fourth Economic Summit, Stanford Institute for Economic Policy Research, Stanford University, <http://www.federalreserve.gov/newsevents/speech/bernanke20070302a.htm>.