Yield Curve Basics

It is January 1, 2030. You give XYZ, Inc. $1,000 today and they promise to pay you back in two years. Congratulations, you just bought a *bond*!

The $1,000 is called the *face* or *par value* and the *maturity date* is two years from now, January 1, 2032 (when you get the face value back). Not surprisingly, you own a 2-year bond.

Of course, you must be compensated for the time value of money—$1,000 two years from now is worth less than $1,000 right now. So, XYZ also promises to pay you interest at regular intervals, say every six months. The *coupon rate*, say 5%, tells you the interest you will be paid in a year. Five percent of $1,000 is $50 so you will get two payments of $25.

Because the coupon (interest) and final payments are on a strict schedule, bonds are called *fixed-income securities.* Bonds are *debt* and they give investors a safer, but lower return, on average, than stocks which are *equity* (since they involve ownership of a corporation).

The jargon, special words or technical language used by professionals, can make financial products and choices difficult to understand. We can make your bond come to life with Excel. As you enter the information, think about the trade-off involved here—the lender (you) gives up money now in return for future payments from the borrower (XYZ). This is the core idea.

STEP Open a blank Excel workbook and save it as *YieldCurve.xlsx*. In cells A1 to A5, enter the dates *1/1/2030, 7/1/2030, 1/1/2031, 7/1/2031*, and *1/1/2032*. In cell B1, enter - *$1000*, this is the amount you invested in the bond (hence the minus sign). Cells B2, B3, and B4 represent the coupon payments so enter *$25* for each of those cells. At the end, you get the last interest payment plus the face value back, so cell B5 is *$1,025*.

Your spreadsheet now looks quite familiar, given the work we did on present value and the internal rate of return (IRR). That's right, a bond is just another application of those ideas. You start with a negative number that represents your investment, then get a stream of income over time that is your return on investment.

We know that the IRR is a measure of the quality of an investment. We can compute the IRR for these cash flows at these dates using Excel's *XIRR* function. It incorporates the dates at which the flows are paid and received and returns the internal rate of return.

$STEP$ Enter the formula *=XIRR(B1:B5,A1:A5)* in cell C1 and format it as a % with two decimal places. In cell D1 enter the label *IRR = YTM* so that your spreadsheet replicates Figure 7.1.

	A	B	C	D
1	1/1/2030	($1,000)	5.06%	IRR = YTM
2	7/1/2030	$25		
3	1/1/2031	$25		
4	7/1/2031	$25		
5	1/1/2032	$1,025		

Figure 7.1: Understanding a bond.

The IRR is a little over 5% because you received the annual interest payment of $50 a little ahead of time: $25 halfway through the year and another $25 at the end of the year instead of all $50 at the end of the year.

$STEP$ Confirm this by changing cells B2 and B4 to zero, cell B3 to $50, and cell B5 to $1,050.

Cell C1 now shows the IRR as 5.00%. This shows that the XIRR function is working as advertised. It also shows that the timing of the coupon payments is critical. Your spreadsheet is now displaying a different bond than the one in Figure 7.1. The IRR of the bond in Figure 7.1 is higher than the one on your spreadsheet because of the timing of the interest payments.

The IRR for a bond is called the *yield to maturity*, YTM. It is calculated as if the investor will hold the bond until the maturity date. But they might not. Bonds can be traded before they mature in the *secondary market*.

A *zero-coupon bond*, also called a *strip*, is just what it says, it has no interest payments.

STEP Change the $25 value in cell B3 to zero (so the values in cells B2, B3, and B4 are all zero) and make cell B5 $1,000.

The YTM is now zero. That's terrible. No investor would buy this bond. To entice buyers, the issuer must sell the bond at a discount (or below par).

STEP Change cell B1 to - *$900*.

That's better. Now the YTM is about 5.4%. Investors are compensated for lending $900 today by getting the face value of the bond, $1000, in two years. Someone might be willing to buy this bond and lend the issuer $900.

Bonds are complex financial assets. They have many variations and the jargon is intimidating, but no matter how complicated it gets, the idea is that a bond is a promise—money in the future is promised in return for money now.

Yield Data

With a basic understanding of a bond and how it works, we can get yield data and create visualizations, including that of our ultimate goal, the yield curve over time.

We will work with United States Treasury securities with different maturity dates. They all work like bonds, but they have different names depending on their maturity dates: Treasury *bills* mature in one year or less, Treasury *notes* in two to ten years, and Treasury *bonds* in 20 or 30 years.

First, we will examine a single security over time, but our eventual goal is to visualize a richer data set with yields for different maturities over time. This will give us the yield curve.

STEP Insert a sheet in your workbook, rename it *GS1*, and enter the Series ID *GS1* (for government security maturing in 1 year) in cell A1. Use the FRED Excel add-in to get the data. Use FRED's charting tools to make a chart with recession shading, like Figure 7.2 (made in October 2023). Refer back to the work we did using FRED to get unemployment data if needed.

Figure 7.2 shows the yield on a 1-year United States Treasury bill on a monthly frequency from April 1953 to September 2023. Your spreadsheet will have this series up to the previous month in which you created it.

Figure 7.2: 1-year US Treasury bill yield over time.

Unlike the unemployment rate which rose in every recession, 1-year US Treasury bill yields are mostly falling when they enter the shaded bars. This is because the government is actively trying to use monetary policy to lower interest rates to stimulate the economy.

The US Federal Reserve (Fed) acts as a central bank and influences many different interest rates, including bond yields, by controlling the *federal funds rate* (the interest rate at which banks lend reserves to each other).

The key point for our yield data is that 1-year US Treasury bill yields are not directly controlled by the Fed. They are the outcome of supply and demand. Bonds, including US Treasury securities, can be traded before their maturity dates. It is the bond market that determines yields.

It is easy to see in Figure 7.2 that in the early 1980s, yields were very high, in double-digit territory. Why? Certainly a contributing factor was high inflation at that time. The yield had to be high to entice the lender to part with money now to be paid back later.

STEP Return to your bond demonstration sheet. You should see the zero-coupon bond. You part with $900 now and get $1,000 in two years, which has a YTM of about 5.4%.

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In the early 1980s, there is no way you would give anyone (XYZ or the US government) $900 now in return for $1,000 in two years. The $1,000 you got back two years later would be so watered down by the high inflation at that time that you would refuse that deal. So, the issuer has to raise the yield by lowering (discounting) the bond by more than $100.

STEP Change cell B1 to - *$800*. What happens?

Not surprisingly, the YTM increases to almost 12%. Is that enough to get you to make the trade? Not in August 1981.

STEP Return to the *GS1* sheet. Enter the formula *=MAX(B:B)* in cell C8 to see the highest yield in the data set. Scroll down to find when it occurred.

In August 1981, the market, or equilibrium, yield was 16.7%. You would not lend unless you got that yield just like you would not buy apples from a particular seller if their price was higher than the market price that many other sellers were selling apples for.

STEP Return to the sheet with the simple 2-year bond we were playing with and use Solver to find the discount in the bond price needed to produce a yield of 16.7%. Be sure to uncheck (if needed) Solver's *Make unconstrained variables nonnegative* option since we want a negative number in cell B1.

You should find that the bond price is roughly $734 so a discount of $266 from the par value.

The inverse relationship between the yield and the bond price is a fundamental concept in the bond world. The Excel implementation of a bond makes it easy to see: the lower the price (the bigger the discount) in cell B1, the higher the yield.

Yields for Different Maturities

Just like *GS1*, the yield on a 1-year US Treasury bill, FRED has data for yields on US Treasury securities with different maturities, also known as the *term structure*. We will get data on US Treasuries from 3-month to 30-year terms.

$STEP$ Insert a sheet in your workbook and name it *TermStructure*. In individual cells in the top row, enter the following *Series IDs*: *GS3M, GS6M, GS1, GS2, GS3. GS5, GS7, GS10, GS20*, and *GS30*. The *M* stands for months and the numbers indicate the length of time. So, *GS6M* is a 6-month US Treasury bill and *GS20* is 20-year Treasury bond. Click the Get FRED Data button.

The series start at different dates. We need to find the latest date and start them all from that point so that we can see how the yields varied by maturity on the same date.

$STEP$ The latest starting date in row 8 is 9/1/1981. Copy this cell and paste it in cells E4, G4, and so on until S4. Update the data.

Each row has yields for differing maturities of US Treasury securities for a particular point in time. Thus, each row has the data for the yield curve for that month.

Here is how the Fed describes the yield curve:

> Investors can trade Treasury securities freely between issuance and maturity. As the market price of Treasury securities varies over time, so does their implied yield—their return relative to their price. At any given time, there is a wide range of Treasury securities with different maturities outstanding. Market forces tend to ensure that the yields on securities with similar maturities are not dramatically different from each other. This feature makes it possible to summarize the information contained in the cross section of market-implied yields by a smooth curve of yield as a function of maturity—the yield curve.
> https://www.federalreserve.gov/data/nominal-yield-curve.htm

Thus, the yield curve shows yield by maturity. Let's make one.

$STEP$ Copy the *TermStructure* sheet and rename it *YieldCurve*. Change each of the *value* labels in row 7 to the corresponding length of time in years. Cell B7 is 0.25 (you may have to increase the decimal places displayed), cell D7 is 0.5, cell F7 is 1, and so on. Delete rows 1 to 6. Delete the date columns, starting with column C (so, C, E, to S). Finally, select the yield data (from B2 to the last row in column K) and display two decimals places.

You now have a data set that looks like Figure 7.3. It has dates in column A, lengths of maturity in years in row 1, and yields for each month by maturity. These are the inputs needed to make a yield curve.

	A	B	C	D	E	F	G	H	I	J	K
1	date	0.25	0.5	1	2	3	5	7	10	20	30
2	09/01/1981	15.61	16.36	16.52	16.46	16.22	15.93	15.65	15.32	15.07	14.67
3	10/01/1981	14.23	15.06	15.38	15.54	15.50	15.41	15.33	15.15	15.13	14.68
4	11/01/1981	11.35	12.12	12.41	12.88	13.11	13.38	13.42	13.39	13.56	13.35
5	12/01/1981	11.32	12.44	12.85	13.29	13.66	13.60	13.62	13.72	13.73	13.45

Figure 7.3: Data to make a yield curve.

STEP Select cells A1:K2 and insert a *Scatter with Straight Lines and Markers* chart. Add a title, *Yield Curve* and label the axes, *Yield (%)* and *Maturity (years)*.

You just made your first yield curve. It is not common. Usually, it is upward sloping. The longer the maturity, the higher the yield because lenders have to be rewarded for locking up their money for longer periods of time.

The 1980s were certainly exceptional economic times. The yield curve was *inverted* because yields for shorter maturities were higher than for longer maturities. This usually means bad tidings for the economy.

There is another step we could take to make our yield curve a true curve: we could fit a smooth curve to the data. The smoothed curve version of yield as a function of maturity is what most people call a yield curve. There are many ways to fit such a curve and it gets complicated so we will stay with our rudimentary version that connects the data with straight lines.

We can easily make another yield curve so we can understand what the yield curve is telling us. We work smart by using the edit SERIES formula approach.

STEP Copy and paste the chart. Click on the data and edit the SERIES formula by changing the 2 to 222 in the *y*-axis part of the formula, *YieldCurve!$B$222:$K$222*.

You just produced a yield curve for January 2000. Unlike September 1981, it rises fast, then stretches out. Figure 7.4 compares the two yield curves.

While the slightly lower yield for 30 versus 20 years is unexpected, the Jan 2000 yield curve (on the right) is a typical yield curve. As the yield to maturity rise from very short term to 2 years, yields rise quickly, but then they rise much more slowly as maturity increases.
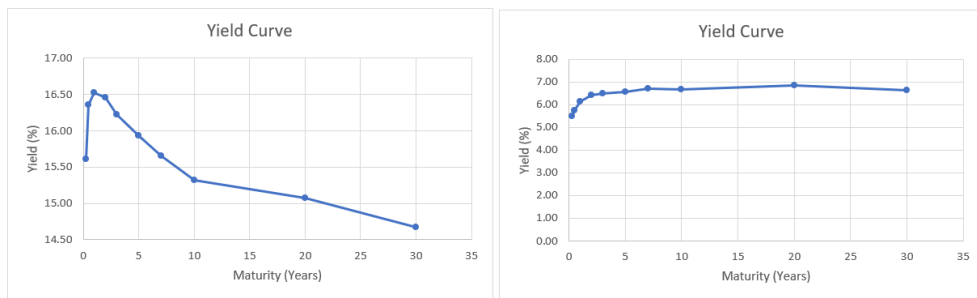

Figure 7.4: Sep-1981 (left) and Jan 2000 (right) yield curves.

We learned about bonds and yields, got yield data, and created yield curve charts. Next up, we work on fancier visualizations of yield curve data.

Takeaways

In everyday English, a bond is a connection between people (a bond of friendship) or objects (to bond is to glue things together). In finance, the connection is between lender and borrower.

A bond is a security in which a borrower (typically a firm or government) promises to pay back the face value at the maturity date and make interest payments at specific dates (to compensate the lender for the time value of money).

A bond is a way for borrowers to raise money. Firms often use bonds to fund operations, while government bonds pay for deficit spending (when outlays are greater than tax revenues).

The funds raised by issuing bonds are debt because the issuer has to pay the lenders back.

The jargon in the bond world is intense. Knowing things like the difference between the coupon rate and the yield to maturity is critical for those who live in the bond world.

It is important to understand the contract is iron-clad so the coupon rate and promised cash flows do not change as interest rates change. You might buy a bond in the secondary market above or below par value and the *spot rate* is the IRR at the time you buy the bond.

"The U.S. Treasury yield curve is of tremendous importance both in concept and in practice. From a conceptual perspective, the yield curve determines the value that investors place today on nominal payments at all future dates—a fundamental determinant of almost all asset prices and economic decisions" (Gürkaynak, et al., 2006, p. 1).

References

The epigraph is from p. 8 of Geneva Smitherman's *Black Talk: Words and Phrases from the Hood to the Amen Corner*, Houghton Mifflin (1994). Here is the full entry for WORD IS BORN!:

> An affirmative response to statement or action. Also, *Word!*, *Word up!*, *Word to the mother!* A resurfacing of an old, familiar saying in the Black Oral Tradition, "Yo word is yo bond," which was popularized by the FIVE PERCENT NATION in its early years. *Word is born!* reaffirms strong belief in the power of the word, and thus the value of verbal commitment. One's word is the guarantee, the warranty, the *bond*, that whatever was promised will actually occur. *Born* is the result of the AAE [African American English] pronunciation of "bond"; see Introduction.

The yield data in FRED are produced by the Fed and it is a complicated process. A good source for digging into the details is Refet S. Gürkaynak, Brian Sack and Jonathan H. Wright (2006) "The U.S. Treasury Yield Curve: 1961 to the Present," Finance and Economics Discussion Series, Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.