Inside the Black Box: Hamilton, Wu, and QE2[*]

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This paper starts with an intriguing affine term structure model with time-varying risk premium and supply effects.

Monika Piazzesi and I (2005, 2008) have spent many months on such models. We learned and explained many hard lessons in their specification and estimation. Among others: OLS is a horrible way to estimate dynamics, and in particular the crucial question of the largest root; it is very sensitive to small details of specification and cointegration; raising weekly dynamics to the 5200th power is an awful way to estimate 10 year forecasts; don't use weekly interpolated bond prices to estimate returns; the data scream for a single-factor model of expected returns, and scream that only level shocks are priced; imposing these restrictions the cross-section becomes a much better way to estimate both risk-neutral and actual factor dynamics than allowing arbitrary market prices of risk and estimating unconstrained OLS dynamics; a 72% forecasting R^2 is surely spurious, and so on and so on. This paper ignores all our hard-learned lessons and horror stories. For an asset pricing audience, this observation could lead to a fun discussion. However, it will bore you to death.
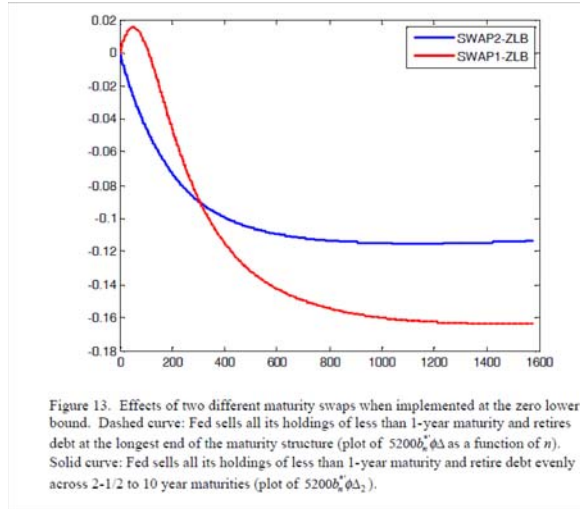
And it turns out Hamilton and Wu throw out the term structure model around p. 23. All of their actual calculations are done with a simple regression, and could be produced easily with no term structure model at all, or at most an eigenvalue principal components model. So, I'll bite my term-structure tongue, and focus on the effects of quantitative easing

13 basis points

This paper's claim is straightforward and precise: 13 basis points. Figure 13 illustrates and provides a dynamic simulation.

Figure 13. Effects of two different maturity swaps when implemented at the zero lower bound. Dashed curve: Fed sells all its holdings of less than 1-year maturity and retires debt at the longest end of the maturity structure (plot of $5200b_a^{*'}\phi\Delta$ as a function of n). Solid curve: Fed sells all its holdings of less than 1-year maturity and retire debt evenly across 2-1/2 to 10 year maturities (plot of $5200b_a^{*'}\phi\Delta_2$).

Obviously, we need to understand that calculation.

Correlations and data

Before digging in to the paper, I want to step back a moment, frame the question, and look at the data.
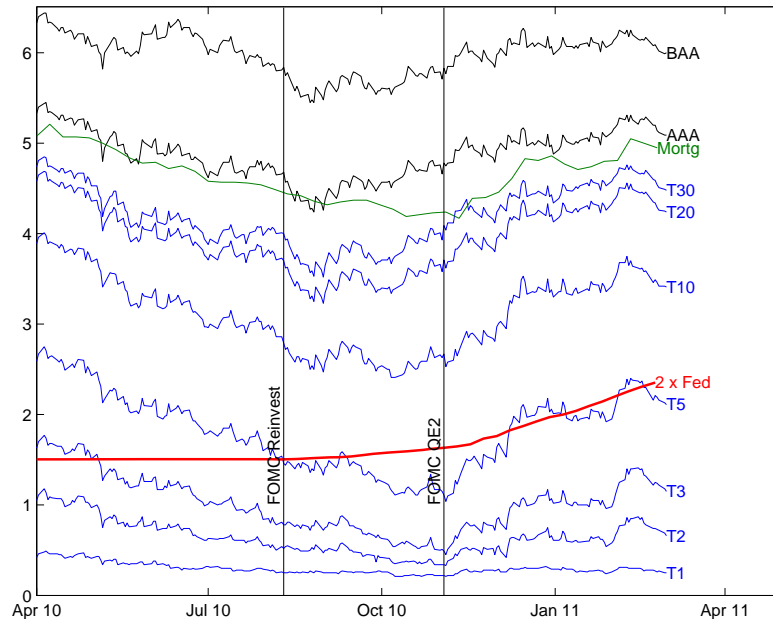
The vertical lines are the two big "announcements" from the FOMC. On August 10, the FOMC announced it would not let longer duration assets roll off the balance sheet, but instead reinvest them. On November 3, the FOMC announced the $600billion QE2 program. News leaked out in between, so we should think of the period between the lines as the announcement effect.

The thin lines are treasury, mortgage, and bond yields.

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The red line gives the Fed's holdings of Treasury notes and TIPS, the results of actual (rather than announced) purchases. You can clearly see the QE2 program in action by the rise of the read line.

QE2 does not seem to have a tremendous effect on interest rates! If anything yields seem to be going up! And 13 bp – or even 25 bp, the largest estimates elsewhere – is tiny compared to the interest rate variation you see here.

How should we read this episode? Ben Bernanke's March 1 Monetary Policy Report (Beranke 2011) says of this data:

> Yields on 5- to 10-year nominal Treasury securities initially declined markedly as markets priced in prospective Fed purchases; these yields subsequently rose, however, as investors became more optimistic about economic growth and as traders scaled back their expectations of future securities purchases.

Talk about having your cake and eating it too! No matter whether yields go up or down, it's good, and it's all the effects of QE2.

Seriously, though, this quote illustrates the problem of correlations – other things are going on, and if interest rates are rising, maybe interest rates would have been higher still absent QE2. (Hamilton and Wu p. 43 note that privately-held long term debt has risen, since the treasury is selling more than buying, and conclude " QE2 as implemented had little potential to lower long-term interest rates via the mechanism explored in this paper." That's similarly a little unfair, as if their estimates are right, QE2 made long-term interest rates 12 bp lower than they otherwise would have been.)

Event Studies

For this reason, a lot of empirical research has turned to event studies. Here is one from Annette Vissing-Jorgensen and Arvind Krishnamurthy (2011).

Figure 3. Intra-day Yields and Trading Volume on QE2 Event Days

Panel A. Yields

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The August announcement has a nice 12 bp effect. But what about November where it goes the wrong way? Here you see the problem of event studies. Annette and Arvind echo the common view that markets had priced in a larger purchase, which (as David Romer pointed out in the subsequent discussion) is consistent with newspaper articles from the time. Or maybe the sign is positive.

More deeply, maybe the August event does not represent cause and effect, but rather markets inferred "wow, the Fed is desperate. They think things are really terrible. If they're doing something this big, even if it's totally useless, it means they're going to keep short term rates low for years to come. Time to buy long term bonds." In this interpretation, the announcement has nothing to do with segmentation, illiquidity, risk bearing, or anything else, it simply is a signal of the likely path of short rates many years ahead. (Much of the subsequent discussion explored this channel.) Many responses to funds rate shocks are interpreted this way, when signs are puzzling – sometimes the funds rate shock "moves the economy," other times it "reveals the Fed's information or opinion about the economy" and has the opposite sign.

So, supply and demand is as hard here as elsewhere in economics. I am hungry to impose some theory on the issue, which is why I so welcomed this paper's premise to view the question through the eyes of an explicit term structure model.

Effects on the rest of the economy.

The larger open question, of course, is what are QE2's effects on the rest of the economy? Here opinion diverges even more – and matters even more.

Janet Yellen (2011) says QE2 will lower long yields by a modest, 25 basis points, but that this is enough to create 700,000 new jobs. That's remarkable. If so, the roughly one percentage point rise in rates since QE2 is a 2.8 million job disaster.

Ben Bernanke (2011) said, that as a direct result of QE2 announcements,

> ..equity prices have risen significantly, volatility in the equity market has fallen, corporate bond spreads have narrowed, and inflation compensation ...has risen to historically more normal levels.

That's a pretty remarkably strong set of effects as well.

On the other hand, Charlie Plosser (in the Wall Street Journal, 2011) thinks there is no job effect, and the extra reserves threaten inflation:

> "You can't change the carpenter into a nurse easily, and you can't change the mortgage broker into a computer expert in a manufacturing plant very easily.... Monetary policy can't fix those problems."
> "We have ... a trillion-plus excess reserves;" these are "the fuel for inflation," which could break out "very rapidly."

You can imagine what Tom Hoenig or Art Laffer think.

From a financial perspective, QE2 is a curious policy. QE2 is *designed* to lose money. When other bond traders buy, they seek to minimize "price impact." The Fed is trying to have the largest price impact possible, to move markets, temporarily, so that it pays high prices for the bonds it is buying. Inevitably, when it stops buying bonds, those prices will fall, and the government will sell at lower prices.

Milton Friedman once said that the measure of effective stabilization policy was whether the government makes money by its trades; then it has bought low and sold high. This policy is designed to do the opposite. For example, if Janet Yellen's 25 bp price impact is correct, the policy is expected to lose $1.5 billion dollars (or 3 billion if sales have the same price impact). That money goes straight to the pockets of bond traders. For example, Pimco announced in early March that it was dumping its entire portfolio of long-term government bonds. "Sell what the government is buying" is a strategy that has made many traders rich over the years. (See Soros.) Any benefits should be weighed against this fiscal cost.

Plea for theory

As you can see, it's important, the answer is not obvious, and it's not easy. I think it's worth going back to basics. We need some guidance from theory, which is why I was exited about this paper. Let us state why we think QE2 works, and evaluate one channel quantitatively.

I agree entirely with this paper's first point:

Money and bonds: *At zero interest rates reserves are exactly the same as short term debt.* Therefore, QE2 is *exactly* the same as buying long bonds and selling short debt. You analyze it as a pure shortening of the maturity structure. Whether the Fed gives us reserves or short term treasuries in exchange for long term debt makes no difference at all.

This fact seems remarkably hard for many people to swallow. I think a lot of Bernanke's enthusiasm comes from thinking of QE2 as "monetary policy," – he uses those words to describe it[1], not "rearrangement of the maturity structure of Federal Debt." I think a lot of Plosser's (equally misguided, in my view) worry comes from thinking that reserves are still special "money," MV=PY, and V will recover any minute now. All the current commentary about banks and businesses holding "idle cash" is just nonsense. It's just debt. We're living the Friedman rule.

(The equivalence also proved hard to swallow in the subsequent discussion, though most ended up following the psychological line: that an increase in reserves, though economically equivalent to an increase in short-term debt, might be a stronger signal of Fed intentions to keep short rates low forever. However, we don't need any frictions for signals.)

This paper makes a related error, in my view, on p. 7-8:

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[1] "Large-scale purchases of longer-term securities are a less familiar means of providing monetary policy stimulus than reducing the federal funds rate, but the two approaches affect the economy in similar ways."

If the private sector were indeed indifferent between holding freely created reserves and long-term Treasury debt, one wonders why the Federal Reserve wouldn't want to buy up the entire stock of outstanding public debt, thereby eliminating the need for future taxes to service that debt. A related question is why the government would choose to use taxes rather than money creation as the means to pay for any of its current or projected future expenditures.

Just because *current* short-term rates are zero does not mean they will *always* be zero, or that interest rates would remain zero if the government announced that all taxes will forever be zero. The latter event would surely provoke a fiscal hyperinflation, and quickly escape from the zero bound. (Cochrane 2011 analysizes this sort of event in much greater detail.)

Ricardo: Given that QE2 is a maturity swap, It's worth remembering that the benchmark prediction for its effect is zero. However, the reason is not arbitrage. After QE2, the private sector *does* bear less interest rate risk, which can affect yields. The reason for zero is that we pay taxes. Any risk "borne" by the government is still risk borne by us.

Now, many say Ricardian equivalence is silly. However, markets can be irrational in both directions, and overestimate future taxes too. Also interpreting event studies that markets are instantly pricing in the present value of liquidity services requires a lot of forethought too!

In any case, a crucial step for a *model* is to isolate *why* Ricardo is wrong. Why are bondholders separated from taxpayers? That's the first "segmentation" we need to understand in order to see if QE2 has an effect. The agents in this paper don't pay any taxes, and don't do anything but hold bonds, which sort of answers that question. But i wish it were a lot more explicit, i.e. I wish it were a full economic model that specifies who does hold taxes and what agents constraints and objectives are.

Non-Ricadian Regimes. A non-Ricardian fiscal regime can exist with rational agents and perfect markets. In that regime, QE2 *does* lower long rates and raise short rates. If surpluses are fixed, then the price level is determined by how many nominal bonds are redeemed, on net, by the fixed surpluses at each date. Fewer bonds coming due in the future means a lower price level in the future, and thus lower nominal yields. Cochrane (2011) explains the mechanism in more detail, but does not give a nice number like 13 basis points. Doing so in this context is an important item on the agenda.

Additional segmentation. We also need to think hard about additional segmentation. Even without Ricardian equivalence, 600 billion is a drop in the credit market bucket.

To Illustrate, here is a table from Janet Yellen's (2011) speech:

**Table 2: Responses of U.S. Interest Rates
to News about the Second Round of Asset Purchases**

Date	10-Year Treasury Yield	10-Year TIPS Yield	30-Year MBS Yield	10-Year BBB Corporate Bond Yield
Aug. 10, 2010	-7	-9	-2	-1
Aug. 11 to Nov. 2, 2010	-11	-47	-9	-23
Nov. 3, 2010	3	2	-2	2

Note: The table displays basis point changes from close of business on the day before the announcement to close of business on the day of the announcement, with the exception of Aug.11 to Nov. 2, 2010, which shows the interperiod change. Changes in the 10-year nominal Treasury yield are computed using a smoothed yield curve estimated by staff from off-the-run Treasury coupon securities. Changes in the yield on 10-year Treasury inflation-protected securities (TIPS) are computed by staff using a smoothed inflation-indexed yield curve. Changes in the yield on 30-year mortgage-backed securities (MBS) are computed using Bloomberg data on securities issued by Fannie Mae. Changes in the yield on 10-year BBB corporate bonds are computed using a smoothed yield curve estimated by staff using Merrill Lynch data.

(Comparing the table to my graph, you see that it takes a very selective choice of rates to get a negative sign between the two announcements! Long term bonds rise.), She here is saying that QE2 lowered mortgage and corporate rates a lot as well.

This is the key problem. If you think segmentation is narrow – limited just to Treasuries – then QE2 can have a bigger effect on Treasury yields, since a given sale or purchases forces the segmented participants to bear more risk. Alas, then, QE2 has no effect on other rates, and thus on the economy as a whole! If you think treasuries are linked to mortgages, corporate bonds, other sovereigns, bank lending, etc. then QE2 has a hope of affecting the rest of the economy. But now even 600b is just a drop in the bucket.

The model in this paper makes a clear contrary statement: segmentation only applies to Treasuries, whose pricing is delinked from all other securities. Thus it makes a clear prediction: QE2 has absolutely no effect on any other interest rate.

Liquidity as an alternative to segmentation

This paper talks about QE2 effects that come from segmentation – limited risk-bearing ability by the agents who absorb a stock of long-term treasury bonds. It's worth pointing out the two alternatives. "Liquidity" is the first – the idea that there is a special demand for Treasury bonds (and on the run bonds in particular) for their particular "liquidity." This view has limits – once liquidity demands are satisfied, additional supply has no effects. It is also more likely issue-specific. But liquidity effects can leave apparent arbitrage opportunities in the term structure, which limited risk bearing in segmented markets cannot. The "psychological" view I alluded to above is the third mechanism, that QE2 is just a way to communicate low future short rates or a higher interest rate target with no direct economic effects.

This paper

Now, how does this paper get to 13 bp?

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1. Hamilton and Wu run a regression of yield curve factors on a bond supply variable.

$$
\begin{aligned}
f_{t+1} &= c + \rho f_t + \phi q_t + \varepsilon_{t+1} \\
f_t &= \begin{bmatrix} \text{level} & \text{slope} & \text{curve} \end{bmatrix}_t \\
q_t &= \text{function of bond supply}
\end{aligned}
$$

2. They calculate the bond supply effect q_t of QE2 operation. They simulate the regression forward. They calculate the movement of individual yields from their loadings on the factors.

$$
\text{yield}_t^{(n)} = b_n f_t
$$

You may ask, what happened to the previous 23 pages and long appendix of affine term structure model? It got thrown out.

Why? If the term structure model is right,the factors f_t should incorporate all the supply q_t information. $P = E(m \times 1|$ all information). Bond prices have a nasty habit of revealing all useful information in these models. *The Term Structure Model predicts that* $\phi = 0$. (p. 20, 21).

Hamilton and Wu do not use the term structure model to infer the effect of bond supply. The results are just a simluation from a regression of yield changes on bond supply.

Prices are not always fully revealing. Extra factors like q_t are sometimes "unspanned" in term structure models, and at other times are "nearly unspanned" so a bit of measurement or estimation error could excuse their entry into a regression such as the above. Piazzesi and I (2008) face this problem as well, since our return-forecasting variable is close to unspanned. It would be very interesting to specify the term structure model so that the bond supply variables q_t really are close to unspanned. That might tell us a lot.

The bond supply variable.

Now, the bond supply variable is clever, interesting and is one important lesson you should take away from this whole business.

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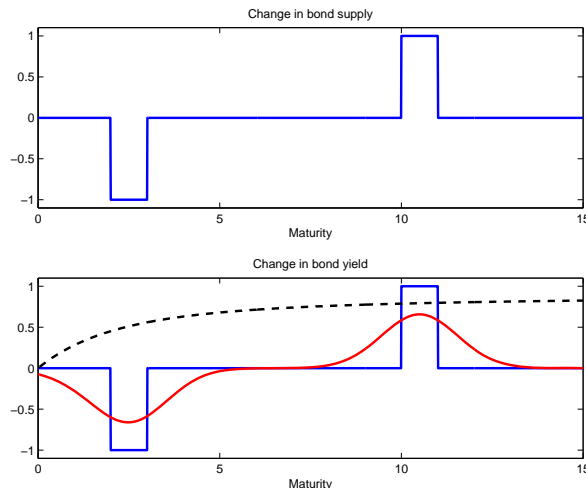
Suppose bond supply changes as in the top graph and markets are segmented. Your first guess might be that yields will respond as in the blue line in the bottom graph[2] – less supply means higher prices. On second thought, 9.9 year bonds are pretty good substitutes for 10 year bonds, so maybe you expect the red line. The Vayanos-Vila model predicts something radical: *all yields rise* as in the dashed line.

Why? It is based on a one-factor model of the term structure. All bonds are perfectly correlated and move in lockstep. A short bond is the same thing as a long bond, just less so. *Bond supply matters only if it exposes you to factor risk times factor risk premium. Then bond supply affects yields according to how it forces arbitrageurs to hold priced factor risk.*

The red intuition implicitly thinks correlations decline with maturity differences. That is NOT true of bonds. Their covariance, and thus is described by level, slope, and curvature.

Vitally, *both risk and risk premium are important.* If bond supply exposes you to factor risk that does not carry a risk premium, it has no effect.

The supply measure

So, here's how Hamilton and Wu construct the supply measure.

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

$$
\begin{aligned}
q_t &= 100 \Sigma \Sigma' \sum_n z_{nt} \bar{b}_{n-1} \\
\bar{b}_{n-1} &= \text{exposure of maturity } n \text{ return to factor } f_t \ (3 \times 1) \\
z_{nt} &= \text{fraction of bonds at maturity } n \\
\sum_n z_{nt} \bar{b}_{n-1} &= \text{how much supply } z_{nt} \text{ forces you to bear factor risk}
\end{aligned}
$$

There are three supply variables q_t corresponding to the three factors. Each is formed by adding up the fraction of bonds of maturity n, z_{nt}, times the exposure of maturity-n bonds to the factor. This tells you the amount of factor risk that you bear if you hold the US bond portfolio.

Then, Hamilton and Wu forecast yield changes with these three linear combinations of bond supply

The result and underlying stylized facts

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[2]This view is echoed by Yellen, citing work in the 1950s: ".. the term structure of interest rates can be influenced by exogenous shocks in supply and demand at specific maturities. Purchases of longer-term securities by the central bank can be viewed as a shift in supply that tends to push up the prices and drive down the yields on those securities."

It's a good and clever idea. If supply does matter, then only supply that exposes you to term structure risk should matter.

But let's look how it works out in Hamilton and Wu's implementation. Here are the three bond supply factors, used to forecast rates:
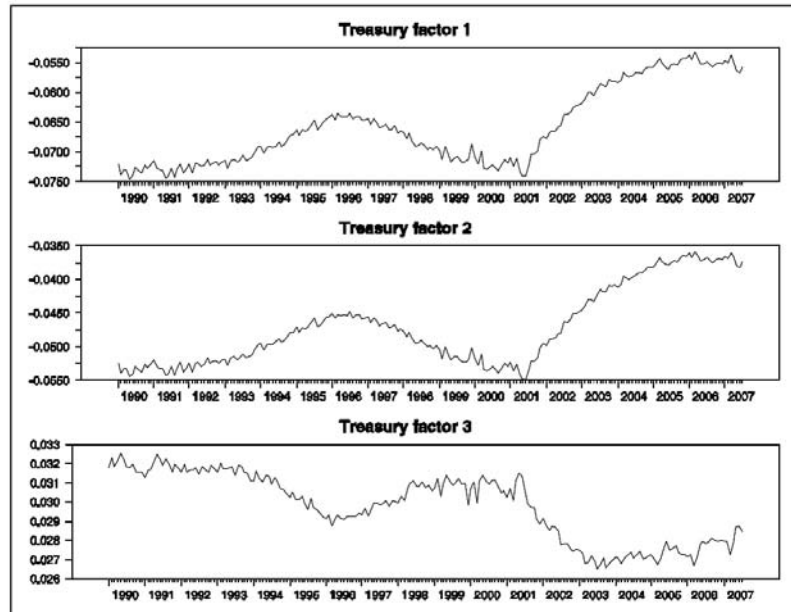
Figure 7. Values of the three elements of $q_t = 100\Sigma\Sigma'\sum\limits_{n=1}^{N-1} z_{nt}\bar{b}_{n-1}$ monthly from Jan 31, 1990 to July 31, 2007.

Obviously there's only one factor here! And here is the average maturity in weeks, squished a bit and cut from the right to match the data sample in the last graph:

Figure 4. Average maturity in weeks of debt held by the public, plotted 31, 1990 to Jan 31, 2011.

You can see the same picture again. *The three bond factors are almost exactly the same, and just give the average maturity in weeks.*

The entire calculation of the paper could be done by just running three factors – or

even just three yields – on the average maturity and simulating the regression forward.

$$
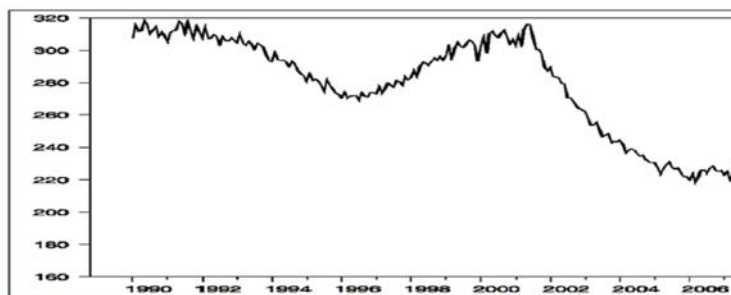\begin{bmatrix} y_{t+1}^{(10)} \\ y_{t+1}^{(5)} \\ y_{t+1}^{(1)} \end{bmatrix} = \rho \begin{bmatrix} y_t^{(10)} \\ y_t^{(5)} \\ y_t^{(1)} \end{bmatrix} + \phi(\text{av. Maturity}_t) + \varepsilon_{t+1}
$$

Ok, a regression is a regression, and we can go back to the standard discussant prison jokes about whether or not VAR simulations are "structural." I would not sound so disappointed if I had not plowed through 23 pages and an appendix of "affine model" that pretended something deeper was going to be used in the calculation.

Facts and regressions

I always like to drill down to the stylized facts in the data driving a regression. Here is a plot of yields and the average maturity variable.

Yields of 1–5 year zeros, fed funds, and average maturity
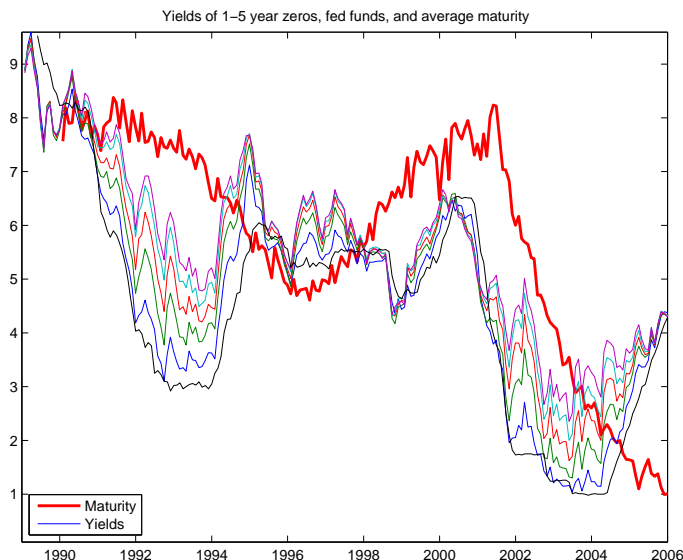
This plot suggests to me an "underlying fact:" *Long maturities in 1990 and 2001 were followed by widening spreads. Shorter maturities in 2003 were followed by flattening spreads.*

Hamilton and Wu's 13 basis points would then come down to this: Suppose this correlation is structural. Then the shortening implied by qe2 will translate to 13bp of flattening.

Regressions and return forecasts

However, their results may not be quite so simply – nor robustly – explained.

There seems to be an industry in which authors add variables to bond-return forecasts and claim ever higher R^2 this paper takes the prize, with a 74% R^2 reported for forecasting the premium of two year returns over one year returns (Table 2).

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Now, 74% R^2 for excess return forecasting is usually a sign of a fantastically over-fit model, so it naturally attracted my attention. My first guess is that it resulted from the use of smoothed data – their returns are not returns of actual securities, but come from prices that are smoothed across maturities at each date. So, I got Hamilton and Wu's q forecast variables along with the Fama Bliss zero coupon bond returns, and started running regressions.

Here is the usual regression – excess returns run on all 5 yields or forward rates,

$$r_{t+1}^{(2)} = a + b_1 y_t^{(1)} + b_2 f_t^{(2)} + b_3 f_t^{(3)} + b_4 f_t^{(4)} + b_5 f_t^{(5)} + \varepsilon_{t+1}$$

```
using fama bliss data sample from  31-Jan-1964 to  31-Jul-2007
 CP uconstrained  regressions -- full sample
           y(1)    f(2)    f(3)    f(4)    f(5)      R2
 rx(2)    -0.92    0.44    1.20    0.33   -0.83    0.33
 t       (-3.24) ( 2.04) (-7.79) ( 1.24) (-2.26)
```

That's the standard result – tent-shaped coefficients and a 0.33 R^2.

Now, the same thing in the much shorter Hamilton-Wu sample (It's not obvious to me why they use such a short sample, covering only two recessions. All the data are available back to the 1960s.)

```
 using maturity data sample from 31-Jan-1990 to  31-Jul-2007
  CP uconstrained  regressions
           y(1)    f(2)    f(3)    f(4)    f(5)      R2
 rx(2)    -0.01   -1.45    2.66   -0.15   -0.41    0.45
 t       (-0.01) (-0.73) (-2.51) ( 0.26) ( 1.18)
```

The R^2 is up to 0.45, as reported in Hamilton-Wu's Table 2. However, the coefficients, though proportional across left-hand maturity (not shown) now have the alternating signs typical of overfitting. That's not surprising as there are only two recessions left in the sample.

Now I add average maturity, based on my guess above that average maturity captures everything

```
 CP uconstrained  regressions with maturity
           y(1)    f(2)    f(3)    f(4)    f(5)     mat      R2
 rx(2)    -0.08   -1.18    2.40   -0.24   -0.36    0.00    0.46
 t       (-0.09) (-0.47) ( 1.54) ( 0.31) ( 1.06) (-0.35)
```

This does not work. Apparently the *multiple* regression using the actual q variables is important. At least for return regressions, my above hunch proves wrong.

Let's look hard at the multiple regressions

```
 CP uconstrained  regressions with q
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	y(1)	f(2)	f(3)	f(4)	f(5)	q(1)	q(2)	q(3)	R2
rx(2)	0.04	-0.17	1.07	0.73	-0.68	36.85	-37.70	12.14	0.75
t	(0.09)	(-0.15)	(0.98)	(-1.51)	(-1.22)	(-2.58)	(2.95)	(-1.10)	

The first row adds all three supply variables along with all five forward rates. I replicate the 0.75 R^2. So, at least I replicate that this result is not due to smoothing of prices across maturities, and is present in direct annual horizons with real price data.

The 0.75 R^2 does not come from overfitting the 5 forward rates, as one or two factors give the same result. Here I created factors by eigenvalue-decomposing the covariance matrix of yields:

	level	slope	curve	q(1)	q(2)	q(3)	R2
rx(2)	3.26	-0.55	-3.34	33.56	-34.55	10.24	0.74
t	(0.92)	(-0.46)	(-0.65)	(-1.91)	(2.16)	(-0.79)	
rx(2)				10.92	-12.91	3.29	0.38
t				(-0.33)	(0.44)	(-0.12)	
rx(2)	1.40			22.64	-24.31	3.91	0.70
t	(-5.97)			(-1.33)	(1.60)	(-0.26)	
rx(2)	0.94	0.20		35.07	-36.20	10.88	0.73
t	(-2.04)	(-1.64)		(-1.87)	(2.10)	(-0.80)	
rx(2)			-0.08	11.86	-13.80	3.87	0.38
t			(0.10)	(-0.43)	(0.57)	(-0.17)	

However, each of the supply factors *individually* is no help at all, leaving the R^2 exactly at 0.46 just as it is with the yield curve variables alone. *We need the multiple regression. We really need to strong +36, -37 pattern of coefficients.*

```
CP uconstrained  regressions with q
```

	y(1)	f(2)	f(3)	f(4)	f(5)	q(1)	q(2)	q(3)	R2
rx(2)	0.04	-0.17	1.07	0.73	-0.68	36.85	-37.70	12.14	0.75
t	(0.09)	(-0.15)	(0.98)	(-1.51)	(-1.22)	(-2.58)	(2.95)	(-1.10)	
rx(2)	-0.07	-1.21	2.43	-0.23	-0.37	-0.31			0.46
t	(-0.08)	(-0.49)	(1.60)	(0.29)	(1.05)	(0.31)			
rx(2)	-0.11	-1.05	2.26	-0.25	-0.35		-0.54		0.47
t	(-0.12)	(-0.42)	(1.35)	(0.39)	(1.12)		(0.53)		
rx(2)	0.10	-1.71	2.87	0.05	-0.48			-1.93	0.47
t	(0.11)	(-0.79)	(-3.50)	(-0.05)	(1.23)			(0.45)	

But, as the plots above point out, q1 and q2 are enormously correlated. Here is their correlation matrix

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correlation matrix of q, average maturity
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	q1	q2	q3	maturity
q1	1.0000	-0.9992	-0.9977	0.9197
q2	-0.9992	1.0000	0.9962	-0.9320

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q3     -0.9977     0.9962     1.0000    -0.8977
mat     0.9197    -0.9320    -0.8977     1.0000
```

A forecasting regression that really needs multiple regression to get its power, among variables that are 0.999 correlated, is obviously a bit dangerous. I made two plots to get at the bottom of this forecast.

The top plot breaks out the fitted values from the regression

$$rx^{(2)}_{t+12} = a + b_1 y^{(1)}_t + b_2 f^{(2)}_t + ... + b_5 f^{(5)}_t + \delta_1 q_{1t} + \delta_2 q_{2t} + \delta_3 q_{3t} + \varepsilon_{t+12}$$

The top left panel gives the fitted value using all right hand variables, together with the ex-post value of the return. This is what a 75% R^2 looks like. The top right panel gives the contribution of yields to this forecast, $b_1 y^{(1)}_t + b_2 f^{(2)}_t + ... + b_5 f^{(5)}_t$ along with the overall forecast. The bottom left panel gives the contribution of the supply q variables, $\delta_1 q_{1t} + \delta_2 q_{2t} + \delta_3 q_{3t}$. The bottom right panel shows the forecast from the forward rates alone, in a regression that excludes the bond supply variables. You can see it's roughly the same as the contribution in a multiple regression.

Now, focus on top right and bottom left panels. *The bond supply variables improve* R^2 *by raising the forecast of returns in one big hump in the mid-2000s.*
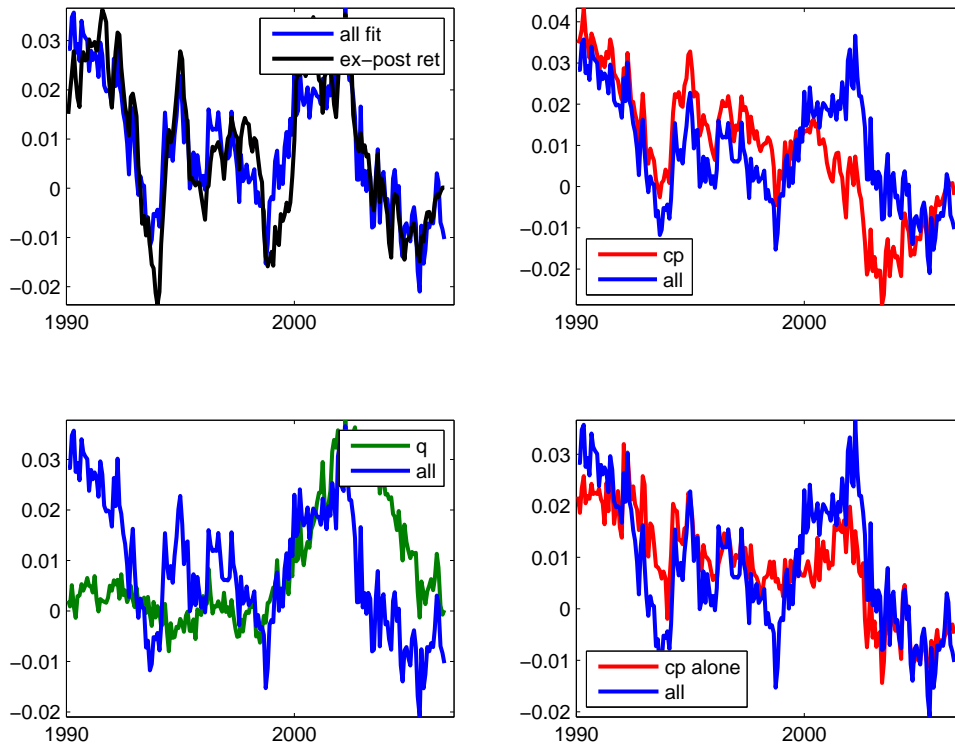
Where does this hump-shaped piece of information come from? The next graph gives the individual contributions, $\delta_1 q_{1t}$, $\delta_2 q_{2t}$, $\delta_3 q_{3t}$ and their sum in green. This green line is

the same green line as the bottom left panel of the previous graph. You can see that the green forecast is produced by a very strong offset of the nearly perfectly correlated q1 and q2 supply variables.

components of q forecast
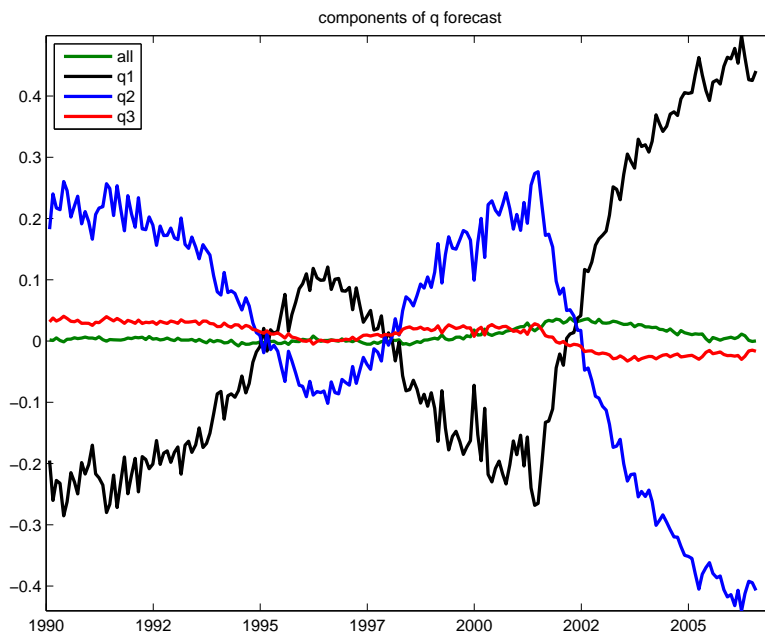
Well, here is the basic stylized fact behind the 0.74% R^2. Decide for yourself if you think it's robust or spurious.

Yield forecasts again

This experience raises an important question: I told a story that the basic yield regression came from the *levels* of the bond supply variable, not delicately offsetting differences. I replicated the basic factor VAR,

$$
\begin{aligned}
level_{t+12} &= a + b_1 \times level_t + b_2 slope_t + b_3 curve_t + \delta_1 q_{1t} + \delta_2 q_{2t} + \delta_3 q_{3t} + \varepsilon_{t+12} \\
slope_{t+12} &= ... \\
curve_{t+12} &= ...
\end{aligned}
$$

```
yield forecasts
          level    slope    curve     q(1)     q(2)     q(3)      R2
level      0.39    -0.08    -0.39    -7.23     7.54     0.46     0.66
t        ( 0.45)  (-0.26)  (-0.21)  ( 0.36)  (-0.40)  (-0.03)
slope     -5.69     1.93     7.44   -57.01    58.50   -15.99    0.76
t        (-1.00)  ( 1.03)  ( 0.89)  ( 1.39)  (-1.55)  ( 0.56)
curve      1.61    -0.51    -2.00     6.83    -6.94     3.51     0.67
t        ( 6.89)  (-3.99)  (-2.53)  (-1.67)  ( 2.10)  (-1.00)
```

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You can see that *the yield forecasts underlying the effect of supply variables are also based on very strongly offsetting coefficients of nearly-perfectly correlated q variables, just like the returns.*

So, my story above of a sensible correlation from the level of q may have been hasty. On the other hand, this estimate is quite different from the pattern reported in Hamilton and Wu's Table 3. So, let's leave it at that, with an encouragement to Hamilton and Wu to document the precise stylized facts behind their regressions in this manner, and credibly connect return-forecast and yield forecast regressions.

Could we use more of the model?

Naturally one wants to take the term structure model a bit more seriously.

- The regression uses bond supply, but ignores market price of risk. The robust result of the affine model is that bond supply only affects yields if the supply forces you to hold factor risk, *of priced factors.* The regression coefficients of yields or returns on bond supply used no such constraints. In particular, it is very unlikely that a sensible specification of market prices of risk is very strongly positive on level, and very strongly negative on slope, as the regression coefficients above are.

- For example, Piazzesi and I (2008) think the data just scream that only level risk is priced. Hamiton-Wu's estimate suggests that only the slope supply factor matters (-0.250 in the right column). If we force the forecasts to operate only on bond supply factors with factor risk premium, we conclude that the right effect of qe2 is zero!

	F test	$\phi_i' \Delta$
level	**3.256**	0.005
	(0.023)	(0.112)
slope	**4.415**	−**0.250**
	(0.005)	(0.116)
curvature	**2.672**	−0.073
	(0.049)	(0.116)

Table 3: Granger-causality tests and scenario impact estimates for factor vector autoregression. First column reports F test (p-value in parentheses) of null hypothesis that $\phi_i = 0$ in regression $f_{it} = c_i + \rho_i' f_{t-1} + \phi_i' q_{t-1} + \varepsilon_{it}$. Second column reports estimate of $\phi_i' \Delta$ for that regression (with standard error) for Δ the average change in q under the alternative scenario.

- The biggest problem with their model implementation of course, is that "supply" held by arbitrageurs is the *entire* Treasury supply and *no* supply of other bonds. In reality, much of the Treasury bond supply is locked away in central bank and pension fund vaults. Furthermore, these agents demand *bonds* not *coupons* as specified in the paper before the model is assumed away. The preferred habitat agents buy and hold, they do not roll over strips to keep a specific maturity. And "Arbitrageurs" take duration risks in mortgage-backed, corporate, and other markets – fortunately, for the hope that qe2 affects anything else.

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To use this model, we really need a much more realistic *measure* of the "supply" that matters to the actual arbitrageurs in this market. Hopefully this measure will have a more persuasive time-series pattern rather than the slow movement that causes so much trouble in the forecasting regressions.

- The model specifies that bond *demand* never changes, and *the only thing* that can affect interest rates is change in bond supply. With no change in supply, level slope or curvature movements cannot happen! If you think Fall 2008 represents a "flight to quality" and interest rates declined from an increase in demand, this model can't help you.

Cheering for interest rate risk

The paper includes a final observation about QE2 that I want to highlight and heartily agree with.

"For reasons having to do with management of fiscal risks, the Treasury is willing to pay a premium to arbitrageurs for the ability to lock in long-term borrowing cost. If the treasury has good reasons to avoid this kind if interest-rate risk it is not clear why the Federal Reserve should want to absorb it." (p. 26)

Translation:

Long term debt is a wonderful buffer against fiscal or interest rate shocks. The prices of long term bonds can absorb shocks. The US government already looks like a big hedge fund, rolling over short term debt to fund a very long-duration risky asset (future surpluses) stream and investments in a lot of credit derivatives, including mortgage, housing, recession, too big to fail, and other guarantees.

The major effect of QE2 is that it shortens the maturity structure. It is not "monetary policy" it is "financing policy." Whether or not QE2 has any effect at all on interest rates, that fact makes the US more exposed to roll-over risk. It means changes in "aggregate demand" must express themselves in quantity markets and not by repricing long-term bonds.

Think how happy Greece would have been if, when its cupboards were discovered to be bare, it had issued a lot of long-term debt, rather than needing to refinance short-term debt.

Amazingly low long term rates and huge intractable deficits amount to a golden opportunity to *issue* long term debt, quickly, while they're still buying! ("Understanding Policy..." has an extended treatment of this point)

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