Essays on the U.S. Treasury Debt Market and Asset-Pricing

by

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For my parents, Hou Tiexin and Lu Qi.

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ABSTRACT

The three essays in this dissertation examine questions in the U.S. Treasury bond market and an asset-pricing anomaly in the stock market. They are unified by the theme relating quantities of assets with asset prices. These essays challenge the notion that because financial markets are highly liquid, quantities of (demand or supply) do not matter for predicting asset prices.

Chapter 1 examines the time-varying impact of the US Treasury debt supply on bond risk premiums. I find that the elasticity of bond risk premium with respect to supply depends on the correlation between stock and bond returns. An increase in the supply of Treasury bonds raises the required bond risk premiums, but the effect is stronger as stock and bond returns become more positively correlated. I interpret this evidence within the context of a preferred-habitat asset pricing model where the arbitrageurs are the marginal investor for all bond maturities. Arbitrageurs demand higher compensation for maturity risk when the stock-bond correlation is positive as bonds are poor hedges for stocks. On the other hand, when the correlation turns more negative, an increased bond supply induces low or even negative risk premiums. The findings have practical implications for understanding the impact of the impending Federal Reserve's unwinding of its $4.5 trillion bond portfolio.

Chapter 2 documents new empirical stylized facts about the postwar U.S. Treasury debt management policy. In particular, I document the puzzling fact that the US Treasury has tended to historically issue more long-term debt when the term spread is greatest. I propose a simple model that captures the practical incentives and constraints faced by the Treasury debt manager. The debt manager seeks to minimize borrowing costs while managing rollover risks. I calibrate the model to generate a measure of time-varying rollover risks faced by the U.S. Treasury.

Chapter 3 investigates the earnings announcement premium puzzle in Finland. Between 1999-2002 and 2006-2009, I find that stocks with earnings announcement earn excess returns over non-announcement stock in the 2 week window before the announcements that quickly dissipates post-announcement. Moreover, I find that the premium is significantly higher and persistent through a 30 day window around the financial statement

releases. I find no premium around the interim earnings report and in fact accumulative losses. I also assess the relationship between announcement premium and trading volume. Using an administrative transaction-level data set, I find some supportive evidence for the attention-grabbing hypothesis. I find a positive correlation between the announcement premium and the net-buying trading volume among individual investors, especially around the financial statements.

CHAPTER I

When Is The Supply Effect Large In The Government Bond Market?

Abstract

I examine the time-varying impact of the US Treasury debt supply on bond risk premiums. I find that the elasticity of bond risk premium with respect to supply depends on the correlation between stock and bond returns. An increase in the supply of Treasury bonds raises the required bond risk premiums, but the effect is stronger as stock and bond returns become more positively correlated. I interpret this evidence within the context of a preferred-habitat asset pricing model where the arbitrageurs are the marginal investor for all bond maturities. Arbitrageurs demand higher compensation for maturity risk when the stock-bond correlation is positive as bonds are poor hedges for stocks. On the other hand, when the correlation turns more negative, an increased bond supply induces low or even negative risk premiums. The findings have practical implications for understanding the impact of the impending Federal Reserve's unwinding of its $4.5 trillion bond portfolio.

JEL Codes:

Keywords: Treasury supply, bond risk premium, QE, stock-bond correlation

1.1 Introduction

With the Federal Reserve's decision to unwind its Large Scale Asset Purchase program and Congress's tax reform, there will likely be big changes to the supply and the maturity structure of the government debt.[1] Market participants are keenly interested in how these changes will affect interest rates, asset prices and the economy. A series of papers since the 2008 financial crisis have found that increasing Treasury supply, either by an increase in the dollar value or a lengthening of the duration of the bond portfolio held by the private sector, raises the expected returns of government bonds.[2] However, the studies that look at long time series evidence have generally assumed a constant demand elasticity for bonds. Yet there is evidence that that the demand curve for Treasury bonds has shifted significantly over time, which could in turn significantly affect the strength of the Treasury supply effect.[3]

In this paper I show both empirically and theoretically that as the stock-bond return correlation becomes more positive, bond risk premiums respond more strongly to an increase in supply. In standard asset pricing theory, there is no role for demand and supply factors. For these factors to matter, there needs to be some degree of market segmentation or imperfect asset substitutability. Greenwood and Vayanos (2014) lays out the theoretical intuition for how supply shocks may affect bond prices. Preferred habitat borrowers issue bonds with an inflexible maturity structure. They pay bond risk premiums to risk averse arbitrageurs for absorbing the bond supply. Supply changes the price of interest rate risk because it changes the sensitivity of the arbitrageurs' bond portfolio to short term interest rates. In their paper, the only traded assets are a continuum of maturity of bonds. I enrich and extend their analysis by observing that if the arbitrageurs hold stocks as well as bonds, then the strength of the supply effect can depend on the time-varying hedging properties of bonds against stocks.

The stock-bond correlation influences the sensitivity of bond risk premium to supply because it tracks government bonds' hedging properties almost in real time. Campbell,

[1]July 6, 2017, FT Alphaville. Richard Koo, the chief economist of Nomura bank observes that the QE unwind will be economically equivalent to issuing new Treasuries to finance fresh deficits. When the Fed stops reinvesting principal payments from maturing Treasury securities, the Treasury Department will have to pay the bonds' face value to the Fed. Since the federal government is not running a surplus, this is money that the Treasury does not have. The Treasury department will then have to market new Treasuries to private investors to fund the Fed's redemption.

[2]See Greenwood and Vayanos (2014), Hamilton and Wu (2012) and D'Amico and King (2013) for surveys of the theory and empirical estimates for the Treasury supply effects.

[3]Because a *supply effect* is the result of a movement along an imperfectly elastic demand curve, time-varying supply effects and time-varying demand elasticities are equivalent and hence may be used interchangeably.

Sunderam and Viceira (2017) shows that increasing stock-bond correlation, which indicates higher covariance between nominal and real assets, is associated with higher bond risk premium. Specifically, they interpret the changing stock-bond correlation more fundamentally as a change in the covariance between inflation and the real economy. As inflation goes from being carriers of bad news for real output growth to goods news over the last 30 years, nominal bonds have also become better hedges for stocks.[4] The contribution of this paper is to point out that the supply factor and the covariance factor as drivers of the bond risk premium actually reinforce each other. As bonds become better hedges for stocks, the arbitrageurs will require less risk premium per unit of supply, vice versa.

I provide empirical evidence by regressing bond risk premiums on the new bond supply using data from 1961 till 2016. The bond risk premium is the difference between a long term bond yield and the average expected short-term interest rate that investors expect to prevail during the life of the bond. It is normally interpreted as the compensation for holding long-dated bonds and withstanding interest rate risk. Since market expectations are not directly observable, bond risk premiums are also unobservable and must be estimated. In the baseline I use a popular off-the-shelf bond risk premium measure from Adrian, Crump and Moench (2013), which gauge expectations statistically by estimating an affine term structure model on bond yields. I construct the bond supply measure with new issuances over the following 12 month period. Specifically, the bond supply is defined as the maturity weighted total face value of issuance over the nominal GDP.[5] Unconditionally, there is a positive relationship between bond risk premiums and supply but it is not statistically significant. However, once I control for the stock-bond correlation, I find that the supply effect becomes more positive and statistically significant. Moreover, there is also a positive and statistically significant coefficient on the interaction term between the supply and the stock-bond correlation. This indicates that the supply effect is stronger when stock and bond returns are more positively correlated or when bonds are poorer hedges for stocks.

The regression has a causal interpretation if the supply measure was exogenous to bond risk premium shocks. However, patently the quantity of government debt supply does respond to risk premium shocks such as business cycle risks. Treasury issuance closely follow deficitis, which are highly countercyclical. The maturity-weighted issuance to GDP ratio is mechnanically the product of the weighted average maturity of the issuance portfolio and

[4]Piazzesi and Schneider (2006) makes a similar observation where they argue that the compensation for inflation risk of nominal bonds should depend on the extent to which inflation is perceived as a carrier of bad news.

[5]I will discuss in greater details below why I choose to focus on issuances rather than the entire stock of debt. It suffices to say that the result is robust to using the stock of debt.

the issuance to GDP ratio. As a result, the supply measure, like deficit to GDP ratio, should rise during recessions and fall during expansions. On the other hand, the required risk premiums near business cycle troughs are high and low near the peaks. Therefore there is a natural endogeneity in the regression. I address the endogeneity issue by instrumenting for the supply measure by the weighted average maturity of issuance while controlling for the quantity of debt. The empirical results remain quantitatively similar. The weighted average maturity (WAM) of issuance is a valid instrument because the government's maturity choice in the short run is exogenous of market bond prices. Indeed, Garbade and Rutherford (2007) as well as Hou (2017a) both document evidence that the Treasury manages its issuance and repurchases to achieve a target maturity of the outstanding debt. It does so by issung a balanced amount across the maturities while tilting toward the long maturities only when the debt to GDP ratio rises.[6]

I present a modified preferred habitat term structure model to formally articulate the theoretical intuition of the empirical results. I add to the Greenwood and Vayanos (2014) model by allowing investment in stocks. As in the GV model, there are two types of agents in the bond markets: the preferred habitat (PH) borrowers and the risk-averse arbitrageurs/investors (Arb). The PH borrowers, which the US Treasury is one by assumption, have a certain maturity preference for her debt issuance and are relatively insensitive to interest rates. For example, the US Treasury, for the purpose of maintaining market liquidity and others, have a preference for issuing a balanced amount across the maturities rather than concentrating issuance in the maturity with the lowest interest rate. The Arb investors on the other hand seek to maximize the mean-variance of his portfolio returns, comprising of stock, bond and the risk-free rate returns. If the only available assets are bonds and the risk free asset, the Arb demand risk premium for absorbing net supply of bonds as compensation for taking on additional durational risk.

I modify the GV model to allow investment in stocks too. I make a key assumption of slow moving investment capital across asset classes. One way to think about this assumption is as follows. Institutions that perform the arbitrageur role, e.g., trading desks or hedges that rely on funding from brokers, are part of a business that is intrinsically exposed to the stock market risk (or business cycle risk for each the stock market proxies).[7] They

[6] Incidentally Bhandari et al. (2017) shows theoretically that this policy is actually optimal as in it maximizes social welfare. In fact, since 1970 the Treasury has made an explicit commitment to a ”regular and predictable” issuance schedule and eschews ”tactical issuances”.

[7] Duffie (2010) first started investigating the implications of slow movement of investment capital. Greenwood et al. 2017 build a preferred habitat model with slow-moving capital across asset classes where they allow the Arb investor to adjust partially. They find asset prices exhibit an overreaction to supply and demand shocks in the short run that dissipates in the long run. In that spirit, our papers have a similar stance on market structure.

cannot easily shed their exposure to stocks without exiting their business. Therefore under this assumption, the Arb investor, unable to quickly adjust her stock positions, must evaluate the additional durational risk of the new bonds against their hedging value for stocks. If the bond returns co-vary positive with stock returns, the required bond risk premium will be a sum of the duration risk compensation and the covariance risk compensation. The covariance risk premium will be increasing in the risk aversion of the Arb investor and the quantity of stocks held by the Arb investor.

Relations to literature. This paper belongs in a nascent literature on the effects of demand and supply factors in asset markets, which is a part of the larger limits-of-arbitrage literature. It also nests in a literature that tries to connect bond risk premiums with fundamental economic drivers. In the first category, because this is the first paper to identify a time-varying risk premium elasticity of bond supply so to speak, the closest papers are those that study the effects of demand and supply shocks in bond markets. Motivated by the policy implications of quantitative easing, there has been a strand of literature that has studied the effects of changing Treasury supply or the composition of privately held Treasury securities outstanding. Greenwood and Vayanos (2014) (henceforth G&V), which is the closest to this paper in spirit, writes down a preferred habitat model and empirically shows that increasing Treasury supply raises bond yields and bond excess returns. However, their paper only considers bonds and do not investigate the time-varying properties of the supply effect. Greenwood, Hanson and Liao (2017) considers a model of partial market segmentation and limited arbitrage and demonstrates how theoretically demand and supply factors can lead to "overreactions" asset prices. The theoretical environment of their paper is very similar to ours but their paper still only deals with the "level" of the supply effect and not the sensitivity of the supply effect to higher moments of asset returns. Hamilton and Wu (2012) structurally estimate a discretized version of the G&V model and find that Treasury supply measures can help predict bond excess returns. A few papers also look directly at the effects of flow measures of supply. Beltran et al. (2013) use an instrumental variable approach to estimate the impact of foreign capital inflows into US Treasury market on long term yields and find that a decrease in foreign inflow raises long yields significantly. D'Amico and King (2013) use the G&V model as motivation to estimate the response of the Treasury yield curve to QE1 purchases. This paper is related to a strand of the macro-finance literature that tries to link bond risk premiums with macro fundamentals. Ang and Piazzesi (2003), using an affine term structure model with fundamental factors, finds that a significant portion of the variability of the yield curves is explained by unobserved latent factors. Ludvigson and Ng (2009) apply dynamic factor analysis to a rich set of factors and finds macro fundamental factors are essential for explaining the (counter-)cyclicality of bond risk premiums.

1.2 Data and Measurements

1.2.1 Data Sources

I obtain the data on Treasury debt primarily from the CRSP Treasury database for the years from 1958 onwards. The dataset contains monthly snapshots of all Treasuries outstanding and includes bond prices, security issue characteristics as well as other special features. The CRSP database obtains the Treasury quantity and issue information from the Monthly Statement of Public Debt (MSPD), which are publicly available from the Treasury website. The CRSP datasets contain numerous instances of entry errors (especially on quantity outstanding) and other mistakes. I manually verify the CRSP datasets against the MSPD records and manually correct any mistakes identified. The bond prices in CRSP are obtained from either GovPX or the New York Fed as detailed in the CRSP Treasury manual. I supplement the CRSP Treasury dataset from prior to 1958 by manually inputting the quantities of the marketable securities from the MSPD. I further obtain bond prices from the archival records of the Wall Street Journal.

Zero coupon bond yields are obtained from the Gurkaynak, Sack and Wright (2006), the bond risk premium series from Adrian, Crump and Moench (2013) and Kim and Wright (2005). These are all maintained and updated daily on the Federal Reserve board website. For the calculation of the stock- bond return correlation, I obtain the S&P 500 total return index and the 10-Year Treasury bond return index series from the GFD (Global Financial Data) database. All other macroeconomic time series are downloaded from FRED.

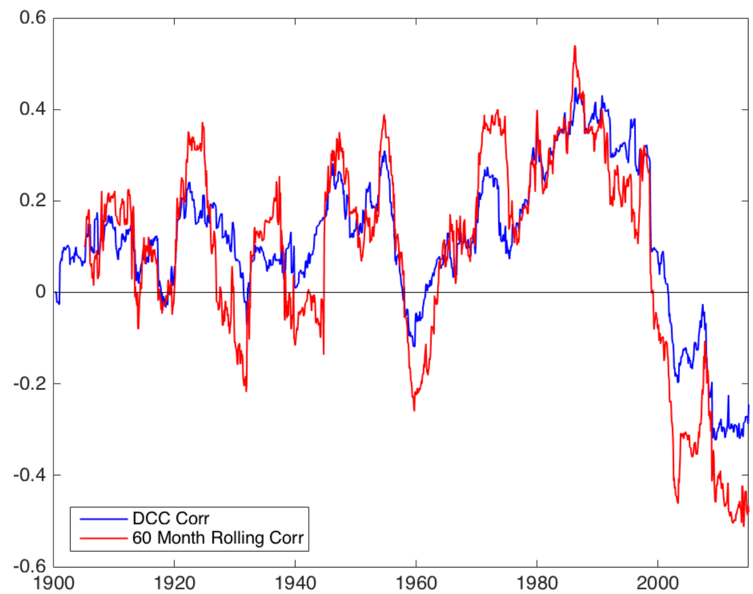
1.2.2 Measurements of Key Variables

In this section I explain the measurements of key variables used in the empirical analysis: 1) stock-bond correlation; 2) Treasury supply; 3) bond risk premium.

Measuring Stock-Bond Correlation

The stock-bond return correlation is the key state variable in this paper that reflects the investors' time-varying demand for Treasury bonds. A simple and nonparametric way of constructing the correlation is by calculating a 60 month moving realized correlation between the monthly total returns of the S&P 500 index and the monthly returns of a ten-year Treasury bond. Figure 1.1 depicts the evolution of this correlation over the last

Figure 1.1: Correlation of Stock and Bond Monthly Returns: 1900-2016



The correlations are obtained from the S&P 500 total return index and the Treasury 10 year bond index at five year moving windows. The data comes from Global Financial Data Inc.

100 years. The stock and bond correlation is highly persistent but has experienced several abrupt sign flips, notably mid 60s and late 90s. Contrary to the conventional financial advisorial wisdom that stock and bonds are inherent risk hedges, stocks and bonds have actually moved together more often than moving in opposite directions.

A chief concern about the moving window correlation is that it ignores autocorrelation and heteroskedasticity of returns. Stock returns, and to a less extent bond returns, are known to have GARCH type of volatility. The strong autocorrelation of monthly stock-bond correlation can be a result of autocorrelated volatility. We can address this concern by estimating correlation using the *dynamic conditional correlation* method proposed in Engle (2002). In this approach, we model stock and bond returns as a multivariate GARCH (1,1) process. A comparison of the correlation is plotted as below. It turns out that the 60 month moving correlation is not that different from the DCC estimates. They are highly correlated. Between 1905 and 2016 the two estimated series have a correlation of 92.1% and since 1961 they are 95.4% correlated. For the baseline results, we will use the DCC estimates. However, it is perhaps unsurprising that the empirical results are very similar using either measure.

In this paper, I do not investigate the fundamental drivers of the stock-bond correlation. I only point out its importance and usefulness as a state variable. However, given its centrality in the paper, I would be amiss not to discuss the likely drivers of the variable and how the bond supply effect is related to these more fundamental drivers. There is presently only a very small literature that has looked at the stock-bond return correlation. In the asset pricing literature, stocks and bonds are typically priced separately. In the smaller but resurgent portfolio choice literature, higher moments like the variance and covariances of asset returns are typically assumed to be constant. A notable exception and recent paper to tackle this topic is Campbell, Sunderam and Viceira (2017). They argue that the stock-bond correlation is driven by the evolving relationship between (permanent and temporary) inflation expectations and the real economy. Campbell, Sunderam and Viceira (2017) use the stock-bond correlation to obtain information about the correlation between real and nominal assets (and between real activity and inflation), which in turn cause time variations in BRP. Whereas Campbell et al. focus on the inflation risk premium component of the BRP, we focus on the supply risk premium component whose time variations are driven by the covariance risk of bonds. Li (2002) analyzes the stock-bond correlation in a statistical asset pricing model and identifies the uncertainty over expected inflation as the primary driver. Piazzesi and Schneider (2006) also identify the relationship between inflation and the real economy as an important factor. They show in a general equilibrium model with recursive consumer preferences that negative covariance between inflation and real growth news gives rise to an upward sloping nominal yield curve and significant term premia.

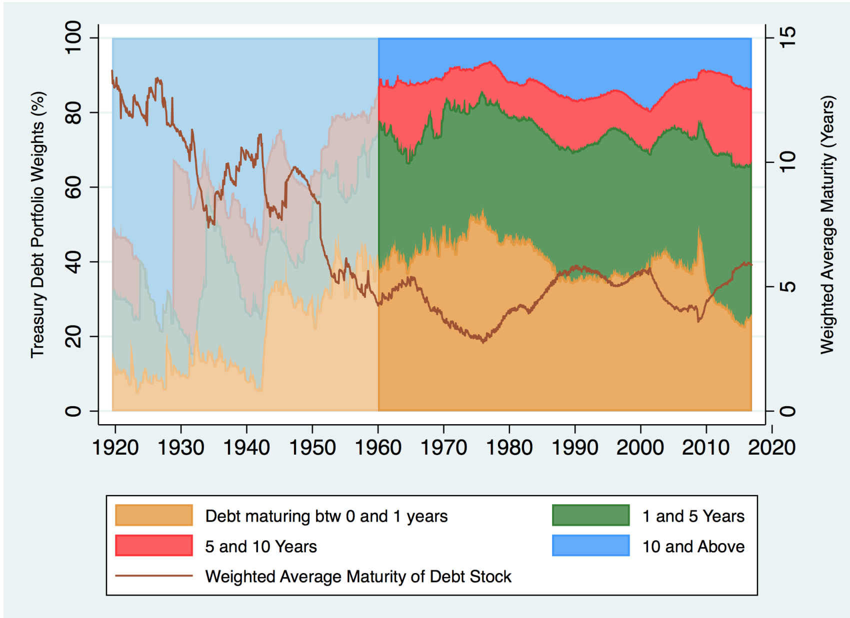
Treasury Supply

Treasury supply is defined as a maturity-weighted sum of new issuances (MWI) normalize by the nominal GDP. Unlike many papers in the literature that treat the outstanding stock of US Treasury debt as supply, I view the new issuances as a superior gauge of the Treasury department debt supply policy. Because the US Treasury has rarely bought back its debt or exercised early redemption, it primarily exercises control over its debt portfolio by adjusting the new issuances. From the market's perspective, the new issuances are also most relevant for the adjustments of arbitrageurs' portfolios. This is particularly true for long term bonds because older bonds are normally shelved and held through maturity by long term investors. Most of the trading in the bond market is on the newer issues. Older bonds are less frequently traded and relatively more illiquid.[8]

For new issuances, I include all new debts issued in the following 12 months. I measure issuance ”forward” or near-future issuances because Treasury issuances are normally well

[8]Krishnamurthy (2002) documents the Treasury bonds that have been issued for some time tend to have a discount compared to newly issued bonds of the same time till maturity. It attributes the price difference to the difference in liquidity quality between old and new bonds.

Figure 1.2: Evolution of the Treasury Debt Portfolio 1920-2016



choreographed to the market ahead of time.[9] Therefore it would reasonable to assume that the bond market reacts to (expected) issuances as news shocks. By the same token, the regression in its baseline setup is not a predictive regression unless market anticipations of near-term Treasury issuances are perfect. For robustness, I move the issuance window back and forward a few months, the results are not qualitatively changed.

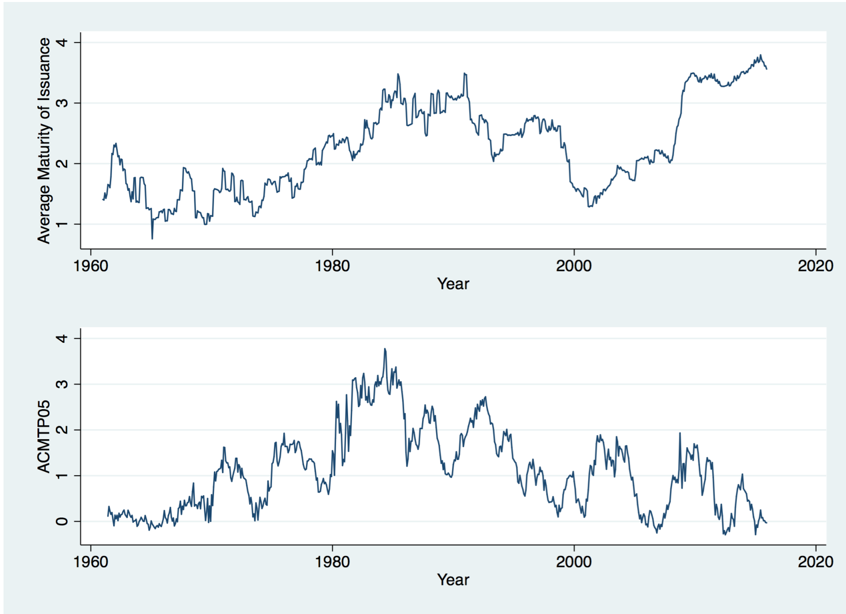
The actual formula of supply is as follows.

$$\begin{aligned} MWI_t =& \frac{\sum_{\tau, t \le s \le t+12} \text{FVOIss}_s^\tau \cdot \tau}{NGDP_t} \\ =& \frac{\sum_{\tau, t \le s \le t+12} \text{FVOIss}_s^\tau \cdot \tau}{\sum_{\tau, t \le s \le t+12} \text{FVOIss}_s^\tau} \cdot \frac{\sum_{\tau, t \le s \le t+12} \text{FVOIss}_s^\tau}{NGDP_t} \\ =& WAM_t \cdot \frac{\text{Total Issuance}_t}{NGDP_t} \end{aligned} \tag{1.1}$$

In the second equality, I decompose MWI into two terms: the weighted average maturity of new issuances and the total issuance as a share of GDP. This decomposition highlights the two different ways in which "supply" may be increased: 1) increasing the weighted average maturity while keeping the quantity of supply to be absorbed constant; 2) increasing the quantity of supply while keeping the quantity supply the same. Since the deficit to GDP ratio is known to be countercyclical, one way to resolve the endogeneity is-

[9]The Treasury Department holds quarterly meetings with the Treasury Borrowing Advisory Committee (TBAC), consisting representatives from Primary Dealers in the Treasury market, to gauge demand and solicit issuance recommendations.

Figure 1.3: Plots of WAM of Issuance and 5 Year Term Premium



WAM (Issue) is the weighted average maturity of new issuances in the next two 12 months. ACMTP05 is the zero coupon five year term premium from Adrian, Crump and Moench (2013).

sue is by instrumenting MWI measure using the WAM of issuance. Whereas the issuance to GDP ratio reflects business cycle risks, WAM of issuance reflects mostly Treasury issuance policy.

This instrument is valid if the US Treasury short term issuance policy is exogenous to shocks to bond risk premia. I argue that this is indeed the case. Garbade (2007) explains that the Treasury follows a “regular and predictable” auction schedule and does not engage in “tactical issuance” or “market timing”. Hou (2018) documents that historically the Treasury issuance has historically been driven by a desire of maintaining stability of its outstanding portfolio rather than a myopic objective of borrowing at the cheapest maturity. Indeed, Bhandari et al. (2017) shows in a theoretical model that the optimal Treasury issuance policy is one that issues evenly across the maturities with a tilt towards the long term debt when the debt to GDP ratio is high.

Bond Risk Premium

The bond risk premium, also called term premium, is the difference between long term bond yield and the average of the expected future short term nominal interest rates. It measures the degree to which the long term debt is more expensive than short term debt. A variant of the BRP, which some papers use, is the next period expected excess return of a long term bond over one period riskless bonds. The regular bond term premium is equal to the average of all future holding period excess returns.

$$y_t\left(n\right) = \underbrace{\frac{1}{n}\sum_{i=0}^{n-1} E_t y_{t+i}\left(1\right)}_{\text{Sum of Expected Short Rates}} + \underbrace{x_t\left(n\right)}_{\text{Term Premium}} \tag{1.2}$$

$$x_t\left(n\right) = \frac{1}{n}\sum_{i=0}^{n-1} E_t\left[p_{t+i+1}^{(n-i-1)} - p_{t+i}^{(n-i)} - y_{t+i}^{(1)}\right] \tag{1.3}$$

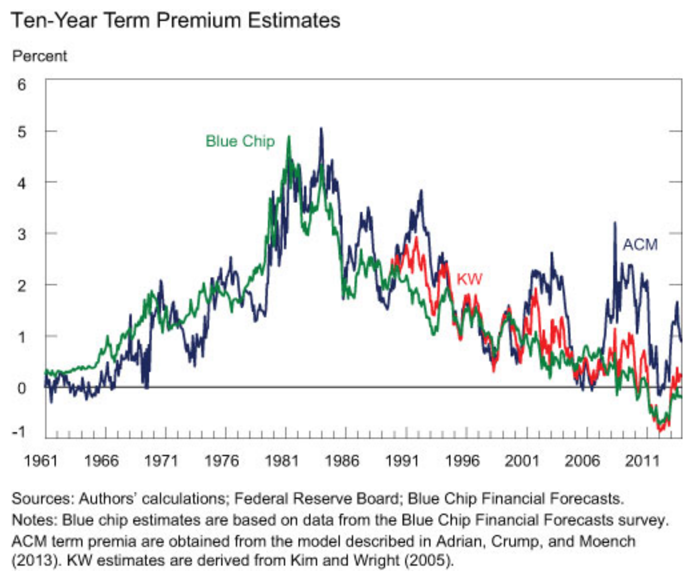
$$= \frac{1}{n}\sum_{i=0}^{n-1} E_t\left[rx_{t+i}^{n-i+1}\right] \tag{1.4}$$

In the baseline I will focus on the regular measure of bond term premium, because it is a direct measure for comparing the relative costs of borrowing across maturities. In addition, it also happens to be the measure that policymakers care about. However, in the section for robustness checks, I verify the results using expected excess returns version of the BRP from Cochrane and Piazzesi (2005) and find that the results are very similar.

Since expectations of future short term interest rates are not observable, term premium must be constructed from either statistical or survey-based measures of short rate expectations. In the baseline, I use the term premiums derived by Adrian, Crump and Moench (2013) (ACM) at the New York Fed. The authors estimate an exponentially affine term structure model of interests on directly observed market coupon bond prices. It is a popular measure that is recognized by many policymakers and market participants as credible and having good out of sample properties.[10] Furthermore, in order to address the concern that the my results are uniquely dependent on the BRP measure used, I verify the results with three alternative measures for BRP: 1) the slope of the yield curve; 2) Cochrane-Piazzesi excess returns measure; 3) Kim-Wright survey based measure; The slope of the yield curve is a nonparametric measure that has been documented to predict excess returns especially in the short run. The Cochrane-Piazzesi measure is the predicted excess returns measure of the BRP. The Kim-Wright measure is special because it is estimated using both the yield curves and survey data.

[10] A number of authors (Bernanke (2015)) agree that especially in the post financial crisis period, the realized short term nominal rates, which have been low relative to long term rates from adjacent prior years, confirm the high term premium predicted by the ACM model.

Figure 1.4: Comparison of the ACM Term Premium With Alternatives

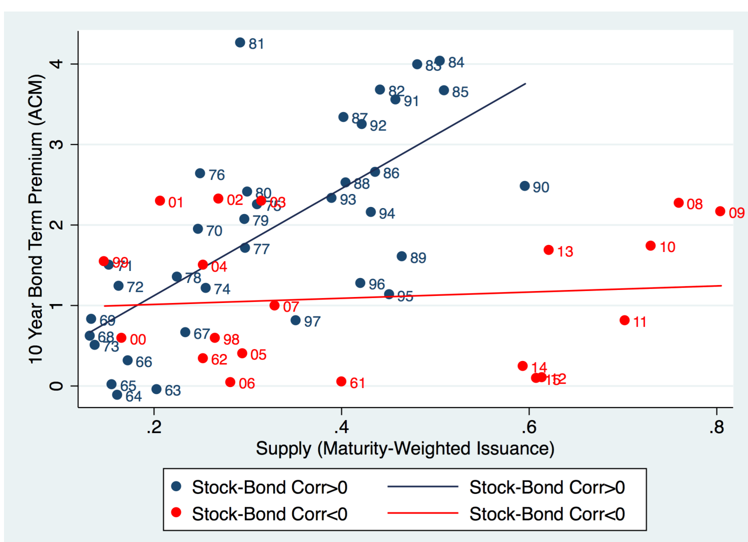


1.3 Empirical Results

1.3.1 Baseline Result

1.3.1.1 Supply Effect Increases in Stock-Bond Correlation

Figure 1.5: Plot of Bond Risk Premium vs. Supply by the Sign of the Stock-Bond Correlation



In this section, I present the main empirical result: the supply effect on BRP increases with the stock-bond correlation. I regress the ten year term premium on the MWI measure of supply. The results are presented in Table (1.1). The maturity choice of 10 year is merely serving as a representative maturity. As will be shown below, both empirically and theoretically, the estimates on all the maturities are qualitatively similar and in fact are amplified across maturities. The risk premium is in percents and the MWI measure is in decimals and defined as above. The stock-bond correlation is calculated using DCC (GARCH(1,1)) model, described in the previous section. The 1 Year Yield is the Treasury 1 year constant maturity bond yield. Finally, sign is a dummy variable that takes the value of one when the stock-bond correlation is positive. Because it is an overlapping monthly regression, there is induced serial correlation. Newey-West standard errors with 48 lags are used.

The interpretation of the columns is as follows. Column (1) indicates that unconditionally there is a positive relationship between supply and BRP. Recall that one unit increase in MWI means that issuing a maturity weighted Treasury equal to the size of the nominal GDP. A one unit increase in the maturity-weighted supply raised the required BRP by 1.8 percent. However, it is not statistically significant. In column (2) and (3), we control for the stock-bond correlation. The positive relationship between BRP and supply (MWI coefficient) becomes both stronger and statistically significant. A one unit increase in supply raises the BRP by about 4 percent. There is a noticeable jump in R^2 value from column (1) to column (2) and (3). The MWI supply is not readily interpretable. A back of the envelope estimation implies that the combined Treasury purchase of QE 1 and 2 ($900 billion), would've lowered 10 year bond risk premium by about 60 basis points. This compares with the estimates by Li and Wei (2013) and D'Amico and King (2013), who estimate the impact as lowering 10 year yields by about 90 bps. The key variable of interest is the interaction term between supply and the stock-bond correlation. This corresponds to the term "MWI x Corr" in column (3)-(5). The coefficient is positive and statistically significant, which indicates that the supply effect increases with the stock-bond correlation. Column (4) and (5) show that the effect is robust to the inclusion of the nominal one year interest rate and the sign of the correlation. Controlling for the one year rate or the short rate, because the BRP is known to be positively correlated with the level of the short rate. I also control for the sign of the correlation because the correlation changed signs quite abruptly. Controlling for the sign helps address the concern that the effect might be purely driven by a regime switch in the late 90s.

An easier way to visualize and understand the empirical findings is by looking at Figure 1.5. Here I have divided the observations into two groups: the instances when the stock-bond correlation is positive and the instances when it is negative. In each case, I plot the 10 year bond risk premium against the MWI supply measure. The two fitted lines with distinctly different slopes may be interpreted as demand curves for Treasury bonds. When the stock-bond correlation is positive, the demand curve is steep, suggesting that bond risk premium is very responsive to supply; when stock-bond correlation is negative, the demand curve, is nearly flat, suggesting that the bond risk premium is very unresponsive to supply changes. The latter case corresponds to studies since the 2008 financial crisis that the removal of large quantities of long term debt from the market due to QE has only led to a very modest reduction in the term premium.[11]

Table 1.1: Regression on MWI

VARIABLES	(1) TP10	(2) TP10	(3) TP10	(4) TP10	(5) TP10
MWI	1.791	3.395***	4.036***	4.185***	4.024***
	(1.126)	(0.922)	(0.763)	(0.709)	(0.736)
Stock-Bond Corr		2.485***	-0.382	-1.211	0.156
		(0.659)	(1.351)	(1.446)	(1.597)
MWI x Corr			6.534***	5.720**	6.203**
			(2.509)	(2.645)	(2.510)
1Y Yield				0.143**	
				(0.058)	
Sign					-0.271
					(0.508)
Constant	1.004***	0.294	0.214	-0.551	0.364
	(0.380)	(0.434)	(0.343)	(0.503)	(0.396)
Observations	665	665	665	665	665
Adjusted R-squared	0.07	0.41	0.48	0.55	0.48

Newey-West Standard Errors with 48 lags.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
TP10 is the 10 year statistical term premium from Adrian, Crump and Moench (2013); MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield; Sign is a dummy variable that equals to 1 when the stock-bond correlation is positive.

One concern about the MWI as the measure of supply is that debt issuance or the deficit is counter-cyclical. A latent business cycle factor could be driving both bond risk premium and the amount of debt issuance. I regress BRP onto the weighted maturity of issuance and issuance quantity separately. The Iss/GDP, which is the ratio of the total face value of debt issuance to GDP, measures directly the quantity of debt issuance normalized by GDP. By controlling explicitly for quantity, it partly address the endogeneity issue and partly shows explicitly the "supply" effect due to maturity structure changes. In Table (1.2) both the quantity and "WAM x Corr" coefficients are positive and significant. WAM by itself is positive but not significant. Supply does not drive out the "cross-partial" effects. It

[11]Hamilton and Wu (2012) estimates that retiring $ 400 billion of long term Treasuries would have only reduced 10 year yield by 14 basis points.

demonstrates that it is not simply that the quantity of debt that influences BRP but that maturity structure itself actually matters. Further, the effect continues to be robust to the inclusion of the short rate and the sign of the correlation.

Table 1.2: Regression on WAM and Issue/GDP Separately

VARIABLES	(1) TP10	(2) TP10	(3) TP10	(4) TP10	(5) TP10
WAM	0.330	0.282	0.313	0.188	0.299
	(0.405)	(0.272)	(0.219)	(0.184)	(0.222)
Corr		2.583***	-1.695	-2.162	-1.004
		(0.559)	(1.531)	(1.730)	(1.822)
WAM x Corr			1.590***	1.272**	1.492***
			(0.512)	(0.559)	(0.510)
IssQuant	4.514	15.611***	15.471***	20.494***	15.957***
	(6.302)	(4.330)	(3.817)	(3.669)	(4.000)
1Y Yield				0.170***	
				(0.052)	
Sign					-0.289
					(0.605)
Constant	0.211	-1.497**	-1.429***	-2.752***	-1.315**
	(0.646)	(0.619)	(0.499)	(0.677)	(0.523)
Observations	665	665	665	665	665
Adjusted R-squared	0.08	0.44	0.52	0.60	0.52

Newey-West Standard Errors with 48 lags.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

TP10 is the 10 year statistical term premium from Adrian, Crump and Moench (2013); WAM is the weighted average maturity of issuance over the following 12 months; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield; Sign is a dummy variable that equals to 1 when the stock-bond correlation is positive.

1.3.1.2 Instrumental Variable Test

To further address the concern that the supply measure may be endogenous, I use the weight average maturity of issuance as an instrument. As discussed previously, the supply measure may be endogenous because it is mechanically driven by the issuance (or roughly deficit) to GDP ratio, which may be countercyclical. On the other hand, there is evidence that the WAM of the issuance is relatively insensitive to the relative costs of borrowing but has historically been driven primarily by the objective of the stabilizing the Treasury portfolio. I discuss the evidence for the validity of the WAM of issuance as an instrument in greater details in Section 2.

The results are presented in Table (1.3).The top panel shows the results from the first stage regression. R^2 is close to 90%, which confirms that most of the variations in the maturity-weighted supply measure comes from the maturity choice of issuance. The main results are shown in the second panel. The results are broadly very similar. The coefficient on the supply measure is again positive but only significant from column (2)- (4). However, they are somewhat smaller compared to the baseline results. The more important variable of interest is the interaction term "$\hat{MWI} \times$Corr is positive and significant and the magnitude is also comparable to those in the baseline regression.

Table 1.3: Instrumental Variable Test

First Stage Regression: $\text{MWI}_t = \alpha + \beta \cdot \text{WAMiss}_t + \delta y_t^{(1)} + u_t$

	Instrument = WAMiss_t
WAMiss	.210
	(.0029)
1 Year Yield	-.00955
	(.00065)
R^2	0.896

Second Stage Regression: $\text{TP}_t = \alpha + \beta \cdot \hat{\text{MWI}}_t + \gamma \cdot \hat{\text{MWI}} \times \text{Corr} + \delta' X_t + u_t$

	(1)	(2)	(3)	(4)
VARIABLES	tp10	tp10	tp10	tp10
$\hat{\text{MWI}}$	1.223	3.182***	3.458***	3.176***
	(1.335)	(0.903)	(0.849)	(0.888)
Corr		-0.383	-1.426	-0.224
		(1.458)	(1.510)	(1.830)
$\hat{\text{MWI}}$ x Corr		6.114**	5.664**	6.001**
		(2.788)	(2.864)	(2.892)
1Y Yield			0.151**	
			(0.070)**	
Sign				-0.076
				(0.544)
Constant	1.207**	0.518	-0.324	0.561
	(0.470)	(0.390)	(0.562)	(0.418)
Observations	666	666	666	666
Adjusted R-squared	0.03	0.39	0.46	0.39

Newey-West Standard Errors with 48 lags.
*** p<0.01, ** p<0.05, * p<0.1

1.3.1.3 Summary

The message of this section is that the sensitivity of the bond risk premium to new Treasury supply is systematically time-varying. In particular, the bond risk premium increases more per unit of supply as the stock-bond correlation increases. In addition to the empirical evidence provided above, I consider a host of robustness checks. I present the results from these robustness checks after the model, which will produce some new predictions that will also be verified. The theoretical intuition given so far for the empirical results is that in an asset market of limited arbitrage, arbitrageurs demand additional risk premium for absorbing new supply of Treasury bonds. As bonds become better hedges for stocks held by the arbitrageurs, the compensatory bond risk premium is reduced by the amount of the hedging benefits of the bonds. In the following section, I use a modified version of the preferred habitat model to more formally articulate the theoretical intuition.

1.4 Theoretical Framework

The model is adapted from the Greenwood and Vayanos (2014) model. There are two types of agents. The first type is the preferred habitat (PH) borrowers or debt issuers, who are price-inelastic and supply a continuum (of maturities) of Treasury bonds. I consider the US Treasury Department (net of the Federal Reserve's demands) as a PH borrower. This assumption is valid if the Treasury's issuance policy, in terms of how much it issues in any particular maturity, is relative insensitive to the relative bond prices.[12] The second type is the arbitrageurs who integrate the bond markets by absorbing supply shocks in exchange for risk premia. They are the net demanders of bonds in this model. Arbitrageurs can invest in a continuum of nominal bonds and a single stock index. I do not allow multiple stocks because the focus of the paper is on bonds and a single stock index is sufficient to illustrate the intuition of the paper. Furthermore, it has been documented by Lines (2016) that the portfolio of most large investment funds are benchmarked to the S&P500. Finally, in line with Brennan and Xia (2002) I assume an exogenous stock price process with a constant equity risk premium. In the appendix, I show that it is possible to allow a stock price process with a time-varying equity premium, predicted by the short rate. Results are amplified when such a generalization is made.

Because the model though simple has quite a few pieces, it may be useful to provide a roadmap. First, I introduce the preferred habitat suppliers, who have exogenous price inelastic supply functions. Second, I describe the economic problem of the representative arbitrageur, who is the marginal investor in all bonds. Third, I describe the exogenous short rate and stock price processes. I conjecture that the bond price has a standard exponentially affine form and derive expressions for bond returns. Fourth, I plug in the expressions for bond returns and stock return into the arbitrageur's budget constraint, ver-

[12]This assumption has been justified by the discussion in section 2. In Hou (2018), I provide evidence that the maturity choice of the Treasury issuance is almost entirely explained by a desire to stabilize the maturity structure of the total Treasury debt portfolio and the debt to GDP ratio. This finding is also consistent with the Treasury's own stated objective that it does not engage in tactical issuance or market timing (Garbade (2007)).

ify the bond price functional form and obtain as the arb's first order conditions that the bond risk premium is a linear function of the risk factors. Finally, I use asset market clearing (arb demand equals PH supply) to generate equilibrium relationship between bond risk premium and supply quantities with which I generate comparative statics predictions.

1.4.1 Preferred Habitat (Treasury) Supply Policy

Following Greenwood and Vayanos (2014), I assume that the Treasury supply of bonds (net of Federal Reserve and other intergovernmental holdings) is driven by a single factor model. The dollar value of the maturity τ bond supplied to the arbitrageurs is

$$s_t^{(\tau)} = \zeta_t\left(\tau\right) + \theta\left(\tau\right)\beta_t \tag{1.5}$$

β_t is a stochastic aggregate supply factor. β_t may be thought of as new budget deficits that must be financed. It follows an Ornstein-Uhlenbeck process, which is essentially the continuous analogue of an AR(1) process.

$$d\beta_t = -\kappa_\beta \beta_t dt + \sigma_\beta dB_{\beta,t} \tag{1.6}$$

$\zeta(\tau)$ is the average supply of maturity τ. $\theta\left(\tau\right)$ measures the sensitivity of the individual bond supply to the aggregate supply shock.

1.4.2 Arbitrageurs Objective

The arbitrageurs invest in a stock index and a continuum (indexed by maturity) of nominal bonds. We can think of the arbitrageurs as "banks" and other large financial institutions that participate actively in the bond market. It is well-known that a group known as the "Primary Dealers", who are typically the largest financial institutions, act essentially as "wholesalers" in the Treasury primary (auction) markets.[13] The arbitrageurs maximizes the mean-variance of the expected instanenous increase in wealth or their portfolio. The objective may be motivated by a value-at-risk internal regulatory constraint within a risk-neutral institution. a is the risk-aversion parameter.

$$\max_{\left\{x_t^{(\tau)}\right\}} \left[E_t\left(dW_t\right) - \frac{a}{2}Var_t\left(dW_t\right)\right] \tag{1.7}$$

[13] In a new strand of literature "intermediary asset pricing", He, Kelly and Manela (2017) tests the theory proposed by He and Krishnamurthy (2013). They show that a stochastic discount factor constructed based on the equity capital ratio of the primary dealers has significant explanatory power for the cross-sectional expected returns of a host of asset classes.

The arbitrageurs are subject to the following budget constraint.

$$dW_t = \underbrace{\int_0^T x_t^{(s)} \frac{dP_t^{(s)}}{P_t^{(s)}}}_{\text{Stock Return}} + \underbrace{\int_0^T x_t^{(\tau)} \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} d\tau}_{\text{Bond Portfolio Returns}} + \underbrace{\left(W_t - \int_0^T x_t^{(\tau)} d\tau \right) r_t dt}_{\text{Riskfree Rate Return}} \tag{1.8}$$

where $x_t^{(\tau)}$ is the dollar investment in the bond of maturity τ and $x_t^{(s)}$ is the dollar investment in the stock index. The arbitrageurs have a short horizon objective, where they maximize the returns to wealth from period to period. The model may be thought of as being the steady state of an overlapping generations model. Finally, I assume further that the arbitrageurs' holding of stocks as exogenous and fixed, $x_t^{(s)} = \bar{x}_t^{(s)} > 0$. This assumption can be interpreted as looking at the effect of supply on impact or in the very short run, when the arbitrageurs are not able to quickly adjust allocations across asset classes. Many institutional bond traders, say trading desks at investment banks or hedge funds, are typically part of a business that is essentially exposed to the stock market risk (which in turn proxies business cycle risk). They cannot easily shed substantial exposure to the stock market risk without essentially exiting their business. The fixed stockholding assumption is an extreme one. More generally, I should only need that the Arb investor faces an downward-sloping demand curve for stocks so that it is slow to unload the stocks when the return correlation turns adverse.

1.4.3 Equilibrium Bond Prices and Bond Returns

In addition to the Treasury supply policy, I assume two additional exogenous asset return processes. First, the nominal short rate follows an exogenous Ornstein-Uhlenbeck process.

$$dr_t = \kappa_r \left(\bar{r} - r_t \right) dt + \sigma_r dB_{r,t}. \tag{1.9}$$

Secondly, the stock price follows a geometric Brownian motion.

$$ds_t = \frac{dP_t^s}{P_t^s} = \left(r_t + \sigma_s \xi_s \right) dt + \sigma_s dB_{s,t}. \tag{1.10}$$

ξ_s represents a constant unit equity risk premium associated with the stock return innovation dB_s.

The bond prices and hence bond returns will be recursively determined in equilibrium as solutions to stochastic differential equations. I solve the the model by a guess-and-verify method. I conjecture that the price of a zero coupon bond of maturity τ is exponentially affine so that the bond yields [14] are linear in the risk factors r_t and β_t and s_t.

$$P_t^{(\tau)} = \exp\left[-\left(A_r(\tau) r_t + A_\beta(\tau)\beta_t + A_s(\tau) s_t + C(\tau)\right)\right] \tag{1.11}$$

where $A_r(\tau)$, $A_\beta(\tau)$, $A_s(\tau)$ measure the sensitivity of the bond price to the risk factors. The $A_i(\tau)$'s and $C(\tau)$ are solutions to the ordinary differential equations implied by the asset market clearing conditions below. In the appendix, I verify the bond price by solving for $A_r(\tau)$, $A_\beta(\tau)$, $A_s(\tau)$ and $C(\tau)$ as deterministic functions of τ. In particular, it will be shown that $A_s(\tau) = 0$.

Now I can express the instantaneous bond return $dP_t^{(\tau)}/P_t^{(\tau)}$ in terms of the underlying shocks. By applying Îto's lemma to (1.6)-(1.11), we obtain the following expression

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} = \mu_t^{(\tau)} dt - A_r(\tau)\sigma_r dB_{r,t} - A_\beta(\tau)\sigma_\beta dB_{\beta,t} - A_s(\tau)\sigma_s dB_{s,t} \tag{1.12}$$

where μ_t^τ, which denotes the expected instantaneous return, is defined as

$$\begin{aligned}\mu_t^{(\tau)} =& A_r'(\tau) r_t + A_\beta'(\tau)\beta_t + A_s'(\tau) s_t + C'(\tau) \\ & - A_r(\tau)\kappa_r(\bar{r} - r_t) + A_\beta(\tau)\kappa_\beta\beta_t - A_s(\tau)(\bar{r} + \sigma_S\xi_t) \\ & + \frac{1}{2}A_r(\tau)^2\sigma_r^2 + \frac{1}{2}A_\beta(\tau)^2\sigma_\beta^2 + \frac{1}{2}A_s(\tau)^2\sigma_s^2.\end{aligned} \tag{1.13}$$

1.4.4 Arbitrageurs Demand

I solve for the arbitrageurs' demand by plugging expressions for the bond returns (1.12) and stock return (1.10) into the budget constraint (2.2) and in turn plugging the budget constraint into the objective function. I further assume that $Cov(\beta_t, r_t) = Cov(\beta_t, s_t) = 0$. In other words, the covariance of the bond supply shock with the stock return and short rate respectively are both zero. These assumptions are not essential but are useful for deriving closed-form expressions of bond risk premia.

[14] Zero coupon bond price and bond yield are related in the following way. $y_t^{(\tau)} = -\frac{\log P_t^{(\tau)}}{\tau}$.

The objection can then be rewritten as follows.

$$
\begin{aligned}
\max_{\left\{x_t^{(\tau)}\right\}} & \left(\left[\int_0^T x_t^{(\tau)}\left(\mu_t^{(\tau)}-r_t\right)d\tau + x_t^{(s)}\sigma_S\xi_S\right]\right)dt \\
& - \sum_{i=r,\beta,s}\frac{a\sigma_i^2}{2}\left(\int_0^T x_t^{(\tau)}A_i\left(\tau\right)d\tau\right)^2 - \frac{a\sigma_s^2}{2}\left(x_t^{(s)}\right)^2 \\
& + a\left(\int_0^T x_t^{(\tau)}A_r\left(\tau\right)d\tau\right)x_t^{(s)}\sigma_r\sigma_s\rho_{r,s} + a\left(\int_0^T x_t^{(\tau)}A_r\left(\tau\right)d\tau\right)x_t^{(s)}\sigma_s^2 \\
& + a\left(\int_0^T x_t^{(\tau)}A_r\left(\tau\right)d\tau\right)\left(\int_0^T x_t^{(\tau)}A_s\left(\tau\right)d\tau\right)\sigma_s\sigma_r\rho_{r,s} + (\text{Irrelevant Terms})
\end{aligned}
\tag{1.14}
$$

Maximizing the mean-variance objective w.r.t. this budget constraint, the arbitrageurs' optimal nominal bond demands yield conditions in the form of instantaneous excess returns.

$$
\begin{aligned}
\mu_t^{(\tau)} - r_t = & A_r\left(\tau\right)\lambda_{r,t} + A_\beta\left(\tau\right)\lambda_{\beta,t} + A_s\left(\tau\right)\lambda_{s,t} \\
& - A_r\left(\tau\right)\lambda_{r,t}x_t^{(s)}\frac{\sigma_s^2}{\sigma_r^2} - \left(A_s\left(\tau\right) + A_r\left(\tau\right)\left(1 + x_t^{(s)}\right)\right)\lambda_{r,t}\frac{\sigma_s}{\sigma_r}\rho_{r,s}
\end{aligned}
\tag{1.15}
$$

where

$$
\lambda_{i,t} = a\sigma_i^2\int_0^T x_t^\tau A_i\left(\tau\right)d\tau,\ i\in\{r,\beta,s\}
\tag{1.16}
$$

$\lambda_{i,t}$ denotes the prices of risk.

1.4.5 Asset Market Clearing

In equilibrium, the stock and bond markets clear so that we have

$$
\begin{aligned}
x_t^{(\tau)} &= s_t^{(\tau)} = \zeta_t^{(\tau)} + \theta\left(\tau\right)\beta_t \\
x_t^{(s)} &= \bar{x}_t^{(s)}
\end{aligned}
\tag{1.17}
$$

The second equality is the assumption that the arbitrageur's stockholding is fixed upon impact. The asset market equilibrium implies a set of ODEs that allows us to solve for $A_r(\tau)$, $A_\beta(\tau)$ and $A_s(\tau)$ as deterministic functions of τ. The details are relegated to the appendix. In particular we find that $A_s(\tau)\equiv 0$. In other words, bond prices are not sensitive to the dynamics of stock returns except through the correlation between stock returns and the short rate. This also significantly simplifies the expression for the bond risk premium.

$$\mu_t^{(\tau)} - r_t = A_r(\tau)\lambda_{r,t} + A_\beta(\tau)\lambda_{\beta,t} - A_r(\tau)\lambda_{r,t}\bar{x}_t^{(s)}\frac{\sigma_s^2}{\sigma_r^2} - A_r(\tau)\left(1+\bar{x}_t^{(s)}\right)\lambda_{r,t}\frac{\sigma_s}{\sigma_r}\rho_{r,s} \quad (1.18)$$

where

$$\lambda_{i,t} = a\sigma_i^2 \int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_i(\tau)\, d\tau$$

Correlation between Stock and Nominal Bond Returns

The stock and bond return correlation can now be calculated. Once again I make use of the two simplifying assumptions $\sigma_{\beta r} = \sigma_{\beta s} = 0$. The first assumption says that the bond supply shock and the level of the interest rate is uncorrelated. I show in the appendix that similar to Greenwood and Vayanos (2014) relaxing this assumption, while significantly complicating algebra, does not affect the results significantly. The second assumption says that the bond supply shock and the stock returns are uncorrelated. It is a less innocent assumption. There is reason to believe that over the business cycle, sharply adverse stock return, say a financial crisis or the news of an impending recession, may predict future deficits. However, at the frequency (less or equal to a year) which this paper looks at, it is not unreasonable to think that deficits may respond less quickly than stock returns.

$$\begin{aligned}\rho_{bs} =& Corr\left(\frac{dP_t^{(\tau)}}{P_t^{(\tau)}}, \frac{dP_t^{(s)}}{P_t^{(s)}}\right) && (1.19)\\ =& Corr\left(-A_r(\tau)\sigma_r dB_{r,t} - A_\beta(\tau)\sigma_\beta dB_{\beta,t} - A_s(\tau)\sigma_s dB_{s,t},\ (r_t + \sigma_S\lambda_S)dt + \sigma_s dB_{s,t}\right)\\ =& Corr\left(-A_r(\tau)\sigma_r dB_{r,t}, \sigma_s dB_{s,t}\right)\\ =& -\rho_{rs} && (1.20)\end{aligned}$$

Because of these simplifying assumptions, stock-bond correlation becomes constant across maturities.

1.4.6 Comparative Statics Predictions

Prediction 0

The supply effect is positive if $\rho_{r,s}$ is sufficiently positive. I call this prediction 0 because I do not explicitly test this prediction in the empirical section.

$$\begin{aligned}\frac{\partial\left(\mu_t^{(\tau)}-r_t\right)}{\partial\beta_t} =& a\left(\sigma_r^2+\sigma_r\sigma_s\rho_{b,s}\bar{x}_t^{(s)}\right)A_r(\tau)\int_0^T A_r(\tau)\,\theta(\tau)\,d\tau \\ &+ a\sigma_\beta^2 A_\beta(\tau)\int_0^T A_\beta(\tau)\,\theta(\tau)\,d\tau\end{aligned}$$

Prediction 1

The supply effect increases with correlation.

$$\frac{\partial^2\left(\mu_t^{(\tau)}-r_t\right)}{\partial\beta_t\partial\rho_{b,s}} = a\sigma_r\sigma_s\bar{x}_t^{(s)}A_r(\tau)\int_0^T A_r(u)\,\theta(u)\,du > 0$$

Intuition: In the presence of positive amount of stockholding, the absorption of additional supply, which manifests in additional duration risk/interest rate risk, must be compensated by higher bond risk premium. This effect is amplified when arbitrageur risk aversion is heightened and when interest rate or stock return volatility is higher. This prediction formally expresses what already been empirically tested.

Prediction 2

The model makes a second prediction. The degree to which the supply effect responds to the correlation increases with maturity. This result has not yet been empirically tested and it is what I will proceed to do.

$$\frac{\partial}{\partial\tau}\left(\frac{\partial^2\left(\mu_t^{(\tau)}-r_t\right)}{\partial\beta_t\partial\rho}\right) = \underbrace{A_r'(\tau)}_{>0}\cdot\underbrace{a\sigma_r\sigma_s\bar{x}_t^{(s)}\int_0^T A_r(u)\,\theta(u)\,du}_{>0} > 0$$

1.4.7 Empirical Test of Prediction 2 of the Model

The model has a second and corollary prediction: the sensitivity of the supply effect to the stock-bond correlation is amplified across the maturities. I test that prediction by regressing BRP of incremental maturities on the supply measure and the stock-bond correlation. The results are presented in Table 1.4. The ”MWI x Corr” coefficients increase in the term of the BRP from 5.5 at 2 year risk premium to about 9.8 at 10 years. The intuition for the result is that long term bonds are more sensitive to short rate risk. Because of the simple assumptions, the model almost mechanically generates a monotonic trend in the supply effect if the interest rate (duration) risk is the sole risk affecting the term structure of the BRP. The fact that the empirical evidence confirms this prediction also provides indirect corroborating evidence for the assumption about the short rate risk being the primary risk.

Table 1.4: Regress on ACM-BRP at Different Horizons

VARIABLES	(1) ACMTP02	(2) ACMTP03	(3) ACMTP04	(4) ACMTP05	(5) ACMTP10
MWI	1.757***	2.256***	2.654***	2.985***	4.042***
	(0.312)	(0.398)	(0.465)	(0.517)	(0.681)
Stock-Bond Corr	-0.818	-1.000	-1.116	-1.199	-1.387
	(0.548)	(0.728)	(0.869)	(0.980)	(1.292)
MWI x Corr	5.480***	6.610***	7.354***	7.918***	9.823***
	(1.084)	(1.425)	(1.686)	(1.884)	(2.424)
Constant	-0.042	-0.008	0.030	0.069	0.273
	(0.140)	(0.178)	(0.210)	(0.237)	(0.323)
Observations	665	665	665	665	665
Adjusted R-squared	0.53	0.53	0.52	0.51	0.50

Newey-West HAC standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

ACMTP‘n’ is the ACM n year term premium.; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

1.5 Robustness Checks

1.5.1 Alternative Measures of Ex Ante BRP

This section addresses the concern that the results may be dependent on the particular choice of ACM risk premium estimates. Adrian, Crump and Moench (2013) extract the bond term premia from a purely statistical no-arbitrage bond pricing model. While it has become popular with industry practitioners and central bank policymakers alike, there is always the worry that these risk premium estimates could suffer from model misspecification. I try to address this concern by looking at three alternative measures of the ex

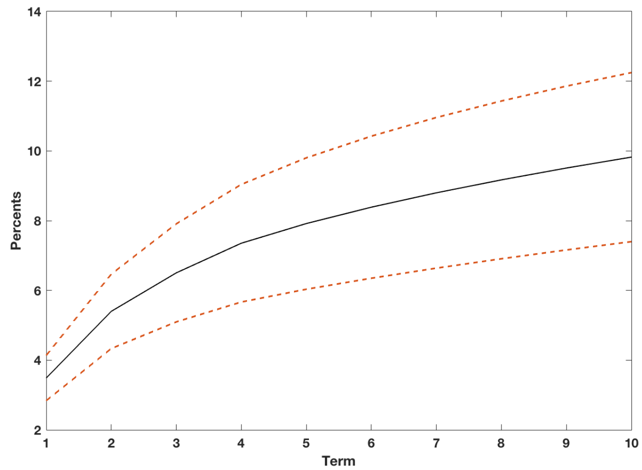


Figure 1.6: MWI Interaction Coefficients at Different Maturities

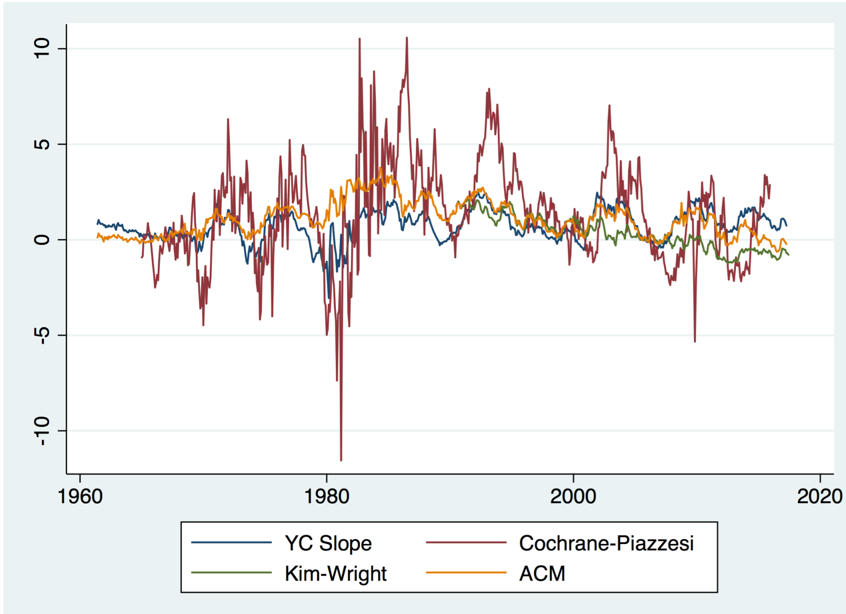
ante BRP: (1) the slope of the yield curve; (2) the Cochrane and Piazzesi (2005) forward-rates-based BRP (CP); (3) the Kim and Wright (2005) survey-based BRP (KW). Figure 1.7 shows the time series plot of all four BRP measures. The ACM, YC and the KW measures of BRP follow each other pretty closely and CP measure is the most volatile. All these measures assume that the bond yields are the sum of expected future short term yield and BRP without forecast errors.[15]

1. Yield Curve Steepness

   The yield curve steepness is the simplest and a popular proxy for ex ante BRP. The shape of the yield curve reflects both the expectations of future short term interest rates and the required term (or risk) premium. Fama and Bliss (1987) and Campbell and Shiller (1991) show that in the near-term the yield curve predicts future excess bond returns rather than future yield changes. However, in the long term, the yield curve is a very poor predictor of BRP because of mean-reversion of short-rate expectations. In table 1.5, we show the results from regressing the difference between 3 and 1 year yields on the same set of regressors. We see that that a very similar pattern as the baseline regression with the ACM BRP. The "MWI x Corr" coefficients remain positive and statistically significant even though the statistical significance drops somewhat. In table 1.6, we see that the second prediction of the model continues to hold. The coefficients increase across the maturities. The statistical signif-

[15] Cieslak (2016) shows that the bond investors exhibit extrapolative beliefs about interest rates, especially around turns of business cycles. People overestimate interest rates as the economy enters a recession and underestimates interest rates when it enters a boom. Allowing forecast errors is beyond the scope of this paper.

Figure 1.7: Different Measures of Ex-ante BRP



icance wanes as maturity increases. However, this could be consistent with the fact that at longer horizons, YC becomes a much poorer and noisier predictor of the BRP.

2. Cochrane-Piazzesi BRP

   Cochrane and Piazzesi (2005) uncovered a better predictor of future bond returns than the yield curve. They regress realized bond returns on the five one-year forward rates (the one to five years ahead marginal discount rates in the term structure) and find that all bond returns seem to be predicted by a single forecasting factor. The single forecasting factor consists of a ”tent-shaped” linear combination of forward rates. The CP-BRP is more volatile than the other measures because it is derived from realized excess returns. In table 1.7, we see that a very similar pattern as the baseline regression emerges. The ”MWI” coefficients are bigger and become significant when the stock-bond correlation is controlled for. The ”MWI x Corr” coefficients are positive and statistically significant. Finally, the R^2 jumps from merely to 2% to 20% when we control for stock-bond correlation. Once again, table 1.8 shows that the supply sensitivity to correlation increases with maturity. For the CP-BRP, we only go up to 5 years because the Fama-Bliss yields, which Cochrane-Piazzesi use, only go up to 5 years.

3. Kim-Wright BRP (Survey-based Term Structure Estimates)

   In contrast with the previous measures of BRP, Kim and Wright (2005) use direct sur-

Table 1.5: Measure BRP with Yield Curve

VARIABLES	(1) Slope3	(2) Slope3	(3) Slope3	(4) Slope3	(5) Slope3
MWI	1.016***	1.052***	1.312***	1.190***	1.313***
	(0.325)	(0.382)	(0.338)	(0.314)	(0.346)
Stock-Bond Corr		0.063	-1.231	-0.737	-1.427
		(0.315)	(0.829)	(0.579)	(1.001)
MWI x Corr			3.206**	4.647***	3.265*
			(1.604)	(1.237)	(1.668)
1Y Yield				-0.122***	
				(0.029)	
Sign					0.111
					(0.221)
Constant	0.058	0.042	0.010	0.674***	-0.052
	(0.147)	(0.169)	(0.151)	(0.206)	(0.232)
Observations	665	665	665	665	665
Adjusted R-squared	0.11	0.11	0.18	0.42	0.18

Newey-West HAC standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Slope3 is the difference of 3 year and 1 year zero coupon yields; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

vey data to purge the future short rate expectations components from bond yields and hence obtain BRP. Using a Kalman filter framework, they incorporate the monthly 6 and 12 month ahead forecasts of Treasury bill yields from the Blue Chip Financial Forecasts. This is supposed to produce more realistic looking yield curve history. The shortcoming of the KW BRP is that it is a much shorter time series, only available since about 1990, because the survey data did not begin until late 1980s. In table 1.9, we see that once again a very similar pattern emerges despite being a much shorter sample. The second prediction of the model is also confirmed in table 1.10.

1.5.2 Inflation Uncertainty

It has been argued that an important source of bond risk premium comes from the inflation uncertainty premium. In particular, high inflation levels are associated with greater inflation uncertainty. While it is know that the level of the nominal short rate is highly correlated with inflation, it is worthwhile to separately control for the inflation uncertainty. Here we capture the uncertainty about long term expected inflation using the difference between the long-term (10 year) government bond yields and the 5-year moving average of real GDP growth rates. Table (1.11) shows that the main predictions of the model re-

Table 1.6: Regress on YC-BRP at Different Horizons

VARIABLES	(1) Slope2	(2) Slope3	(3) Slope4	(4) Slope5	(5) Slope10
MWI	0.701***	1.312***	1.839***	2.289***	3.750***
	(0.197)	(0.338)	(0.438)	(0.513)	(0.720)
Stock-Bond Corr	-0.740	-1.231	-1.597	-1.888	-2.794
	(0.475)	(0.829)	(1.090)	(1.289)	(1.837)
MWI x Corr	2.168**	3.206**	3.743*	4.045*	4.514
	(0.937)	(1.604)	(2.081)	(2.435)	(3.407)
Constant	0.020	0.010	-0.008	-0.025	-0.063
	(0.086)	(0.151)	(0.201)	(0.238)	(0.342)
Observations	665	665	665	665	665
Adjusted R-squared	0.16	0.18	0.21	0.25	0.38

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Slope-n is the difference of n year and 1 year zero coupon yields; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

mains robust after controlling for inflation uncertainty. Column 1 shows that the result holds for the MWI measure of supply and column 2 shows that the result continues to hold when we control for the quantity of issuance.

1.5.3 More Robustness Checks

There is a host of other robustness checks that are relegated to the appendix.

- Quarterly regressions and non-overlapping annual regressions: qualitatively very similar but annual reg has less power.
- Different time sub-samples. In a way, the KW regressions are telling because the KW series starts in 1990 Jan.

1.6 QE Unwind Application

The Fed is expected unwind about $180bil of Treasuries in 2018. Without calibrating the model, we can only do a back of the envelope calculation of the expected effect of the QE unwind taking stock-bond correlation into consideration. Assume that the Fed winds proportionally so that its ”issuance” has the same maturity structure as its current holdings, we can infer the duration risk from its current holdings. Roughly, an anticipated $180bil unwinding corresponds to about 10bps an increase in 10 year term premium as opposed to

Table 1.7: Measure BRP with Cochrane-Piazzesi Factor

VARIABLES	(1) CP-BRP-3y	(2) CP-BRP-3y	(3) CP-BRP-3y	(4) CP-BRP-3y	(5) CP-BRP-3y
MWI	1.204	2.035*	2.905***	2.506***	2.905***
	(1.105)	(1.123)	(0.843)	(0.755)	(0.817)
Stock-Bond Corr		1.464	-3.072*	-2.115	-3.057
		(0.988)	(1.806)	(1.456)	(2.201)
MWI x Corr			11.240***	14.468***	11.238***
			(3.625)	(3.000)	(3.535)
1Y Yield				-0.260***	
				(0.051)	
Sign					-0.009
					(0.621)
Constant	0.463	0.077	-0.017	1.486***	-0.012
	(0.395)	(0.494)	(0.356)	(0.485)	(0.524)
Observations	612	612	612	612	612
Adjusted R-squared	0.02	0.08	0.20	0.34	0.20

Newey-West HAC standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

CP-BRP-3y is the estimated ex-ante 3 year BRP. It is generated by regressing the realized excess returns of 3 year bonds on the Cochrane-Piazzesi factor, which is a linear combination of forward rates; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

about 25bps not considering the correlation effect. This is mostly a ”qualitative” estimate. I'm working on a fully specified discrete VAR to obtain quantitatively meaningful estimates and dynamic effects.

1.7 Conclusion

This paper analyzes the Treasury bond issuances as a driver of the bond risk premium. I provide empirical evidence for a new fact that the effect of Treasury supply on bond risk premium strengthens when the stock-bond return correlation increases in maginitude. This empirical finding is robust to a battery of robustness checks. I rationalize this empirical finding using a modified version of the preferred habitat term structure model. Treasury as a borrower supplies bonds across the maturity spectrum with a certain inflexibility that is driven by institutional policy. Risk averse arbitrageurs demand ex ante bond risk premium for absorbing new supply of Treasury bonds to compensate for both the duration risk (interest rate risk) as well as the covariance risk with respect to the existing stocks in their portfolio. The second risk factor appears because the arbitrageurs are unable to

Table 1.8: Regress on CP-BRP at Different Horizons

VARIABLES	(1) CP-BRP-2y	(2) CP-BRP-3y	(3) CP-BRP-4y	(4) CP-BRP-5y
MWI	1.503***	2.905***	4.373***	5.181***
	(0.436)	(0.843)	(1.269)	(1.503)
Stock-Bond Corr	-1.590*	-3.072*	-4.624*	-5.479*
	(0.935)	(1.806)	(2.718)	(3.221)
MWI x Corr	5.818***	11.240***	16.920***	20.049***
	(1.876)	(3.625)	(5.456)	(6.465)
Constant	0.018	-0.017	-0.155	-0.291
	(0.184)	(0.356)	(0.535)	(0.634)
Observations	612	612	612	612
Adjusted R-squared	0.20	0.20	0.20	0.20

Newey-West HAC standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
CP-BRP-'n'y is the estimated ex-ante n year BRP; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

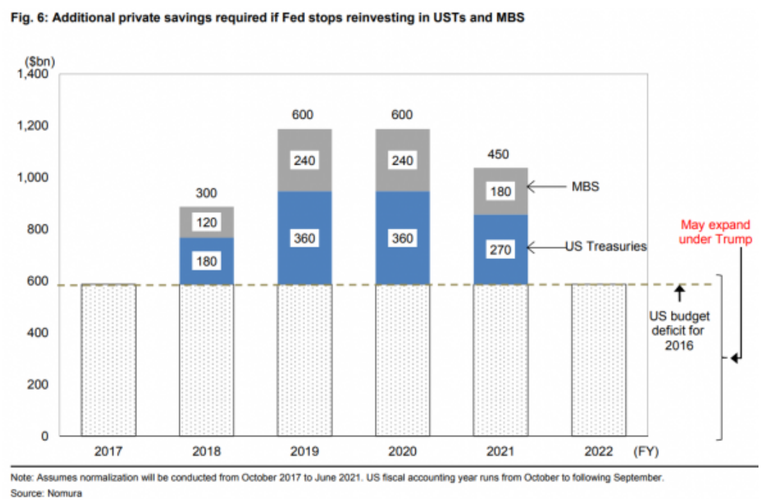


Figure 1.8: QE Unwind Schedule

quickly shed their exposure to stocks or business cycle risks. As a result, they are unable to unload the additional covariance risks introduced by the new bonds and therefore demand additional (possibly negative) bond risk premium. The effects identified in this paper are new and economically meaningful. They have implications for understanding the impact of shrinking Federal Reserve's balance sheet as well as informing government debt management policy.

The findings in this paper also prompt a couple promising directions of future research. First, additional corroborating evidence may be found for the theory by looking directly at financial arbitrageurs' capital flows across asset classes. The model says that the high stock-bond correlation plus slow asset allocation adjustment plus new Treasury lead to higher bond risk premium. This implication may be tested by examining the portfolio dynam-

Table 1.9: Kim-Wright Survey-based BRP

VARIABLES	(1) KWTP5	(2) KWTP5	(3) KWTP5	(4) KWTP5	(5) KWTP5
MWI	-1.805***	-0.950**	1.983**	2.096***	1.531*
	(0.674)	(0.429)	(0.934)	(0.774)	(0.795)
Stock-Bond Corr		2.498***	-2.430**	-2.410**	-2.569*
		(0.418)	(1.209)	(1.087)	(1.333)
MWI x Corr			11.450***	10.212***	10.329***
			(2.976)	(2.597)	(2.542)
1Y Yield				0.083	
				(0.057)	
sign					0.359
					(0.499)
Constant	1.150***	1.148***	0.009	-0.390	-0.016
	(0.281)	(0.185)	(0.357)	(0.391)	(0.411)
Observations	316	316	316	316	316
Adjusted R-squared	0.15	0.65	0.75	0.76	0.76

Newey-West HAC standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

KWTP5 is the Kim-Wright 5 year term premium. It is estimated by incorporating survey data into a three factor term structure model; The MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

ics of the key bond-trading institutions, e.g., mutual funds, pension funds and insurance companies. Secondly, we may write down a discretized version of the model following Hamilton and Wu (2012) and incorporate the stock-bond correlation as a state variable to generate quantitatively meaningful estimates for the supply effects of the QE unwinding among other policies.

Table 1.10: Regress on KW-BRP at Different Horizons

VARIABLES	(1) KWTP2	(2) KWTP3	(3) KWTP4	(4) KWTP5	(5) KWTP10
MWI	1.024***	1.351*	1.679*	1.983**	2.861***
	(0.313)	(0.777)	(0.887)	(0.934)	(0.982)
Stock-Bond Corr	-1.344***	-1.737*	-2.103*	-2.430**	-3.326**
	(0.405)	(0.997)	(1.145)	(1.209)	(1.383)
MWI x Corr	7.548***	9.239***	10.494***	11.450***	13.441***
	(0.969)	(2.426)	(2.810)	(2.976)	(3.298)
Constant	0.101	0.059	0.024	0.009	0.177
	(0.124)	(0.307)	(0.344)	(0.357)	(0.369)
Observations	316	316	316	316	316
Adjusted R-squared	0.79	0.78	0.77	0.75	0.67

Newey-West HAC standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

KWTP'n' is the Kim-Wright n year term premium.; MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

2. Maturity Distribution of Securities, Loans, and Selected Other Assets and Liabilities, September 13, 2017

Millions of dollars

Remaining Maturity	Within 15 days	16 days to 90 days	91 days to 1 year	Over 1 year to 5 years	Over 5 year to 10 years	Over 10 years	All
Loans	47	173	0	0	0	...	220
U.S. Treasury securities (1)							
Holdings	0	38,559	323,378	1,144,904	325,435	633,193	2,465,468
Weekly changes	0	0	- 1	- 3	+ 196	- 12	+ 179
Federal agency debt securities (2)							
Holdings	0	2,366	1,982	62	0	2,347	6,757
Weekly changes	0	0	0	0	0	0	0
Mortgage-backed securities (3)							
Holdings	0	0	1	93	17,608	1,764,644	1,782,346
Weekly changes	0	0	0	0	0	+ 14,792	+ 14,793
Repurchase agreements (4)	0	0	...	...	...	...	0
Central bank liquidity swaps (5)	87	0	0	0	0	0	87
Reverse repurchase agreements (4)	366,719	0	...	...	...	...	366,719
Term deposits	0	0	0	...	...	...	0

Figure 1.9: Federal Reserve Portfolio on Sep-13 2017

Table 1.11: Regression on MWI: Inflation Uncertainty

VARIABLES	(1) tp10	(2) tp10
WAM		0.359*
		(0.186)
Corr	-1.529*	-2.647*
	(0.836)	(1.567)
WAM x Corr		1.749***
		(0.525)
IssQuant		16.359***
		(3.656)
Infl Uncertainty	0.123***	0.116***
	(0.030)	(0.044)
MWI	4.504***	
	(0.477)	
MWI x Corr	7.838***	
	(1.654)	
Constant	-0.356	-2.069***
	(0.223)	(0.577)
Observations	658	658
Adjusted R-squared	0.54	0.57

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

TP10 is the 10 year statistical term premium from Adrian, Crump and Moench (2013); MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the dynamic conditional correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

CHAPTER II

A Realistic Model of U.S. Treasury Debt Management

Abstract

The operation of the U.S. Treasury debt management is understudied and not well understood theoretically. I document new empirical stylized facts about the postwar U.S. Treasury debt management policy. In particular, I document the puzzling fact that the US Treasury has tended to historically issue more long-term debt when the term spread is greatest. I propose a simple model that captures the practical incentives and constraints faced by the Treasury debt manager. The debt manager seeks to minimize borrowing costs while managing rollover risks. I calibrate the model to generate a measure of time-varying roll-over risks faced by the U.S. Treasury.

JEL Codes:
Keywords: U.S. Treasury, debt management, safe asset, roll-over risk

2.1 Introduction

In this paper, I study how the U.S. Treasury has historically managed its debt obligations and issued new debts. This is an important but also understudied question. Its importance comes from both the sheer size of the U.S. federal government debt and the unique and pervasively important role U.S. Treasury securities play in the global financial markets. To date, the economics literature has mostly either dismissed the government debt management policy as an unimportant subject under some version of the Ricardian neutrality argument or focused on the question of *optimal* debt maturity structure. As a result, few academic studies have engaged seriously the actual way in which the U.S. government debt is historically managed and the practical incentives and constraints faced by the Treasury debt managers. Against this background, this paper makes two contribution to the subject of government debt policy. First, I document a few new systematic patterns that characterize the U.S. Treasury debt issuances since the end of World War 2. Second, I propose a simple theoretical model that captures the essential trade-offs faced by the debt manager and rationalizes some salient facts observed in the data.

I begin by presenting *four* stylized facts that characterize the empirical patterns of the U.S. Treasury issuance policy since 1950.[1] The first fact says that about 50% of the Treasury's issuance decisions involve choosing how much to borrowing in short-maturity (less than 1 year in time to maturity) versus in the rest of the maturities. Furthermore, the amount borrowed in the longer maturities is typically spread out evenly across the maturity spectrum. The other 50% of the decisions are about adjusting issuances between adjacent maturity buckets further down the maturity spectrum. This latter set of decisions is likely driven by the goal of having some recently issued securities in every maturity bucket.[2] The second fact says that when the Treasury decides to lengthen the maturity of its issuance, it does so by spreading the new gross issuances across the maturity spectrum rather than concentrating on a single point of maturity. I show that the weighted average maturity of quarterly issuance is strongly positively correlated with measures of the issued securities's maturity dispersion. The second fact reinforces a message in the first fact that the Treasury appears to have a strong desire to spread the issuance of large amount of longer-term

[1] I focus on the Treasury's gross quarterly issuances and not the stock of Treasury debt outstanding. The reason is that the debt stock is a cumulative reflection of the past issuance decisions, whereas the gross issuances reflect the decisions made by the Treasury in response to current incentives and constraints.

[2] There is well-documented evidence that newly issued Treasury securities are traded at a higher market price than older Treasury securities with similar time-till-maturity. This phenomenon is known as the "on/off-the-run liquidity premium".(Krishnamurthy (2002)) Having recently issued benchmark Treasury securities promotes liquidity and higher secondary market prices of Treasuries and in turn benefit primary market operations.

debt across many different maturity points. The first two empirical facts suggest that the Treasury historically has been highly conscious about the impact of its issuance's maturity allocation. This is also consistent with the U.S. Treasury's own emphasis of the liquidity or price impact of its supply actions.[3] This runs somewhat contrary to the common impression that the market for U.S. Treasury securities is the world's most largest and most liquid financial market.

The third and fourth stylized facts deal with the fundamental drivers of issuance and the cyclicality of the issuance maturity. Fundamentally, there are two sources of federal government borrowing needs at any given time. Either there is old government debt maturing that must be refinanced or there are fresh federal deficits.[4] The third fact says that the weighted average maturity of issuance lengthens in response to both sources of funding needs. Moreover, I show that (long-term) debt maturing has only a temporary impact on the issuance maturity while a rise in deficit has a much more persistent effect on the issuance maturity. The fourth empirical fact points out a positive correlation between the issuance maturity and the term spread, which reflects the relative expensiveness of long-term debt over short-term debt. Since 1950, the periods of high deficit-to-GDP ratio have consistently coincided with the local peaks of the spread between long-term and short-term interest rates. And since deficits lead to a persistent lengthening of the weighted average maturity of issuance, this means that larger issuances of long-term debt have tended to happen when long-term interest rates are high relative to short-term interest rates. I further confirm that this correlation exists between the issuance maturity and a purer measure of the term premium of long-term Treasury debt.[5] This last empirical regularity is particularly puzzling if one believes that the Treasury's operation, similar to an ordinary borrower, is guided by the objective of minimizing borrowing costs.[6]

[3]The Treasury's public documents and the reports and minutes of the primary dealers have historically repeatedly emphasized the importance of "not exceeding market demand" for securities of particular maturities. See Treasury Borrowing Advisory Committee (1982-2017*b*) and Treasury Borrowing Advisory Committee (1982-2017*a*).

[4]After World War 2, recognizing that the a maturing Treasury security was more likely to be refinanced than extinguished, Treasury officials gradually began to think in terms of regular schedule of debt issuances and later predictable debt maturities and quantities. (Garbade (2007))

[5]The simple difference between long-term and short-term interest rates does not necessarily reflect the relative expensiveness of borrowing long-term. Because long-term interest rates contain both expectations about future short-term interest rates and the risk premium over the uncertainty about future short rates, a purer measure of the relative expensiveness strips out the expectational component of the term spread. In this paper, I will use a popular measure first proposed by Cochrane and Piazzesi (2005).

[6]The Treasury's own website and internal historical documents state that its top objective, both presently and historically, is to minimize the cost of borrowing over time. Of course, the U.S. Treasury is no ordinary borrower and it might interpret the concept of "cost" more broadly than interest costs and to include welfare costs. Yet, peppered throughout Treasury's documents and its advisory council (TBAC)'s minutes are references to "interest costs". Of course, the Treasury also lists other objectives such as liquidity and roll-over

To help understand these empirical facts (in particular the last two), I propose a simple positivist model of the Treasury debt management. This contrasts with existing models in the small public debt maturity structure literature that are almost all normative. Starting with Lucas. and Stokey (1983), the optimal debt management literature emphasizes the fiscal insurance property of public debt and the minimization of tax distortions. The idea is to structure the public debt a such a way that the variations in its market value can shield the government against the need to raise taxes during bad fiscal times.(e.g., Angeletos (2002)) Such models turn out to be highly impractical. Because of the high correlation of returns between bonds of different maturities, to achieve any meaningful fiscal insurance, the U.S. government would need to take unrealistically large long-short positions in Treasury bonds and private debt.[7] This has clearly not been the historical practice of the U.S. Treasury, which has been averse and constrained from issuing publicly-held government debt even close to parity with GDP. And before the financial crisis, the U.S. Treasury has never held any meaningfully large quantities of privately-issued debt securities. The fact that government's actual practice strays from the predictions of the normative models has usually been viewed as the government not operating "optimally".

In this model, I emphasize the practical incentives and realistic constraints faced by the Treasury officials that may have led to the observed issuance decisions. In a two-period model, the Treasury seeks to minimize the cost of borrowing and the disutility of roll-over risk. It is taken as exogenous that short-term debt is cheaper than long-term debt.[8] Therefore, the Treasury can conserve borrowing costs by issuing more short-term debt. However, borrowing short-term comes with its own "cost" that is the roll-over risk: short-term debt mechanically must be rolled over more frequently. An over-reliance on short-term debt means that the government must return to the bond market frequently, which carries the risk that one of these times there are not sufficient number of investors whose aggregate demand can roll over the maturing debt. And this risk is costlier as the quantity of debt (to be issued) rises in its size as a share of the economy. I capture the roll-over risk in the model as a quadratic deviation of short-term share in the issuance from a target share. Another feature of the model is that short term interest rate, and to a less extent

risk, which shall form part of the theoretical investigation in this paper.

[7]Buera and Nicolini (2004) and Faraglia, Marcet and Scott (2010) show using a calibrated model that the government would need to buy and hold (long) private bonds and sell (short) government bonds that are at least 5 or 6 times of the GDP to meaningfully insure the U.S. against the types of fiscal shocks it has experienced historically. And since even debt stock approaching 100% of GDP already causes alarm, such prescriptions are wildly unrealistic.

[8]This is an empirical regularity that short-term interest rates are usually lower than long-term interest rates. Even though the yield curve has occasionally "inverted", the term structure of interest rates has historically been almost always positively sloped.

long-term interest rate, decreases in response to an adverse aggregate shock that raises the deficit to GDP ratio. This is an empirical regularity, but may be thought of as coming from either central bank intervention or "flight to safety" demand. Finally, I assume that the market has a limited capacity to absorb long-term debt elastically. When the government issues too much long-term debt beyond a certain threshold, it faces a downward-sloping demand curve that further supply depresses the price of long-term bond and raises bond yield.

The model provides us with a useful framework to understand the postwar Treasury's issuance policies. Specifically, there are three elements that the Treasury cares about: borrowing costs, roll-over risk and market liquidity in terms of price impact. My model shows how these three objectives naturally come together as practical incentives for Treasury officials as they weigh the trade-off of debt maturities. Besides making a number of reasonable comparative statics predictions, I show in the model why the Treasury would willingly issue long-term debt exactly when long-term debt is more expensive. As the deficit to GDP ratio rises sharply, short-term bond yield falls while long-term bond yield falls by less. As a result, the interest savings from issuing short-term debt is now greater. At the same time, the rising deficit to GDP ratio raises the borrowing need and hence the roll-over risk per unit of short-term debt issued. In the equilibrium in which the inelastic demand threshold for long-term debt has not been hit, the Treasury lengthens average maturity in response to the deficit/GDP shock if the marginal interest rate savings from shortening is less than the marginal disutility of roll-over risk. The model allows us to quantify the amount of the actual risk faced by the Treasury, which in turn allows us to assess whether the Treasury's issuance policy during bad times is a reflection of risk or its risk aversion.

2.2 Relation to Literature

This paper sits at the intersection of three main strands of literature. The first strand is a small but resurgent literature on the (mostly theory) of Treasury debt management.[9] Starting with Barro (1979) and Lucas. and Stokey (1983), and extended by papers such as Bohn (1990) Angeletos (2002) and Nosbusch (2008), fiscal insurance theory of optimal debt management argues that the government debt should be managed with the objective of smoothing tax burdens across time. Buera and Nicolini (2004) and Faraglia, Marcet and Scott (2010) show that debt management models based on tax-smoothing argument alone

[9]There is a related literature that investigates the determinants and sustainability of the U.S. debt to GDP ratio. Because it is about the aggregate amount of debt and not directly about the maturity structure of debt, I will not describe in details but want just mention. Notable papers include Bohn (1998) and more recently Hall and Sargent (2011).

tend to produce wildly unrealistic prescriptions.[10] Most recently, Bhandari et al. (2017) show that it is not possible for the government to fully hedge its fiscal shocks given the high correlations of bond returns. If the government only aims for partial fiscal insurance, the optimal maturity structure should a balanced amount of long-only government debt, slightly tilting towards long maturities. Greenwood, Hanson and Stein (2015) propose a simple model of debt management where the government trades off between roll-risk and the the liquidity premium of short-term debt. Their model is related to the model in this paper. However, they interpret roll-over risk in terms of distortionary tax burdens. Moreover, in their paper short-term Treasury debt is cheaper because it is more liquid than the private debt of a similar maturity. They emphasize the liquidity premium of Treasury bills to advocate that the government should optimally issue more short-term debt to "chase out" private short-term debt. In this paper, I seek to understand the government's actions.

The second strand of literature is related to the corporate debt maturity structure in the corporate finance. Diamond (1991) and Diamond and He (2014) propose that firms choose its optimal debt maturity by trading off the signaling or displining value of short-term debt against the associated roll-over risk in the sense of inefficient early liquidation. This paper presents a contrast with that literature by showing the government's incentives. Greenwood, Hanson and Stein (2010) suggest that taking government's issuance policies as given, firms tend to time its debt issuance's maturity by filling in the "gaps" in the maturity spectrum, which are not populated by Treasury securities. This paper presents a theory on why and how the government may go about timing its own issuances' maturity.

The last strand of literature is on the supply of "safe assets". The U.S. Treasury securities are widely considered a safe asset in the sense that it serves as a storage of value in the worst contingent state of the world. Caballero and Krishnamurthy (2009) and Caballero and Farhi (2017) suggest that there is a general shortage of safe assets in the world, which can lead to financial and macroeconomic fragility. He, Krishnamurthy and Milbradt (2018) presume a general shortage of safe assets and propose a mechanism that endogenously determines the safety status of the U.S. Treasury securities. Their paper shares a similar understanding for the fundamental cause of the roll-over risk: the self-fulfilling lack of common action by investors to roll over the debt. In this paper I detail a simple framework of how the U.S. Treasury chooses the supply of safe assets. To the extent that short-term Treasuries are considered safer than long-term Treasuries, by lengthening maturity during bad fiscal times the U.S. Treasury has effectively reduced supply of safe asset exactly during

[10]As mentioned in the introduction, meaningful fiscal insurance typically requires the government holding long-short positions of private and public debt to the order of multiples of the U.S. GDP.

periods when they are most needed.

2.3 Data

In this paper, I use two types of data: 1) the historical data on the prices and quantities of outstanding Treasury securities; 2) other fundamental financial and macroeconomic time series data. I will describe the Treasury data first. The data on the historical Treasury security portfolio mainly comes from the CRSP Treasury database from 1955 to 2017. The CRSP Treasury database contains snapshots of all Treasury securities outstanding at the end of each month. Each observation contains the end of month second market price of the security, quantity outstanding as well as other issue characteristics such as issuance date, maturity date, call date, coupon rate, bond type etc.[11] The CRSP Treasury database obtains the quantity and issue information from the Monthly Statement of Public Debt (MSPD), which is publicly available form the U.S. Treasury website. (Treasury (2018)) The bond prices in the CRSP database come from either GovPX or the New York Fed as detailed in CRSP (2014) document. The CRSP database contains, especially between 1955 and 1960, numerous instances of errors, missing entries and other mistakes. I manually verify the CRSP datasets against the MSPD records and manually correct any mistakes or missing entries. Furthermore, I extend the CRSP Treasury database backward to 1919 by manually inputting the quantity outstanding and other issue information of marketable Treasury securities from the MSPD.[12] Old bond prices prior to the start of the CRSP database or missing from the it are obtained from the archival records of the *Wall Street Journal*.

From the extended Treasury database, I can create a complete history of the Treasury gross issuances. I collapse the monthly Treasury database into a quarterly dataset when I create the issuance dataset. This is because the U.S. Treasury makes issuance decisions quarterly at the so-called "quarterly refunding". It turns out that new Treasury issuances can take two main forms: new securities and "reopenings". Because the Treasury database tracks each security from the month of its birth to the month of its extinguishment, I am able to see the evolution of the changes in the quantity outstanding over its lifetime. The new issuances are easily identified whenever a new security shows up for the first time in the database. Reopenings are less straightforward. In a security reopening, the Treasury issues additional amounts of a previously issued, typically long maturity, security. The reopening has the same maturity date and coupon rate as that of the original security.

[11] See CRSP (2014), the data documentation, for details on the CRSP Treasury database.

[12] When I started the project, this was the first and most complete dataset on the historical U.S. Treasury debt portfolios. However, since then Hall and Sargent (2015) and Hall, Payne and Sargent (2018) have created a longer dataset on the historical Treasury debt going back to 1776.

Securities are sometimes reopened either because the Treasury wants to lengthen maturity using some recently issued ultra-long-maturity securities and sometimes to support the market liquidity of these securities.[13] Either way, reopenings reflect the Treasury's issuance decisions and should be properly identified. Because reopenings are not separately reported in the database, I develop proxy identifier for reopenings based on the changes in the quantity outstanding of a given security. Details are explained in the appendix.

In addition to the data on Treasury debt, I also use some fundamental financial and macroeconomic time series data. The interest rate-related data can all obtained from the Federal Reserve Board website. Specifically, I use zero coupon bond yields that are estimated by Gurkaynak, Sack and Wright (2006). This data series is maintained and updated daily on the Federal Reserve board website. The term spread is calculated from these zero coupon yields. In addition, the Cochrane-Piazzesi term premium measure is taken from Cochrane and Piazzesi (2005) and extended by the author. Cochrane and Piazzesi use the Fama-Bliss bond yields that are available from the CRSP Treasury data base. The rest of the macro time series data comes from either Global Financial Data (GFD) or the FRED database at the St. Louis Fed.

2.4 Empirical Stylized Facts

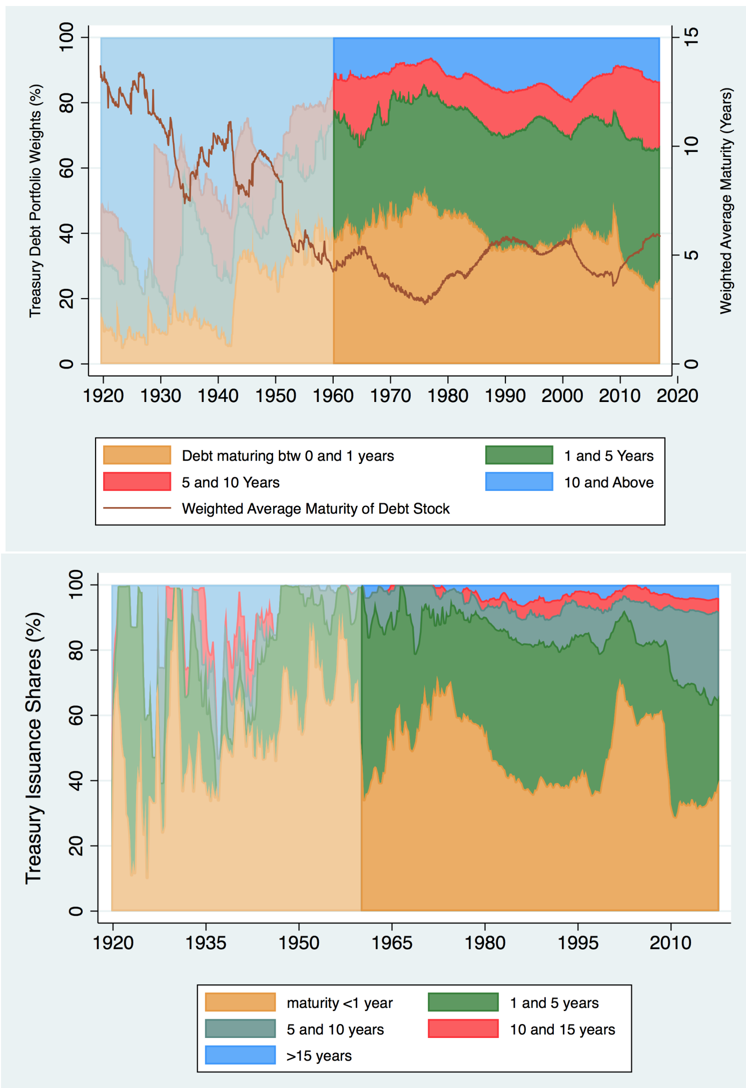
In this section I will present a few empirical facts about the U.S. Treasury debt issuance policy since the end of World War 2. These stylized facts summarize salient and consistent features of the Treasury debt management even as the policy and the debt instruments have evolved over this time period. Before discussing these facts, I will provide a brief general description about the evolution of the Treasury securities market over the last 100 years and explain why I restrict the focus of this study to time period after World War 2.

I restrict the focus on the postwar time period because the the Treasury debt market operated under drastically different institutional conditions.[14] Prior World War 2, the U.S. federal government mostly relied on one off, sometimes fixed price, sale of very long-term

[13]The reason that the Treasury may reopen a 30 year bond 2 years later rather than issuing a 28 year bond is because gradually the Treasury recognized the value of having "benchmark" securities at standardized maturities. Benchmark securities are somewhat akin having fewer but iconic products for a consumer product brand. The Treasury and its market advisors believe that eliminating a myriad of maturities can boost market liquidity. Currently the benchmark maturities include 2, 7, 10, 20, 30 year bonds.

[14]See Garbade (2012) for an excellent and comprehensive account of the U.S. Treasury debt market prior to the end of WWII. In the 1920s, the U.S. Treasury used a combination of auction of Treasury bills and fixed price sale of long-term bonds. The auction mechanism was suspended in the 1930s through the end of WW2. Leading up to and during WW2, the Treasury issued several heavily discounted fixed price long-term bonds to help finance the war. Generally speaking, the market for Treasury was significantly less developed and less liquid before the World War 2.

Figure 2.1: The Evolution of the Treasury Debt Stock and New Issuances

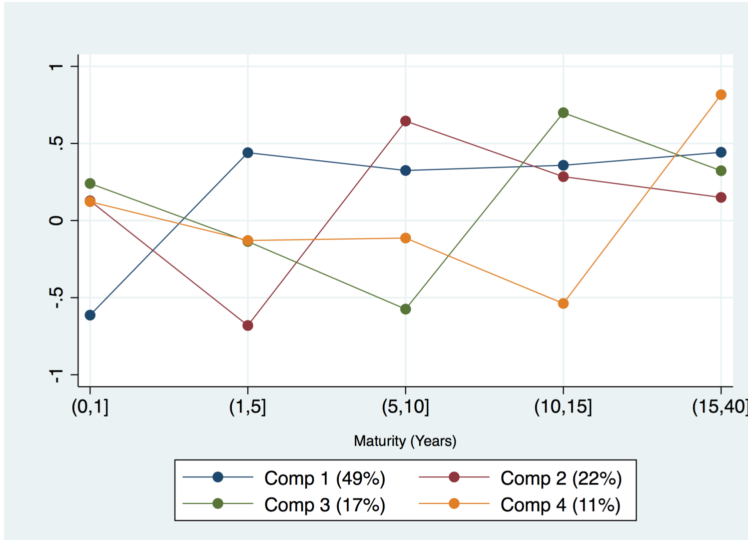


The top figure depicts the evolution of the maturity structure of the U.S. Treasury debt from 1920 Jan to 2017 Dec. The securities are organized into time-till-maturity buckets. Each color represents the total face value of the Treasury securities in a maturity bucket as a percentage of the total debt outstanding in that month. The data before 1960 is faded out because the market structure was significantly different and hence not the focus of this study. The bottom figure depicts the evolution of the maturity structure of Treasury new issuances. Each color represents the total face value share of the securities in a maturity bin issued within the quarter. The maturity shares are smoothed over the past 4 quarters for a clearer depiction. The empirical analysis of the issuance data does not smooth the data.

bonds to finance its deficits. In fact, until 1939, Congress had to authorize the sale of individual Treasury securities rather than specifying a limit on the aggregate amount of public debt outstanding.[15] This is the reason that in the top figure in Figure (2.1), we see much a much larger and much more volatile shares of the debt outstanding coming from long maturity debt. The volatility of maturity shares (shown up as sharp spikes in the maturity shares) comes from single long-term securities maturing. For the same reason, the weighted average maturity of the debt outstanding (dark line in the top figure in Figure (2.1)) started high early in the century and gradually trended down until the 1950s. Since the early 1950s, the maturity structure of the debt outstanding has become much more stable as seen in the the much smoother evolution of the different maturity shares in the top figure in Figure (2.1). The weight average maturity has also taken up a more statistically stationary profile, averaging just under 5 years.

The focus of this paper is on the maturity structure of the issuances since the 1950s. In the bottom figure in Figure (2.1) I depict the face value shares of different maturity buckets of new Treasury securities issued in each quarter. Note that compared to the top figure Figure (2.1), only new securities issued within the quarter are plotted here.[16] Similar to the evolution of the debt stock in the top figure of Figure (2.1), we see a similar moderation of the maturity share volatility since the end of World War 2. However, the maturity shares of new issuances are still significantly more volatile than the debt stock. This is a mechanical feature because we are looking at a "flow" variable instead of a stock variable. Another notable mechanical feature of the bottom figure of Figure (2.1) is that we significantly greater shares of short-term issuances. This is because short-term debt by construction is maturing and reissued much more frequently. In any given quarter, we will unsurprisingly see a larger share of the short-term (gross) issuances. At the same time, the significance of the longer-term issuances is understated in the plot. Because long-term issuance remains outstanding for along time, a small share of the long-term issuance in fact represents a weightier policy choice. Therefore while the dynamic evolution in the bottom figure of Figure (2.1) is the subject of this study, we need to employ other tools to better visualize of how the issuance maturity structure has evolved.

Figure 2.2: Principal Components of Quarterly Issuance Shares



PCA is applied on the maturity shares of the quarterly new issuances. The first four principal components (PCs) sum up to 100% of the variability. Their loadings are plotted above.

Fact 1: Treasury's Issuance Decisions Consist Of Two Types of Strategies

In the first stylized fact I decompose the Treasury's issuance decisions into interpretable strategy types. Given an exogenous amount of aggregate borrowing need, an issuance decision in each quarter consists of assigning a set of numbers to the different points on the maturity spectrum that add up to one.[17] To make the analysis feasible, I discretize the maturity spectrum by lumping it into five maturity categories (as in Figure 2.1): less than 1 year, 1 to 5 years, 5 to 10 years, 10 to 15 years, 15 years or more.[18] For each maturity category, I calculate the total face value of new issues in the category as a share of the total face value of debt issued in that quarter.[19] Therefore the history of the Treasury's quarterly issuance decisions since 1950 is now encoded into a sequence of five-vectors. I apply a principal component analysis to these maturity shares to further reduce the high-dimensional sequence into orthogonal and more interpretable components or strategy types. The result of the principal component analysis is presented in Figure (2.2).

[15]See Hall and Sargent (2015) for a detailed discussion of the history of the U.S. debt limit and its wider economic implications.

[16]The issuance shares have been smoothed over the past four quarters for a clearer rendering. The empirical analysis does not use the smoothing. The plot of the unsmoothed issuance shares is in appendix.

[17]In principle, the Treasury could issue debt of any fractional years in maturity, thereby making the problem an infinite dimensional one. In practice, the Treasury only has only issued maturities in whole number of months for short-term debt and whole number of years for long-term debt.

[18]Because these are all new issues, there is minimal difference between maturity at birth and time till maturity. I measure maturity with maturity at birth for every security within the same quarter.

[19]The difference with what is depicted in Figure 2.1 is that these maturity shares are not smoothed.

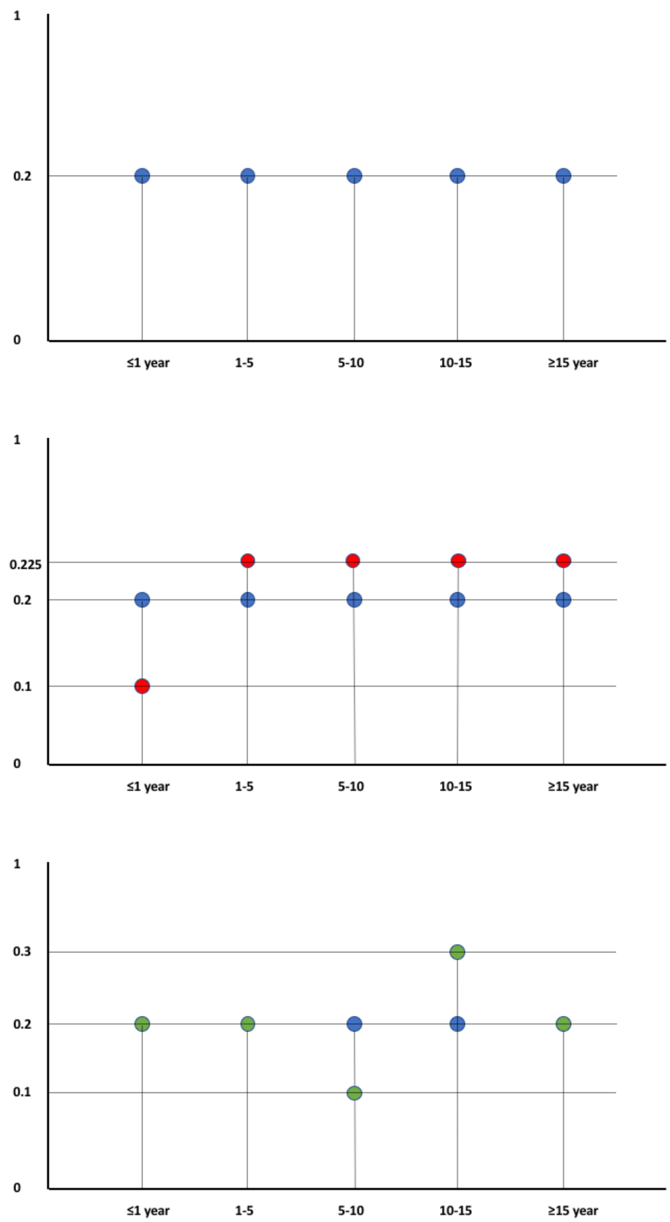
The principal component analysis reveals that the Treasury issuance decisions can roughly be condensed into two types of strategies. The first principal component (PC) in Figure (2.2), which looks like a hockey stick, explains about 49% of the variations in the issuance decisions. It is negative in the first maturity bin and positive and approximate flat across the other maturity bins.[20] This is saying that about 50% of the time, the Treasury is deciding between how much to issue in short maturity (maturity <1 year) like Treasury bills versus those of longer maturities, like Treasury Notes and Bonds. Furthermore of the amount issued not issued in short-maturity, it tend to be spread relatively evenly across the maturity bins. I present drawings of some highly stylized issuance strategies in Figure (2.3) to further illustrate this idea. Let the top figure of Figure (2.3) represent the issuance choice of issuing 20% in each maturity bin. Then the middle figure in Figure (2.3) represents the first PC or the strategy of issuing 10% less of maturity bin 1 and 2.5% more in maturity bin 2 through 5.[21] I call this issuance strategy "bracketing" in the sense of the Treasury bracketing how much to issue in short-maturity and spreading the rest evenly on the longer-maturities.

The second through the fourth PCs have a common shape which "tilts" or "wiggles" between two adjacent maturity bins. I call such issuance strategies a tilting strategy. Take the third PC as an example. PC3 is negative in the [5,10] bin, positive in the [10,15] bin and close to zero otherwise. Using the top and bottom subfigures in Figures (2.3) as illustration, this is roughly equivalent to reducing the [5,10] bin's issuance share by 10% and raising [10,15] bin by 10%. The story is similar for PC2 and PC4. This "wiggling" of issuance shares between adjacent maturity bins is likely driven by a desire to promote market liquidity of Treasury securities. There is widely documented evidence that recently issued (also known as "on-the run") long-term Treasuries enjoy a liquidity premium over older Treasury securities with similar time-til-maturities(Krishnamurthy (2002)). As a result, the Treasury officials have regularly expressed the desire to ensure the availability of recently-issued Treasury securities across the maturity spectrum. Therefore, if a 7-year bond or 10-year bond can both fulfill the purpose of lengthening maturity, a 7-year bond may be issued if there has not been any issuance of 7 year bonds in a while.

[20] Some argument will necessarily be of a different sign from the others because the maturity shares have to add up to 1. For one argument to go up, some other argument(s) must go down.

[21] Note that since the PCA loadings are eigenvectors and bases of the issuance strategy space in linear algebra language. The issuance strategies represented by these PCs are equivalent up to scaling including a change of sign. Therefore, PC1 can also easily be interpreted as raising the share of the [0,1) bin and lowering the shares of longer-term debt bins. Similarly for PC2-4.

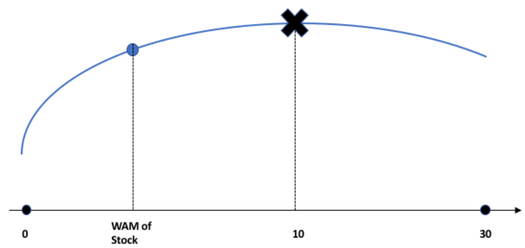
Figure 2.3: Issuance Choices Can Be Decomposed Into Two Strategy Types

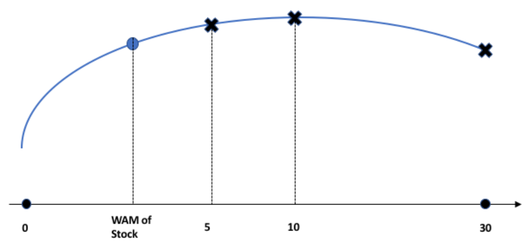


These figures illustrates how the PCA results in Figure (2.2) can be interpreted in terms of issuance strategies. The top figure sets up a baseline issuance pattern of 20% in each maturity bin. The middle figure represents the first principal component, which is to reduce the share of the first maturity and evenly raise the shares of the longer maturity bins and vice versa. The bottom figure represents the third principal component, where the Treasury is tilting the issuance between the [5,10] and [10,15] maturity bins.

Fact 2: Treasury lengthens maturity by spreading new issuances across the maturity spectrum.

Figure 2.4: Demonstration Of Alternative Ways Of Lengthening Maturity

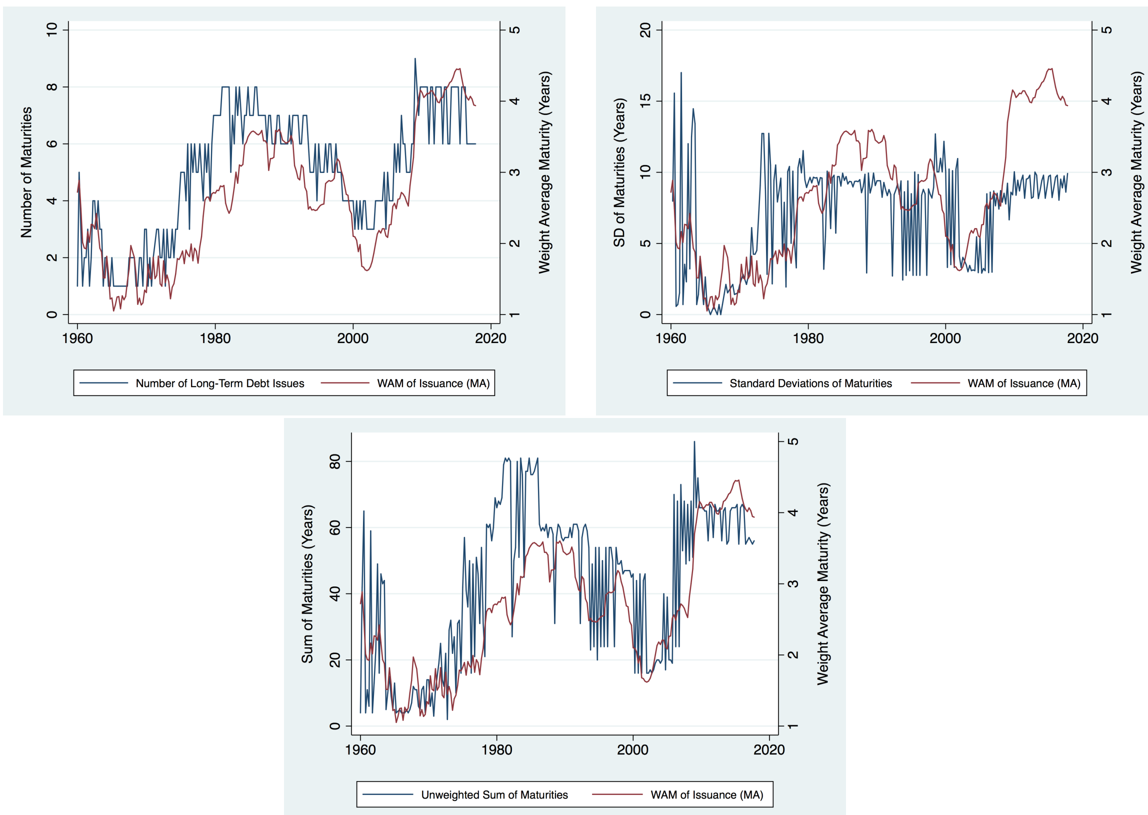




These two figures depict the two alternative ways in which the Treasury can lengthen maturity. The horizontal axis is the maturity in years and the blue curves are some generic yield curve. The Treasury is trying to raise the average maturity of by issuing debt at some longer maturities. In (a), it issues only 10 year bonds. In (b), it issues three equal portions at 5-, 10- and 30-years respectively. The two figures help illustrate the empirical observation that when the Treasury lengthens the maturity of issuance, it tends to spread the issuance on multiple points of maturity rather than concentrating on a single point.

The second stylized fact tells us that when the Treasury lengthens the average maturity, it tends to spread new issuances across the maturity spectrum. To illustrate what this means, I provide a generic example in Figure (2.4). In this example, the Treasury is trying to raise the average maturity of the debt stock by issuing $10 billion (exogenous borrowing need) at some longer maturities. Instead of issuing $10 bil of 10 year bond, the Treasury has tended to issue $3.3 billion of 5 year bond and $3.3 billion of 10 year bond and $3.3 billion of 30 year bond. To show that this is the case historically, I plot the weighted average maturity of issuance against three different measures of the maturity dispersion of new issuances. The first measure is the count of the number of unique maturities issued in a quarter. For example, if the Treasury sells $5 billion of three month bills in eight separate auctions, $5 billion of five year bonds in two auctions and $10 billion of ten year bonds in two auctions, the measure will simply record 3. Because shorter-term bonds are auctioned more regularly than long-term bonds, this measure distinguishes for example five auctions

Figure 2.5: Maturity Is Extended By Spreading Issuance Across the Yield Curve



All three figures depict the smoothed weighted average maturity of new issuances. Figure (a) plots the number of unique maturities, which exceed 2 years, issued in a quarter. For example, if within a quarter 2 auctions of 10 year bonds are conductions, they count only as one. Figure (b) computes the standard deviation of the maturities of all the securities with maturity longer than 2 years issued within a quarter. Figure (c) is sum of the unique maturities issued in a quarter.

of 2 year bonds in a quarter from two auctions of 2 year bonds plus two auctions of 10 year bonds in a quarter. Effectively, this measure overweights the longer-term and less frequently issued maturities in order to more accurately capture the maturity dispersion. The top subfigure in Figure (2.5) shows a clear positive correlation between the weighted average maturity of issuance and this maturity count measure.

To show that the relationship between the issuance maturity and the maturity dispersion is not mechanical, I define two additional measures. The second measure, as in the middle subfigure of Figure (2.5), is the standard deviation of the maturities of the new issuances, which is taken over all individual securities issued within a quarter. The third measure, as in the bottom subfigure in Figure (2.5), is the sum of the unique maturities within a quarter. In the example of the first measure, this would be the sum of 2, 5 and 10, which gives us 17 years. Both of these measures again affirm the observation the extension of the issuance maturity is accomplished by spreading the issuance across the yield curve. The regression results in Table 2.1 confirm the strong positive correlations in Figure (2.5).

Table 2.1: Regression of Weighted Average Maturity of Issuance on Measures of Issuance Dispersion

VARIABLES	(1) Year 1950-2017 WAM of Issuance	(2) Year 1950-2017 WAM of Issuance	(3) Year 1950-2017 WAM of Issuance
mat_count	0.380***		
	(0.017)		
mat_sum		0.038***	
		(0.002)	
mat_sd			0.160***
			(0.014)
Constant	0.718***	0.963***	1.431***
	(0.087)	(0.071)	(0.113)
Observations	266	266	241
Adjusted R-squared	0.66	0.69	0.36

Standard errors in parentheses

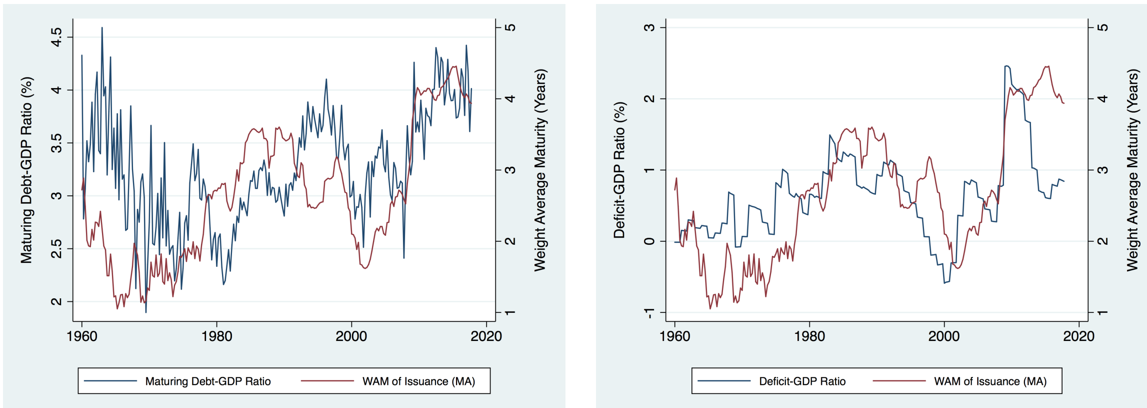
*** p<0.01, ** p<0.05, * p<0.1

Quarterly regression of weighted average maturity of issuance on measures of the dispersion of the maturities of the securities issued within the quarter. mat_count counts the number of unique maturities issued within the quarter. mat_sum sums up the maturities of all the securities issued within the quarter. mat_sd calculates the standard deviations of the maturities issued within the quarter. For all three measures, I only include securities with a maturities of 2 years or more. The strong positive correlations confirm that the issuance maturity extension is accomplished by spreading the issuance across the yield curve.

Fact 3a: The maturity of issuance lengthens when funding need spikes

The third stylized fact deals with the maturity of issuance's response to funding needs and is stated in two parts: the static and dynamic responses. The first part says that the maturity of issuance responds strongly and positively to spikes in funding needs. There are two types of funding needs: old debt maturing and deficits. Maturing debt represents

Figure 2.6: Weighted Average Maturity of Issuance's Relationship to Funding Needs



These two figures show that the maturity of issuance has historically been positively correlated with the two sources of funding need as a share of nominal GDP. The weighted average maturity of issuance is depicted in both figures. The first subfigure plots the total face value of maturing debt, whose original maturity exceeds 2 years, as a share of the nominal GDP. The second subfigure plots the federal deficit as a share of nominal GDP.

a mechanical funding need. Since the end of World War 1, the U.S. Treasury gradually accepted that the government debt would not be extinguished but rather will generally have to be refinanced.(Garbade (2012)) On the other hand, fresh deficits are structural funding needs. In both cases, I normalize the magnitude of the funding need by dividing the quantities by the nominal GDP.

In Figure (2.6), I show the weighted average maturity of issuance has historically been positively correlated with both types of funding needs as a share of GDP. In the left subfigure in Figure (2.6), I plot the total maturing debt, whose original maturity was greater than 2 years, in a quarter as a share of GDP next to the weighted average maturity of new issuances in the same quarter. I only include maturing securities that were issued at least two years ago in order to isolate the funding need arisen from decisions made some distant time ago.[22] For the purpose of plotting, the weighted average maturity of issuance shown here is smoothed over the next three quarters. It is evident that the weighted average maturity of issuance correlates positively with that of the funding need due to maturing debt. In right subfigure of Figure (2.6), I plot the deficit-to-GDP ratio next to the same weighted average maturity of issuance measure as in the left subfigure in Figure (2.6). The average maturity of the new issuance is also strongly positively correlated with the deficits-to-GDP ratio. As the funding need rises as a share of the GDP, the Treasury tends to use longer term debt to finance it.[23]

[22]For robustness, I also try other cutoffs like 3 or 4 years, the results are qualitatively very similar.

[23]This finding is also echoed by some Treasury officials' own sentiments. Larry Summers, the former U.S. Treasury secretary, said the following in a private correspondence.(Greenwood, Hanson and Stein (2015)) "I think the right theory is that one tries to [borrow] short to save money but not [so much as] to be imprudent with respect to rollover risk. Hence there is certain tolerance for [short-term] debt but marginal debt once

Table 2.2: Regression of Weighted Average Maturity of Issuance on Measures of Funding Needs

VARIABLES	(1) Year 1950-2007 WAM of Issuance	(2) Year 1960-2007 WAM of Issuance	(3) Year 1970-2007 WAM of Issuance	(4) Year 1980-2007 WAM of Issuance	(5) Year 1990-2007 WAM of Issuance	(6) Year 2008-2017 WAM of Issuance
MLD/GDP	0.781***	1.060***	1.170***	0.691***	1.019***	-0.106
	(0.123)	(0.147)	(0.164)	(0.250)	(0.333)	(0.246)
Deficit/GDP	1.069***	0.875***	0.800***	0.655***	0.768***	-0.257
	(0.112)	(0.112)	(0.116)	(0.132)	(0.155)	(0.158)
Constant	1.087***	1.098***	1.106***	1.727***	1.313***	4.635***
	(0.120)	(0.143)	(0.173)	(0.289)	(0.386)	(0.599)
Observations	223	186	151	112	72	36
Adjusted R-squared	0.36	0.34	0.33	0.17	0.13	0.18

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

WAM of Issuance is the (unsmoothed) weighted average maturity of quarterly gross issuance. MLD stands for Maturing Long-term Debt, which is the total face value of securities, whose original maturity was 2 year or more, that are maturing in this quarter. The main specification is column (2) with the sample between 1960 and 2007. The sample is cut off in 2007 because there appears to be a structural break in the relationship after 2007.

In Table 2.2, I regress quarterly weighted average maturity of issuance on the maturing long debt to GDP ratio and the deficit to GDP ratio. Consistent with Figure (2.6), the WAM of issuance is statistically significantly related to the maturing debt to GDP ratio and the deficit to GDP ratio. While the main specification covers the sample from 1960 onwards, I have run the regression on different time sub-samples and also extended the sample backwards to 1950. The coefficients on LMD/GDP ratio are comparable across the different time sub-samples and the coefficients on the deficit/GDP ratio show a slight decline in magnitude suggesting that the Treasury used to lengthen maturity more aggressively to a deficit or structural shock to the funding need. The relationship between issuance maturity and the two funding need measures breaks down between 2008 and 2017. In particular, as deficits significantly declines the maturity of issuance stays relatively elevated. This is likely due to the unique economic environment since the 2008 financial crisis.[24] Taking column (2) as the main specification, the coming due of long-term debt worth 5 percent of GDP corresponds to a lengthening of the weighted average maturity by about 0.05 years. This compares with an average weighted average maturity of 2.35 years between 1960 and 2007. A quarterly increase in deficit worth 2 percent of GDP corresponds to about 0.0175 years increase in weighted average maturity.

[total] debt goes up has to be more long term." Other Treasury officials have expressed similar sentiments in the their consultations with primary market dealers. (Treasury Borrowing Advisory Committee (1982-2017*a*))

[24]Greenwood et al. (2014) suggest that the Treasury took advantage of the quantitative easing program and the increase demand for long term Treasury to issue more long term debt and capture the low cost of borrowing.

Fact 3b: Issuance maturity has a temporary response to maturing debt and a persistent response to deficit

In the second part of the third stylize fact, I document that the issuance maturity has very different dynamic responses to maturing debt/GDP and deficit/GDP shocks. I use a vector-autoregressive (VAR) model involving *maturing debt-GDP ratio*, *deficit-GDP ratio* and the *WAM of issuance* to capture these dynamic relationships. The details of the VAR model setup are in the appendix and the results are illustrated in Figure (2.7). The first subfigure in Figure (2.7) shows that the response of the weighted average maturity of issuance to debt maturing is initially positive and statistically significant but fades away in about four quarters. (The coefficient becomes statistically insignificant and hence indistinguishable from zero.) Because the funding need due to maturing long-term debt is a mechanical one, the rise in issuance maturity could be interpreted as the Treasury's desire to "replace" maturing long-term debt in order to maintain a stationary weighted average maturity of the overall debt stock.[25] As will be spelled more specifically in the theory section below, the desire to maintain a stationary average maturity that's neither too low or too high is likely motivated by both a desire for borrowing cost savings and an aversion toward rollover risk. In contrast, in the second subfigure in Figure (2.7) we see a much more persistent rise in issuance maturity in response to a deficit-to-GDP ratio shock. The funding need created by deficits is structural and likely unanticipated. If the Treasury decides to finance the deficits with long-term bonds but faces a somewhat inelastic demand curve for long-term bonds, it may choose to implement the maturity lengthening over many quarters into the future.[26] This finding is also consistent with the second stylized fact that when the Treasury lengthens maturity, it has tended to spread the issuance over many points on the maturity spectrum.

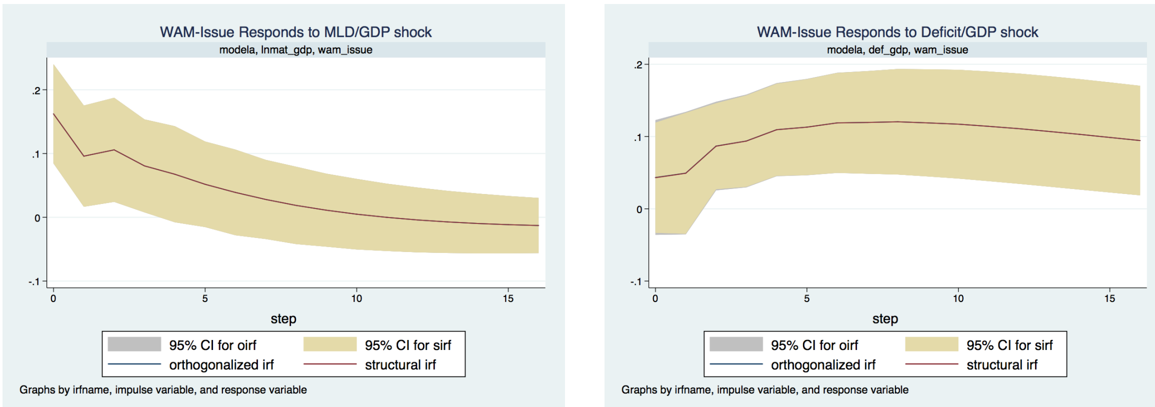
Fact 4: Treasury tends to issue long term debt when term premium is high

The fourth and final stylized fact is that the Treasury has historically issued long-term debt exactly when the term spread and the term premium are the highest. It has been shown that the issuance maturity is strongly and positively correlated with the size of funding needs, particularly the deficits/GDP. An increase in the deficit-to-GDP ratio leads to a positive and sustained increase in the weighted average maturity of Treasury issuances. Figure (2.8) shows that there is a strong relationship over time between deficits and the

[25]While it is true that all maturing debts are really debts with near-zero maturity, if the policy of replacing the same security with that of the same maturity does produce a steady state of relatively stable maturity structure.

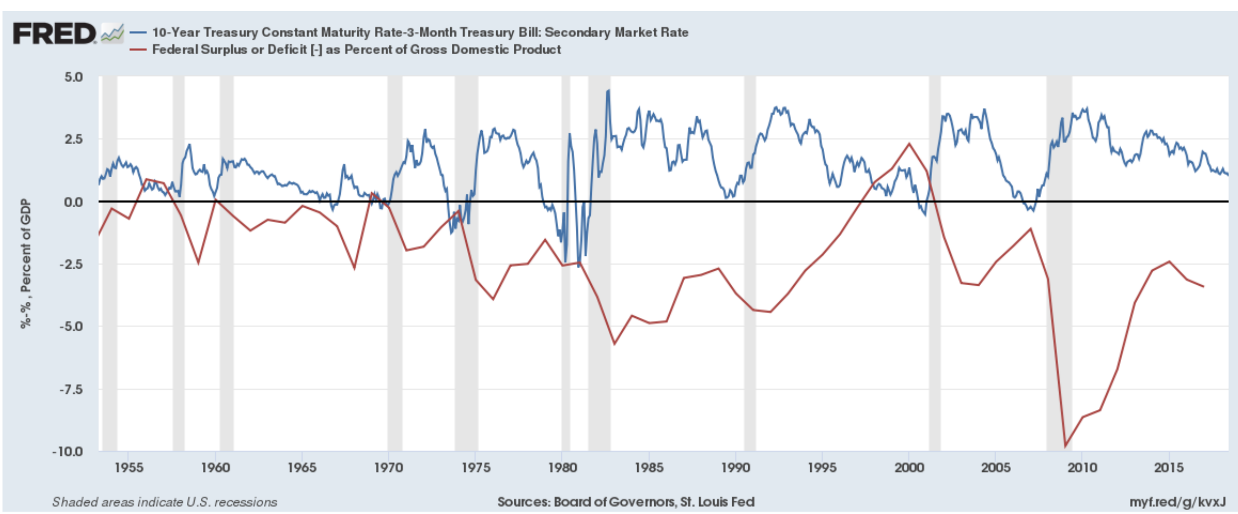
[26]This is particularly the case if the deficit shock are persistent.

Figure 2.7: Dynamic Response of Maturity to Funding Needs



The impulse responses are generated from a VAR with two lags using quarterly data 1960 and 2007. The VAR involves three variables: maturing long term debt to GDP ratio, quarterly deficit to GDP ratio and the weighted average maturity of new issuances. The first subfigure shows that a maturing debt shock has a positive but temporary impact on the maturity of new issuances. The effect fades away (no longer statistically significant) in about 4 quarters. The second subfigure shows that a deficit shock has a positive but much more persistent effect on the maturity of new issuances.

Figure 2.8: Deficit and The Term Spread



This plot is generated and downloaded from FRED database at the St. Louis Fed . The plotted curves are (1) monthly term-spread of 10 year Treasury yield and the 3 month Treasury bill rate; and (2) yearly deficit-to-GDP ratio. There is a clearly negative correlation between the Deficit/GDP ratio and the term spread. Ignoring the high-frequency noises in the term spread, the term spread tends to be at a peak when the deficit/GDP ratio is at a trough (high deficits).

spread between short and long term interest rates. It is well known that the inversion of the yield curve (negative term spread) has been a powerful predictor of impending U.S. recessions since the end of WWII. However, it has been less often observed that by the time the federal deficits actually arrive the yield curve has typically become positively sloped again.[27] In Figure (2.8), between 1950 and 2017 the troughs of the deficit/GDP ratio have consistently coincided with local peaks of the term spread between the 10 year Treasury yield and the 3 month Treasury bill rate. The peaks of the deficit/GDP ratios have coincided with the local troughs of the term spread.[28]

Since the issuance maturity tends to lengthen with spikes in the deficit/GDP ratio, it also tends to lengthen when the term spread is largest. Indeed, column (1) of Table 2.3 confirms this positive relationship between the issuance maturity and the term spread. To the extent that the term spread is a crude measure of the relative expensiveness of short-term and long-term bonds, this seems to suggest that the Treasury has tended to issue more long-term debt when the long-term debt is more expensive. Because long-term interest rates are known to contain expectations about the path of future short-term interest rates, the term spread cannot be readily interpreted as the true relative expensiveness of long-term bonds to short-term bonds.[29] Cochrane and Piazzesi (2005) propose a successful predictor of excess returns of long term bonds using a combination of forward rates. Using this alternative measure of bond term premium, I show in column (3) of table 2.3 that the issuance maturity tends to be positively correlated with a purer measure of bond term premium.

In column (2) and (4) of table 2.3, I include the two funding needs that are drivers of the issuance maturity as controls. Both measures of the term premium are no longer positive and statistically significant. In fact, the term spread has become negative and statistically significantly. It is perhaps unsurprising that the controls, particularly the deficits, should squeeze out the term spread as a positive driver of the issuance maturity given the strong correlation between the two. Because the issuance maturity rises the most when the deficit/GDP ratio rises most sharply, the deficit/GDP ratio may simply be a less noisy measure of the term spread than the term spread itself. The negative loading on the term spread, after the inclusion of the controls, may be attributed to a general desire for issuing

[27]In fact, by the time the federal deficits arrived, the recessions have often passed. This is likely to due to the fact that tax liabilities during a recession are predetermined by income before it and the fall in tax revenues come with a delay.

[28]Here I have taken the fed funds rate as a representative of short-term interest rates because FRED plots a nicer graph with NBER recession indicators. However, the pattern is pretty identical if the 3 month Treasury bill rate is used instead.

[29]A higher long-term bond yield doesn't necessarily mean a higher cost of borrowing if it simply reflects the expectation of the path of future short-term interest rates.

short-term debt in response to higher relative cost of long-term borrowing.[30]

Table 2.3: Regression of Weighted Average Maturity of Issuance on Term Spread and Term Premium

VARIABLES	(1) Year 1960-2007 WAM of Issuance	(2) Year 1960-2007 WAM of Issuance	(3) Year 1965-2007 WAM of Issuance	(4) Year 1965-2007 WAM of Issuance
10Y-3M Bill Rate	0.104***	-0.096***		
	(0.037)	(0.034)		
MLD/GDP		2.380***		2.588***
		(0.306)		(0.276)
Deficit/GDP		0.870***		0.799***
		(0.099)		(0.083)
CP 5Y Term Premium			0.074***	-0.010
			(0.024)	(0.019)
Constant	2.319***	1.481***	2.331***	1.363***
	(0.071)	(0.094)	(0.074)	(0.091)
Observations	204	204	184	184
Adjusted R-squared	0.03	0.41	0.04	0.51

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Quarterly regression of weighted average maturity of issuance on the term spread and a measure of term premium. Column (1) shows that the issuance maturity is strongly and positively correlated with the term spread between 10 year Treasury yield and the 3 month Treasury bill rate. In Column (3), I use a measure of term or risk premium of long term bond from Cochrane and Piazzesi (2005) to capture the relative expensiveness of long-term bonds. Column (2) and (4) put in the other two drivers of issuance maturity as controls. In both instances, the term spread and the CP term premium cease being positive and statistically significant. This is likely because the Deficit/GDP is a less noisy measure of heightened structural funding needs and heightened bond risk premium.

2.5 A Simple Model of Debt Issuance

2.5.1 Setup

In this section I present a simple model of the Treasury debt management problem while capturing some of the salient stylized facts presented above. In contrast with normative models of debt management, this model captures the practical incentives and constraints faced by the Treasury debt manager that are informed by historical evidence and institutional details.[31] In a static model, the Treasury debt manager minimizes the single period cost of borrowing as well as a measure of "roll-over" risk. Specifically, the debt manager solves the following optimization problem.

[30]It is possible that the Treasury officials have used the term spread as a crude gauge for term premium rather than explicitly estimating the actual term premium. Perusing the Treasury Borrowing Advisory Committee's minutes and reports to the Treasury, I find many instances of references to the slope of the yield curve in relation to cost of borrowing but no mentioning of a distinction between the term spread and the term premium.

[31]In mainstream macroeconomics, the benchmark view is that the timing of debt and its maturity structure are both irrelevant given fiscal policies because of the Ricardian equivalence principle. The normative models, in which debt maturity structure matters, typically seek to maximize welfare by minimizing tax distortions caused by the maturity structure and timing of borrowing.

$$\min_{B_i} B_1 (1 + y_1) + B_2 (1 + y_2) + \gamma \frac{(B_1 - aD)^2}{2Y} \cdot \mathbf{1} \{B_1/D > a\} \tag{2.1}$$

subject to the following constraints

$$B_1 + B_2 = D = X + \Delta \tag{2.2}$$

$$y_1 = \bar{y}_1 + \phi_1 (B_1) - h(\Delta) \tag{2.3}$$

$$y_2 = \bar{y}_2 + \phi_2 (B_2) - \psi h(\Delta), \ \psi \in (0, 1) \tag{2.4}$$

$$\phi_1 (B_1) \equiv 0 \tag{2.5}$$

$$\phi_2 (B_2) = \phi_2 \cdot \left(\frac{B_2 - \bar{L}}{Y} \right) \cdot \mathbf{1} \left\{ B_2 - \bar{L} \right\} \tag{2.6}$$

$$h(\Delta) = \zeta \cdot h \left(\frac{\Delta}{Y} \right) \tag{2.7}$$

The Treasury debt manager can finance its single period funding need D by issuing either short-term or long-term nominal bonds. As in (2.1), it minimizes the total borrowing costs and a quadratic measure of the roll-over risk by choosing B_1 and B_2. The first two terms correspond to the one-period total borrowing cost. y_1 and y_2 are the (annualized) yields to maturity of the short-term and long-term bonds.[32] The third term is a measure of the (disutility of) roll-over risk, which takes the form of a quadratic deviation of the short debt to the total issuance ratio from a certain target ratio a. The quadratic variation is normalized by the size the of economy so the whole term is on the same order of magnitude as the previous two terms. This penalty term is triggered when the target ratio is exceeded. γ is a risk-aversion parameter and $\mathbf{1}$ is an indicator function. The disutility of roll-over risk is greater when the amount of debt is greater. This objective is both very intuitive and also explicitly voiced by the Treasury officials. With a shorter maturity, the amount of debt that must be rolled over each period is greater, which increases the (tail) risk of insufficient demand and the price impact of bond sales or equivalently borrowing costs. The Treasury officials as well as active market participants have frequently referenced the importance of not exceeding some threshold ratio for short-term bond issuance.[33]

[32]This model compresses a multi-period problem into a single period by measuring the cost of a long-term bond in terms of its yield to maturity. One way to think about this model is to think of the Treasury debt management in a steady state. I do not require that the bonds are zero coupon bonds.

[33]I find frequent references to such a threshold in the minutes and reports of the Treasury Borrowing Advisory Committee. For example, in their report to the Treasury secretary Treasury Borrowing Advisory Committee (1982 Q1) state: ”Past principles of regularity and predictability of offerings, the use of the auction techniques, the striving for a positively sloped yield curve and the mix of no more than 25 - 30% in bills are only reinforced in today’s environment.”

Equations (2.2)-(2.7) are the constraints faced by the debt manager. X is the total face value of the expiring Treasury securities, which must be rolled over and financed by new debts. Δ is the amount of fresh deficit, which is allowed to be negative or a surplus. Together they comprise the total funding need D in the period. $\bar{y}_1$ and $\bar{y}_2$ are some baseline values of the short and long yields. I assume that $\bar{y}_2 > \bar{y}_1$ or that the baseline yield curve is generally upward-sloping. $h(\cdot)$ in equation (2.3) is a positive and increasing function of the deficit (normalized by the exogenous output Y) with $h^{'}(\cdot) > 0$. This reflects the empirical regularity that the nominal rate decreases in response to a deficit shock (an adverse aggregate shock). This could be due to a combination of the central bank cutting nominal short rates in response to adverse aggregate shocks to the economy and the so called ”flight to safety”. ψ in equation (2.4) is number between zero and one. It means that for a given deficit shock the long bond yield does not decrease by as much as the short yield. This is either because of the expectation that the short yield may mean-revert in the future or the risk premium embedded in the long yield over the uncertainty about future short rates. Finally, the $\phi_i(\cdot)$ functions in equations (2.3) and (2.4) represent the assumption that the demand curves for Treasury bonds can be downward-sloping. For simplicity, I assume that the demand for short-term bonds is perfectly elastic so $\phi_1(\cdot) \equiv 0$. However, for long-term bonds I assume that the the bond investors are willing to absorb an inelastic supply of long-term debt $\bar{L}$ beyond which the additional supply of long-term bonds depresses the price of the long-term bond and hence raises the long yield.

For simplicity, the model can be restated in ratios rather than levels. Assuming D to be exogenous for now, divide the objective function (2.1) and let $s = B_1/D$ denote the share of short-term debt issuance. The debt manager's problem can then be restated as follows.

$$\min_s s y_1 + (1-s)\, y_2 + \gamma d \frac{(s-a)^2}{2} \cdot \mathbf{1}\{B_1/D > a\} \tag{2.8}$$

s.t.

$$y_1 = \bar{y}_1 - h(\delta) \tag{2.9}$$

$$y_2 = \bar{y}_2 + \phi_2(s) - \psi h(\delta)\,,\ \psi \in (0,1) \tag{2.10}$$

$$\phi_2(s) == \phi_2 \frac{\left(B_2 - \bar{L}\right)}{D} \cdot \frac{D}{Y} \cdot \mathbf{1}\left\{B_2 > \bar{L}\right\} \tag{2.11}$$

$$= (1 - s - \ell) \cdot \phi_2 d \cdot \mathbf{1}\{1 - s > \ell\} \tag{2.12}$$

$$h(\delta) = \zeta \cdot h\left(\frac{\Delta}{Y}\right) \tag{2.13}$$

where $d = D/Y$ is the financing-GDP ratio and $\ell \equiv \bar{L}/D$.

2.5.2 Comparative Statics

I will take the solution of the model as given and perform comparative analysis on it. The details of the solution for the model is relegated to the appendix.

1. When the amount of deficit increases (as a share of the GDP). There are two cases: the constrained and unconstrained cases. For illustrative purpose, I'll present the unconstrained case here first and leave the constrained case results to the appendix.

$$s^* = \frac{(\bar{y}_2 - \psi h(\delta)) - (\bar{y}_1 - h(\delta))}{\gamma d} + a \tag{2.14}$$

$$\frac{\partial s^*}{\partial \delta} = \frac{-\gamma d (1-\psi) h^{'}(\delta) + \gamma (\bar{y}_2 - \bar{y}_1 + (1-\psi) h(\delta))}{(\gamma d)^2} < 0 \tag{2.15}$$

This is the case if

$$\underbrace{(\bar{y}_2 - \bar{y}_1 + (1-\psi) h(\delta))}_{\text{benefit of shortening}} < \underbrace{d (1-\psi) h^{'}(\delta)}_{\text{disutility of rollover risk}} \tag{2.16}$$

2.6 Conclusion

In this paper, I present new stylized facts characterizing the postwar behavior of the U.S. Treasury debt issuance policy. These empirical facts uncover the practical incentives and constraints that face that Treasury debt managers. I document that the Treasury's debt management is driven by a dual goal of managing *maturity* and *liquidity*. It lengthens maturity and issues more long-term debt when the funding need, particularly government deficit, rises as a share of GDP. And when it tries to lengthen maturity, it tends to issue debt on multiple maturity points rather than concentrating on a singular maturity. And finally, I document that the issuance of longer maturity debt has tended to coincide with periods of high relative expensiveness of long-term debt. I present a simple model that captures the realistic incentives facing the Treasury and explain the some of the empirical facts. In particular, the model clarifies how the management of maturity and liquidity translates into a trade-off between conserving borrowing costs and reducing roll-over risk. Finally, the model provides a realistic framework for understanding the rationale behind the behavior of one of the most important financial institutions in the world over the last half a century. It also sheds light on promising directions of future research of the supply of safe assets.

CHAPTER III

Earnings Announcement Premium: Evidence From Finland

Abstract

This paper investigates the earnings announcement premium puzzle in Finland. Between 1999-2002 and 2006-2009, I find that stocks with earnings announcement earn excess returns over non-announcement stock in the 2 week window before the announcements that quickly dissipates post-announcement. Moreover, I find that the premium is significantly higher and persistent through a 30 day window around the financial statement releases. I find no premium around the interim earnings report and in fact accumulative losses. I also assess the relationship between announcement premium and trading volume. Using an administrative transaction-level data set, I find some supportive evidence for the attention-grabbing hypothesis. I find a positive correlation between the announcement premium and the net-buying trading volume among individual investors, especially around the financial statements.

JEL Codes:

Keywords: earnings announcement premium, Finnish stock market, behavioral finance,

3.1 Introduction

The earnings announcement premium is a well known and well documented phenomenon in global stock markets. It refers to a puzzling empirical pattern that the stock prices tend to rise on average in the days around earning announcement days. This phenomenon has been known at least since Beaver (1968). A more recent study by Lamont and Frazzini (2007) documents that the earnings announcement premium is large and robust in the U.S. since 1927. The announcing stocks tend to earn annualized monthly excess returns over the non-announcing stocks by up to 18% with higher Sharpe ratios than other popular anomalies.[1] Barber et al. (2013) further shows that the premium also exists across the globe in as many as 20 countries. The persistence of the premium is puzzling because the earnings announcement dates are typically known well ahead of time. Investors have ample opportunities to buy up the announcing stocks during the lead-up, bid up the stock prices, and eliminate these predictable returns.

In this paper, I document the earning announcement premium in Finland and provide new supportive evidence for a popular behavioral explanation of the puzzle by leveraging a unique transaction-level administrative dataset. Barber and Odean (2008) propose the so-called "attention-grabbing" hypothesis, in which individual investors suffering from limited attention and short-sale constraints tend to exhibit a net-buying bias about any stocks in the news. As a potential explanation for the earnings announcement premium, the idea is that stocks with upcoming earnings announcement news are likely to catch the limited attention of the individual investors, who would tend to respond by buying the announcing stocks on net since they tend to be constrained from short-selling. As a result, the hypothesis can contain two versions of predictions. A stronger version predicts that the rise in announcing stock price is accompanied by a rise in overall trading volume as well, caused by increased attention or sentiments. This is also simply known as the "volume hypothesis". A weaker version predicts that the rising stock prices are accompanied by increasing individual net-buying orders around announcement dates. There have been other papers that test this prediction using aggregate trading volume data relying on rather imprecise imputation about individual transcations. This paper represents one of the first papers to document evidence of actual individual trading behaviors around earnings announcement dates.

With the benefit of a unique and detailed administrative data set from Finland, I examine whether earnings announcement premium is driven by the different individual and

[1] In the academic asset-pricing literature, the word "anomaly" roughly speaking refers to asset price behaviors that present ostensible arbitrage opportunities in an informationally efficient financial market.

non-individual (institutional) trading behaviors around announcement dates.[2] I perform the analysis in two steps. In the first step, I verify and characterize the earnings announcement premium in Finland on the Helsinki Stock Exchange (HEX). Furthermore, I compare the premium's behavior in Finland to its counterpart in the U.S. as a baseline. In the second step, I compare the trading behaviors of individual and institutional investors around announcement dates. I document suggestive evidence in support of the attention-grabbing hypothesis as an explanation of the asset-pricing anomaly surrounding earnings announcement dates.

Firstly, I confirm that indeed there is earning announcement premium in Finland between 1998 and 2009, but with some significant differences to the behavior of the premium in the U.S. stock markets. Lamont and Frazzini (2007) documents the premium in the U.S. stock markets with a symmetrical 20-day window around announcement dates. Averaging over all announcement windows between 1973 and 2004, they find a *concurrent* and *continuous* rise in the cumulative excess returns and the cumulative abnormal trading volume of the announcing stocks.[3] I perform similar event studies on the Finnish stock market using symmetrical time windows. In Finland, the average behavior of stock prices and trading volume is similar to the U.S. market *before* the earnings announcements. On average, I observe a significant rise of the price of the announcing stock and a significant initial drop in trading volume leading up to the earnings announcement. The trading volume spikes up on the eve of the earnings announcement, continues to drift up, and starts to taper off about five days after the event. However, in contrast with the U.S. case, the average stock price starts to fall almost immediately after the announcement such that the cumulative excess returns of announcing stocks over 30 days will be zero on average.

Underneathe the difference in the unconditional average behaviors between the U.S. and Finland lies the fact that the stock prices in Finland behave very differently around different types of earnings announcement events. In Finland, each public firm has four annual earning announcement events: one annual financial statement release and three interim earnings releases. When focusing on the average premium over the annual financial statement releases, I find that there is an average 1.5% earnings announcement premium held through a 30 day window. However, over the other three interim earnings

[2]The data set will be discussed in greater detail in the dedicated data section. However, briefly speaking this is a comprehensive transaction-level data set covering all stock trades, by individuals and institutions, on the Helsinki Stock Exchange between 1998 and 2009. The proprietary access was provided to the author through the University of Michigan Ross School of Business.

[3]Excess return is defined as the daily return minus an equal weighted portfolio of non-announcing stocks. Scaled volume is defined as share volume in month t divided by average volume in the previous 250 trading days. Abnormal volume is defined as the scaled volume minus the equal weight average of scaled volume for all stocks on that day.

releases, I find that over a 30 day window the cumulative excess returns of announcing stocks are on average negative. These findings are consistent with the cross-country study by Barber et al. (2013), which find significant announcement premium around annual financial statements but no evidence of any premium for the interim quarterly earnings announcements.

In the second part of the exercise, I document the significantly different trading behaviors of individuals versus institutions around earnings announcement events. I find that on average around announcement dates individuals indeed tend to generate more net buying volume while institutions tend to generate more net selling volume. This evidence is consistent with the hypothesis that individuals tend to buy stocks that grab their attention, which in this case are assumed to be the stocks with upcoming earnings announcements. It is also consistent with the conjecture that individuals are short-sale constrained and therefore they tend to on average be buying more than selling.

3.2 Relation to Literature

This paper sits inside a sizable literature on explaining the earnings announcement premium puzzle. In particular, it contributes to a set of studies providing explanations that are based on the empirical correlation between the stock returns and the trading volume. The most closely related paper to this study is Lamont and Frazzini (2007). It is one of the first papers to test the attention-grabbing hypothesis as an explanation for the earnings announcement premium.[4] They document that U.S. stocks with high trading volume around earnings announcements have subsequently high premiums and high imputed buying by individual investors. Lamont and Frazzini (2007) must impute the individual buying volume based on some highly imperfect assumptions.[5] For example, they impute whether an order is initiated as a buy or sell based on the price's position in the most recent bid/ask spread. Furthermore, an order is imputed as coming from an individual based on some dollar amount threshold for the trade size. These assumptions are acknowledged by the authors to be less reliable in the modern market environment, where algorithmic trading has enable large orders from institutions to be processed in sequences of small orders. This paper has the advantage that each transaction is clearly reported as either buyer- or seller-initiated and whether it comes from individuals or institutions.

Another closely related paper is Barber et al. (2013) which documents and analyzes the

[4]Lamont and Frazzini (2007) was based on a 2004 working paper version of Barber and Odean (2008).

[5]This is because they obtain the stock transactions from the NYSE Trade and Quote database, which does not report whether a transaction is a buy or sell or whether the trader is an individual or an institution.

earnings announcement premium in non-U.S. stock markets. Of the 46 countries (including Finland) examined, they find significantly positive premium in nine markets but that most of the excess returns are concentrated in the pre-announcement window. Furthermore, contrary to a prediction of the attention-grabbing hypothesis, they find on average negative correlation between the announcement premium and trading volume. Similar to Barber et al. (2013), I do not find an unconditional earnings announcement premium in Finland from 1998-2009, but do find an average premium around the annual financial statement release events. Furthermore, I find a negative relationship between the trading volume and the excess returns of the announcing stocks. Yet, I argue that this does not necessarily rule out the attention-grabbing hypothesis as an explanation. Indeed, after separating the individual and institutional orders, I find that individuals are generating net buying volume of he announcing stocks and it is rising with the excess returns. Since institutions typically form the majority of the trading volume in a market, it is plausible to have an increase in individual net buying volume while the overall trade volume falls. The prices of the announcing stocks are driven up by the net-buying from individual investors, which is consistent with the attention-grabbing hypothesis.

Lastly, it is worth mentioning briefly several other papers that have used the same Finnish data set to analyze investor behaviors around earnings announcements. Ekholm (2006) studies the period 1994-2000 and reports that most Finnish investors tend to sell (buy) stocks after a positive (negative) earnings surprise. Moreover, they are biased towards buying immediately after an annual financial statement release. Consistent with the spirit of this paper, they find that large investors tend show opposite behaviors to the rest. While I do not examine earnings surprises in this paper, the contrarian behavior of individual investors is consistent with our finding that individuals are buying as stock prices fall while institutions are on average selling. Grinblatt and Keloharju (2000) also finds that domestic investors in Finland tend to be contrarian investors and generally underperform compared with foreign investors in Finland who tend to be momentum investors.

In section 3 I will describe the data used in this paper. In section 4, I describe the methodology for identifying earnings announcement premium in the Finnish stock market and the trading behaviors of different investor groups. In section 5, I present and discuss the empirical findings. Section 6 will conclude.

3.3 Data

In this paper, I use two types of data on the Helsinki Stock Exchange(HEX) between 1998 and 2009.[6] The first type of data is hand-collected market data. I gather the earnings announcement dates as well as end-of-day daily stock prices of all public companies listed on the exchange during this period. The second type of data is transaction-level micro data. The data on individual and institutional transactions, which comes from a proprietary administrative data set that will be described in details here.

Before discussing the data-gathering process, a brief introduction of the Finnish stock market is in order. The Helsinki Stock Exchange (HEX), which is the only stock market in Finland, is a very small and highly concentrated stock market.[7] As of the end of 2000, the HEX has a total market capitalization worth $349 billion in USD or about 1% of the world's total market cap, as compared to the U.S. total stock market capitalization of $16,635 billion or 46% of the world's.[8] Between the year 1998 and the 2009, the HEX had between 120 and 150 listed companies, as compared to an average over 3000 listings on the New York Stock Exchange alone. Finally, the HEX is also the world's most concentrated stock market. As of the end of 2000, the largest three stocks on the HEX make up 79% of the total market capitalization and the biggest company (Nokia) alone makes up 70% of the total market cap. Taken together, these features of the HEX create some significant challenges for analyzing and interpreting the price behaviors. It also means that one has to be careful with drawing external inference from these results in Finland.

3.3.1 Announcement Dates and Market Prices

Now I will discuss the public disclosure rules on the HEX. In Finland, the publicly listed firms are required to file three interim reports (IR) and an annual financial statement (FS). In addition, there is usually an annual general meeting (AGM). Therefore, each public company has as many as five regular planned earnings-related dates in a year. The financial statement release typically occurs sometime in the first quarter of the calendar year. In addition to discussing the earnings in the previous quarter, it also summarizes the earnings performance of the firm in the previous year. The three interim earnings reports are more or less evenly spaced throughout the other three quarters of the year. The AGM occurs typically in the first quarter close to the financial statement release date. Some companies combine the financial statement release with the AGM. Importantly, the

[6]I cut the sample in 2009 because that is when the coverage of the administrative transactions data set ends

[7]The HEX, through a sequence of mergers and acquisitions, is now part of the Nasdaq Nordic.

[8]Data source: Dimson, Marsh and Stanton (2002)

earnings announcement dates are pre-announced at the beginning of each calendar year with adjustments usually within the same week. Therefore it is possible to keen investors to be aware of them and act in anticipation of them.

The earnings announcement dates between 1998 and 2009 are collected in two time blocks each from a different source. The first block, which covers a selection of the listed companies from 1999 through 2002, is downloaded from the Bloomberg terminal . The second block, which covers all the listed companies from 2006 through 2009, is manually collected from the Helsinki Stock Exchange website.

Finally, I also obtain from the Bloomberg terminal the end of day daily prices all listed and delisted stocks on the HEX between 1998 and 2009.

3.3.2 Transaction-level Stock Trade Data

The trade by trade stock transaction data comes a proprietary database called the Finnish Central Securities Depository (FCSD) Registry. This paper is crucially enabled by the access to the unique and detailed data set. The Finnish government mandates that all stock trades must be registered in great detail with this database. It records all stock trades and daily portfolios of all the Finnish households and institutions investing in the HEX. I have access to the data set from Jan 1995 through June 2009.[9] Because this is an official administrative data set is, it is very accurate and reliable.

The FCSD database contains detailed information on each stock transaction as well as supplementary information on the trading entities. Each transaction observation contains: the trade date, type of order (market/limit), the security identifier (ISIN), the legal form of the investor, buy- or a sell-initiated order status, the quantity, and the price at which the order is fulfilled when available. Additionally, the database provides basic biometric information on the individuals, such as gender and primary language. For institutional investors, the database contains industry codes.

The FCSD database also provides market-wide information such as the daily returns and trading volume of each stock. However, this data set appears to be incomplete as it does not completely overlap or contain the price and volume data from Bloomberg. I supplement this data set with the Bloomberg data where it is missing, however, maintain the data as is where they disagree.The earnings announcement premiums are calculated using the combined data set.

[9]This is the end of my access. The database continues to be updated til the present day.

3.4 Methodology

In this section, I introduce the methodology used to estimate the earnings announcement premiums and measure the trading volume patterns around the announcements. Following Lamont and Frazzini (2007), I employ primarily event studies methods to analyze the excess returns and the behaviors of the trading volumes. Specifically, I construct measures of 1) excess returns of announcing stocks; 2) "excess" or abnormal trading volume of announcing stocks; 3) excess net buying/selling by individual investors and finally 4) the standard errors of the cumulative measures.

Daily Abnormal Returns

If there is earnings announcement premium, then on average the stocks with upcoming earnings announcements are supposed to outperform stocks without announcements. Specifically, in a relatively small window around the earnings announcement date, the cumulative returns of the announcing stocks in excess of the non-announcing stocks should be positive and significant.

The abnormal return of a firm j on day t is defined as its stock return on that day minus the unweighted average returns of the non-announcing stocks.[10] Let t be the calendar day of the event and let $T+1$ be the length of the event window.[11] For example, if we are looking at a 40 day symmetrical window about an earnings event, then $T+1=41$, with the additional day being the event itself in the middle. Finally, let the capital letter A denote the set of announcing stocks and the symbol $\sim A$ denote the set of stocks that do *not* have any announcement events during this time window.

In mathematical symbols, the abnormal return is defined as follows.

$$\mathrm{AR}_t^j = \mathrm{RET}_t^j - \frac{1}{N^{\sim A}} \sum_{i \in \sim A} \mathrm{RET}_t^j \qquad (3.1)$$

The daily abnormal return is equivalent to the trading strategy of forming a so called "long-short portfolio" of earnings announcement stocks. On any given day, the expression (3.1) tracks the returns from buying and holding (long) a dollar worth of the announcing stock while short-selling (short) a dollar worth of the unweighted group of the non-announcing

[10]The reason I use "unweighted" average is so that that the average return of the non-announcing stocks is not alway dominated by the returns of the biggest stocks that happen to be not announcing on those days. An alternative is to exclude the largest stocks and do a weighted average. I have tried both of those approaches and the results are similar.

[11]I consider multiple time window lengths, e.g., $T=20$, 30 or 40.

stocks.[12]

Furthermore, I define a related measure: the cumulative abnormal returns (CAR). This is a sequence of $T+1$ numbers that tracks the cumulative returns from a strategy of holding the long-short portfolio of the announcing stocks. This allows us to most clearly visualize the presence of any earnings announcement premiums.

$$\text{CAR}^j_{t,h} = \sum_{i=-T/2+1}^{h-T/2+1} \text{AR}^j_{t+i}, \ h = 1, \ldots, T+1 \tag{3.2}$$

For each firm and each announcement date, I generate $\left\{\text{CAR}^j_t\right\}_{h=1}^{T+1}$, which is a $T+1$ day path. Finally, the unconditional average behavior of the excess returns is an unweighted average of all the paths. Naturally, the conditional average behavior, e.g., the premium around only financial statement dates, is just an average taken over those specific instances. If there exists an earnings announcement premium (over a certain horizon), then the CAR curve should end up positive and statistically significant at the end of the time window. However, note that because these measures are constructed based on event days, whatever premiums detected do not reflect a feasible trading strategy since the earnings announcement dates may have varied slightly from when it was first announced.

Daily Abnormal Volume

The volume hypothesis predicts that the trading volume of the announcement stocks should rise in tandem with the stock prices around announcement dates. To assess this hypothesis, I define a measure of abnormal trading volume of the announcement stocks. Because trading volume varies significantly in the cross section, a more natural way of gauging whether there is additional trading volume is by comparing a stock's trading volume against its own historical levels. To that end, I define a measure called "scaled volume" following Lamont and Frazzini (2007). The scaled volume of a firm j on date t is the ratio between the firm j's *share* volume on date t and the firm's average *share* volume over the previous 250 trading days.[13] Mathematically this is represented as follows.

[12]Because of the heavily distorted nature of the market cap distribution on the HEX, such a strategy may have serious limitation in its scalability. For example, one may not be able to easily put as much money into the smaller companies as the bigger companies. Though this is perhaps a common problem for this strategy on any stock market, it could be particularly severe on the HEX.

[13]250 days because this is roughly the number of trading days in a year in Finland as well.

$$\text{SV}_t^j = \frac{\text{VOL}_t^j}{\frac{1}{250}\sum_{s=-251}^{-1}\text{VOL}_{t+s}^j} \tag{3.3}$$

In other words, with this measure, we are asking "how big is today's trading volume relative to its normal level?".

Then an announcing firm j's idiosyncratic abnormal volume on date t is defined as its scaled volume on date t minus the average market scaled volume on the same day. This is the volume analogue of "excess returns" as it compares the (self-)abnormal volume of the announcing stock against the abnormal volume of the rest of the market, in particular the non-announcing stocks.[14]

$$\text{AV}_t^j = \text{SV}_t^j - \frac{1}{N}\sum_{i=1}^{N}\text{SV}_t^i \tag{3.4}$$

$$= \text{SV}_t^j - \overline{\text{SV}}_t^j \tag{3.5}$$

Because the trading volume is calculated on the units of shares rather than the dollar-value of the orders, an equal-weighted cross-sectional average of trading volume is equivalent to a value-weighted average of dollar-valued trading volumes.

Similar to returns, I define a cumulative abnormal volume (CAV) measure, which helps us visualize the pattern of trading volume changes.

$$\text{CAV}_{t,h}^j = \sum_{i=-T/2+1}^{h-T/2+1}\text{AV}_{t+i}^j,\ h = 1, \ldots, T+1 \tag{3.6}$$

Finally, under the null hypothesis of there being no announcement effect, we should expect both abnormal returns and abnormal volumes to be zero. Equivalently, we should expect to see both CAR and CAV as flat lines at zero. Under the volume hypothesis, we expect to see a simultaneous increase in CAR and CAV around the announcement dates.

Order Imbalances By Investor Groups

In order to assess the attention-grabbing hypothesis, specifically that the announcement premium is driven by buying pressure from individual investors, I construct measures of

[14] An alternative measure would be to exclude the announcing stocks from the second term. However, I keep this format for comparability with the Lamont and Frazzini (2007) paper. I have tried the other way. It does not make a qualitatively difference.

net trading volume for each investor group.[15] I construct a *net buy* metric for each investor group. For each investor group, (individual/institution), the net buy metric for firm j on date t is defined as the ratio between the difference of the total *buy-initiated volume* and total *sell-initiated volume* and the firm j's *average daily trading volume* over the previous 250 trading days. For example, the individual net-buy metric for firm j on date t is defined as follows.

$$\text{Net Buy}_{j,t}^{Ind} = \frac{\text{Buy}_{j,t}^{Ind} - \text{Sell}_{j,t}^{Ind}}{\frac{1}{250}\sum_{s=-251}^{-1}\text{VOL}_{t+s}^{j}} \tag{3.7}$$

where $\text{Buy}_{j,t}^{Ind}$ represents the total buy-initiated share volume by individual investors and $\text{Sell}_{j,t}^{Ind}$ represents the total sell-initiated share volume by individual investors. Note because I can observe directly whether a trader order is originally placed as a buy or sell order and by what investor type, I do not need to make any imputations about these quantities unlike Lamont and Frazzini (2007). Each order is assigned correctly to be either buy-initiated or sell-initiated. Similarly, I define a net buy metric for institutional investors

$$\text{Net Buy}_{j,t}^{Ins} = \frac{\text{Buy}_{j,t}^{Ins} - \text{Sell}_{j,t}^{Ins}}{\frac{1}{250}\sum_{s=-251}^{-1}\text{VOL}_{t+s}^{j}} \tag{3.8}$$

Because the total net buy volumes between individuals and institutions should sum to zero, it is expected that a positive net-buy volume by individuals will be accompanied by a negative net-sell volume by institutions if the data is accurate. Furthermore, these measures can exceed 100% if the trading of a stock is infrequent and generally inactive, in which case any active trading day can easily see volumes that are several times larger than the average. Finally, I define as above a cumulative version of the net-buy metric to help us visualize the accumulative impact of investor actions by investor types.

$$\text{CNB}_{j,t,h}^{\text{``type''}} = \sum_{i=-T/2+1}^{h-T/2+1} \text{NB}_{j,t+i}^{\text{``type''}},\ h = 1, \ldots, T+1 \tag{3.9}$$

[15] Ideally, I should look specifically at investors who do not already know the announcing stocks to tease out the short-sale constraint from the limited attention story. This is technically also feasible because the data set contains information on individual portfolios. However, this was given up because the relatively infrequent trading among households that such restriction would have cut down the sample too much to have any statistical powers to draw inferences.

The attention-grabbing hypothesis explanation especially applied to individuals predicts that the cumulative net-buying by individual investors should be rising with the excess returns of the announcing stocks.

Cumulative Standard Errors

For all three cumulative measures, CAR, CAV and CNB, I apply the same method for calculating standard errors. Let X denote either AR, AV ro NB as defined above. I assume that X is serially uncorrelated, then the standard errors of the cumulative version of X can be calculated as follows.

$$se\left(CX\right) = \sqrt{se\left(X_1\right)^2 + se\left(X_2\right)^2 + \cdots + se\left(X_{T+1}\right)^2} \tag{3.10}$$

The confidence interval bounds can be generated using standard errors if we assume X is i.i.d. normal. An alternative is to bootstrap the quantiles from the empirical distribution.

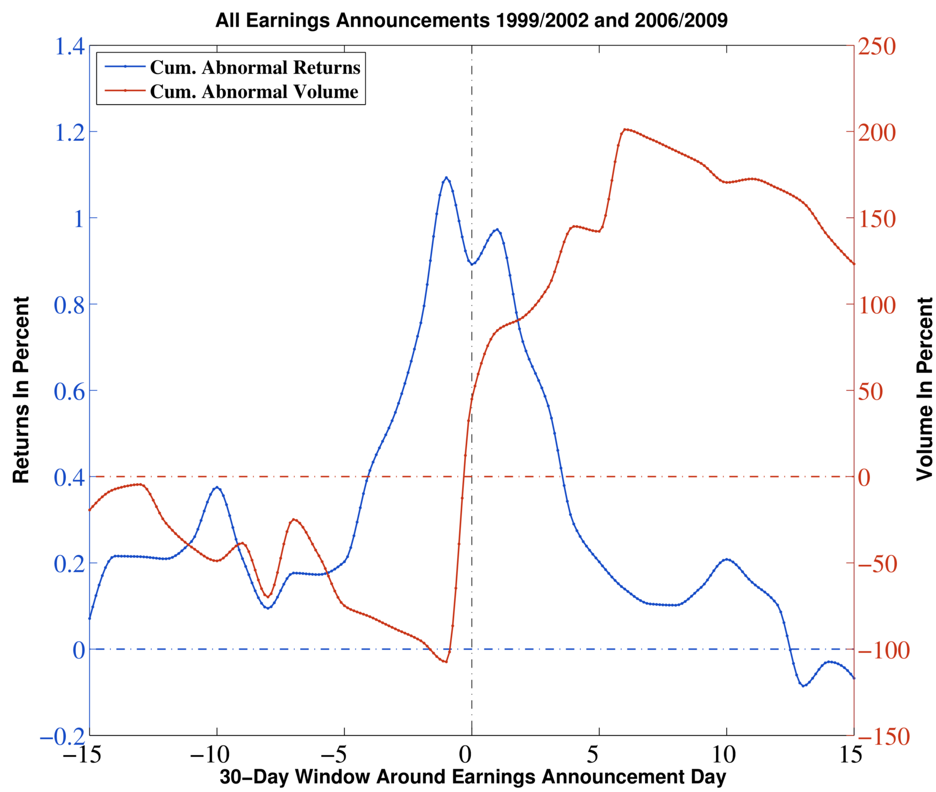
3.5 Empirical Results

The empirical results will be discussed in three main steps. In the first steps, I examine the earnings announcement premium, the trading volume of the announcing stocks and the relationship between them or the so called volume hypothesis. In the second step, I dig a little deeper into the earning announcement premium by looking at the excess returns of the announcing stocks around different types of announcements. In the third step, I take a closer look into the trade volume pattern. I look at the net-buying pressure from individual and institutional investors separately. Finally, I use the results from the second and third steps to assess the attention-grabbing hypothesis, which suggests that the earnings announcement premium could be driven by individual investors buying announcement stocks that catch their attention.

3.5.1 The Earnings Announcement Premium And Volume Hypothesis

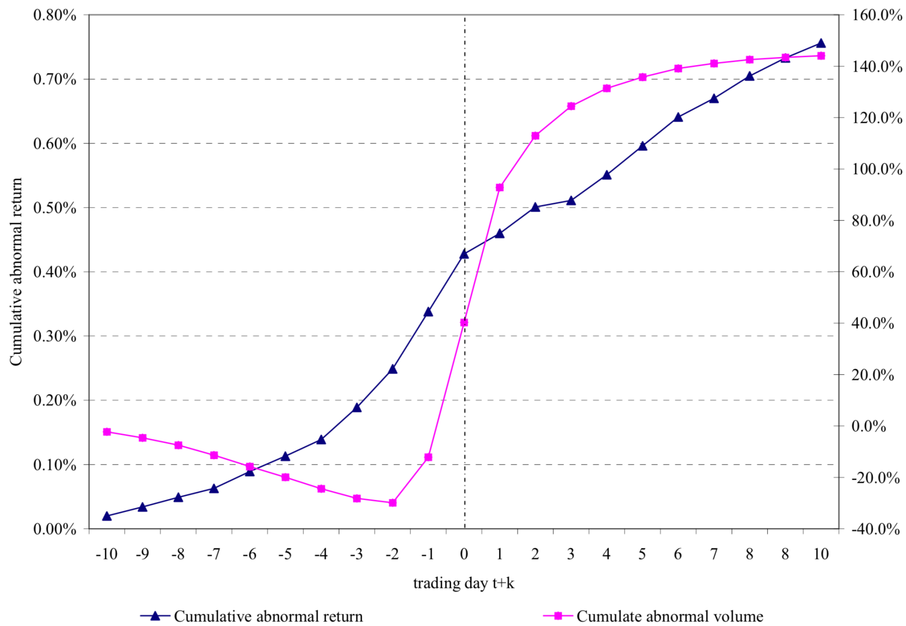
In this section,I present the results on the unconditional excess returns around the earnings announcements as well as assess the volume hypothesis. The analysis is conducted using daily event studies. In other words, I calculate the cumulative abnormal returns and cumulative abnormal trading volume in a tight time window around the announcement days. This methodology is chosen because of the limited availability of earning announcement dates that would allow us the infer the excess returns of a monthly-rebalanced long-

Figure 3.1: Unconditional Average CAR and CAV Around Earnings Announcements



This figure shows event-time daily cumulative abnormal return and cumulative turnover in trading day $t + k$ for firms announcing earnings at date t. Abnormal return is defined as daily return minus an equally weighted portfolio of non-announcing firms. Scaled volume is defined as share volume on day t divided by average volume in the previous 250 trading days. Abnormal volume is defined as scaled volume minus the equal weight average of scaled volume for all firms on that day. Volume and return are in percent.

Figure 3.2: Average CAR and CAV Around Earnings Announcements in the US



This figure is taken from Lamont and Frazzini (2007) for comparison with the Finland results in Figure (3.1). It depicts the cumulative abnormal returns and cumulative abnormal returns around earnings announcements in the U.S. between 1973 and 2004 for firms above the median market capitalization of the CRSP firms. The definitions of measures of returns and volume are the same as this paper.

short portfolio strategy. Moreover, as will be seen below, that to the extent that there is some run up of excess returns around the announcements, most of it is earned (and subsequently lost) in the 10 days around the announcements. This motivates the choice of using a daily event study rather than a monthly portfolio analysis.

In the time periods 199-2002 and 2006-2009, I find evidence of earnings announcement premium and a relative elevation of idiosyncratic trading volume around announcement dates. Figure (3.1) depicts the average cumulative abnormal returns (CAR) and average cumulative abnormal volume (CAV) as defined in equations (3.2) and (3.6).[16] The standard errors are reported in the appendix. I also include Figure (3.2), which is the same plot but for the U.S. stocks borrowed from Lamont and Frazzini (2007), as a baseline comparison. Looking at Figure (3.1), there is clearly a run up of CAR or premium up to the announcement day. There is a run-up around 1% within the 15 trading days prior to the announcement. Even if within the 10 trading days prior to the announcement, there is a 80 basis points of premium. As a matter of fact most of the premium is earned within the last five days prior to the announcement, earning as much as 90 basis points before falling

[16]These CAR and CAV are equal-weighted average of the CARs and CAVs at every earnings announcement event.

back slightly on the announcement day. The size of the premium is significantly bigger than in the U.S.. Looking at Figure (3.2) as a comparison, the U.S. announcement stocks only earn a premium of 40 basis points over the 10 trading days prior to the announcement and no more than 80 basis points 10 days after.

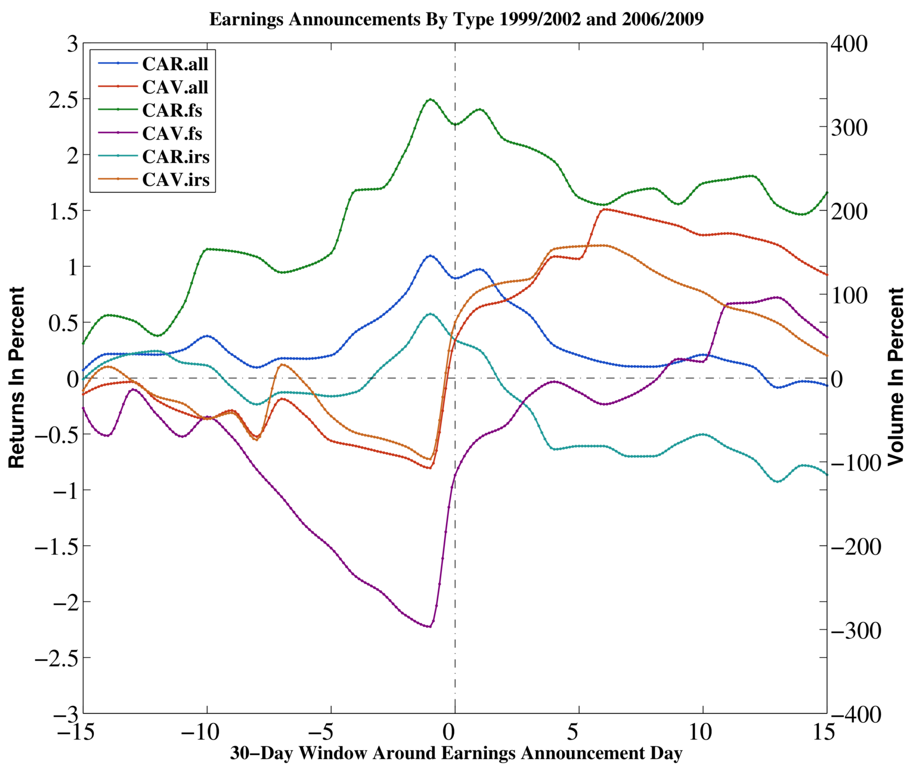
While the pre-announcement premium in Finland differs quantitatively from that of the U.S., the difference becomes qualitative post-announcement. As shown in Figure (3.1), the premium earned pre-announcement is rapidly and entirely given up in the 15 trading days after the event. In fact, similar to the run-up, about 80 basis points or 90% of the gains are lost in merely the 5 days after. This is in contrast with the U.S. case, where the announcing stocks see a *gradual* and *continuous* increase in cumulative abnormal returns in the 20 days around the announcement. Both the fact that the Finland premium is larger than in the U.S and the fact that it is only earned in prior to the announcement are consistent with the findings in Barber et al. (2013).

Lastly, I move to discuss the trading volume and the volume hypothesis. Cumulative abnormal volume exhibits a significantly different pattern from cumulative abnormal returns. In Figure (3.1) we can see that the volume is well below average before the announcements. However, it spikes upward at the announcement, drifts up for about 6 trading days before tapering off, but still remaining above average for the entire 15 days after the announcement. While quantitatively different, the announcing stocks' trading volume in Finland exhibits an overall similar pattern as in the U.S. Furthermore, because the announcement premium in Finland rapidly vanishes exactly as the trading volume gathers steam, we observe a strong negative correlation between volume and the announcement premium both before and after the announcement. As a result, we should be able to comfortable reject the volume hypothesis as an explanation of the earnings announcement premium in Finland. Yet, this is not the end of the story for trading volume as I pick it up again later in the paper.

3.5.2 Earnings Announcement Premium By Announcement Types

In this section, I dig deeper into the earnings announcement premium by examining for different types of earnings announcements. I find that the earnings announcement premium behaves very differently around two different types of earnings announcements. As described in section (3.3.1), in Finland each stock has four main earnings announcements in a year. One (annual) financial statement release and three (quarterly) interim earnings reports. Inspired by Barber et al. (2013), I separately calculate the cumulative abnormal returns and cumulative abnormal volume for the financial statement (FS) releases and the interim earnings (IRS) report releases. The results are depicted in Figure (3.3) and the

Figure 3.3: Average CAR and CAV Around Earnings Announcements By Announcement Types



This figure shows the cumulative abnormal returns and cumulative abnormal volume by different types of earnings announcements. As mentioned in section (3.3.1), in Finland each stock has four main earnings announcements in a year. One (annual) financial statement release and three (quarterly) interim earnings reports. CAR.all and CAV.all repeat the unconditional premium and volume as in Figure (3.1). CAR.fs and CAV.fs represent the return and volume averaged over only financial statement events. CAR.irs and CAV.irs represent the return and volume averaged over only interim report events. Volume and return are in percent.

standard errors are reported in the appendix. CAR.all and CAV.all are the same premium and volume curves as in Figure (3.1). Similarly, the suffix ".fs" represents the premium or volume from *only* the financial statements, the suffix ".irs" represents the premium or volume of the interim earnings reports.

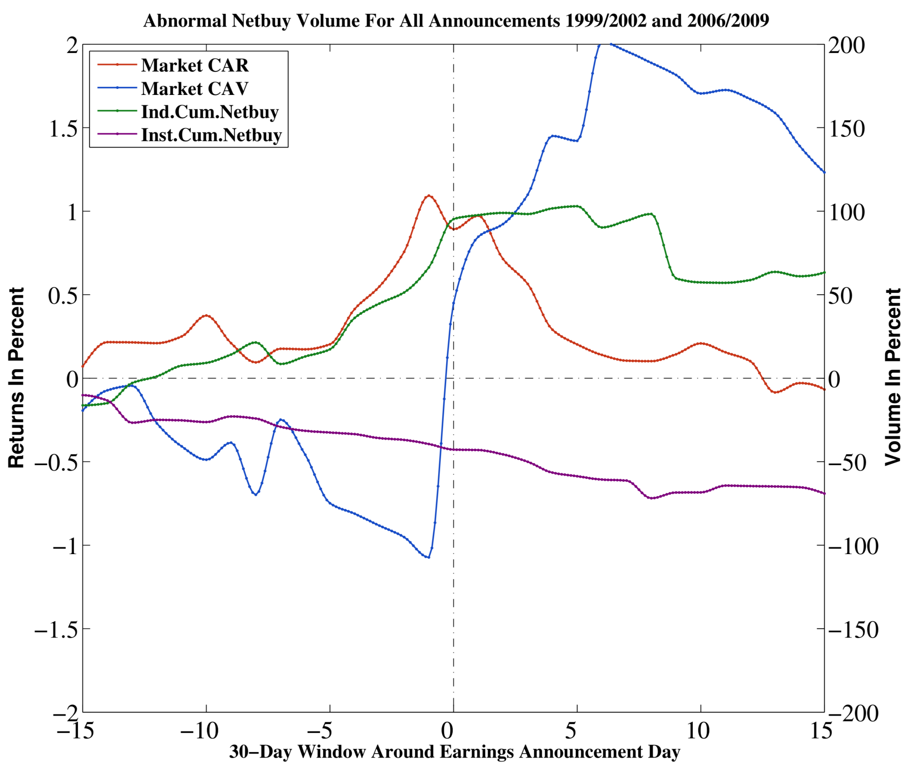
It turns out that the financial statement premium is much higher and more persistent than the interim earnings report premium. CAR.fs (green line) represents the excess returns earned from holding the long-short portfolio of announcement stocks *only* around the financial statements. The returns from the financial statement announcements are much higher than the unconditional average premium. Pre-announcement, the premium climbs up to over 2% over 15 trading days. After the announcement, the cumulative premium drifts down somewhat, however still remains positive and above 1.5% after 15 trading days after the announcement. Because the unconditional premium is basically a weighted average between the financial statement premium and the interim earnings premium, unsurprisingly the interim earnings premium is generally smaller and statistically indistinguishable from zero and eventually ends up being negative. In other words. there is no interim earnings announcement premium and almost of the unconditional announcement premium comes from the financial statement premium. Both the magnitude and the general pattern are consistent with the findings in Barber et al. (2013).

The trading volume around the financial statement announcement tells a similarly dramatic story. While volume generally decreases ahead of announcements, the trading volume around the financial statements is significantly below average by as much as 300% below average just before the announcement. While the trading volume spikes up at the announcement and gradually recovers, it still remains generally around average 10 days post-announcement. On the other hand, the trading volume around the interim earnings releases is quite similar to the unconditional CAV. This is somewhat puzzling because one potential explanation for the higher premium around financial statements may be that there is a lot more informational content in these releases. The general lack of trading volume seems to undercut this explanation.

3.5.3 Trading Volume By Investor Types

The general decrease in trading volume in the lead up to the earnings announcements is puzzling. From either an information or attention viewpoint, one would not expect a decrease in trading volume. Moreover, the attention-grabbing hypothesis suggests that *individual investors* should be particularly susceptible to the pure salience-value of the earnings announcement statements. Both reasons motivate a closer examination of the trading volume around earning announcements that separate the contributions from individual

Figure 3.4: Average CAR and CAV Around Earnings Announcements By Announcement Types



This figure depicts the unconditional premium and volume around earnings announcement. Market CAR and Market CAV are the same CAR and CAV as in Figure(3.1) respectively. Ind.Cum.Netbuy represents the trading imbalance on the announcing stock by the individual investors as defined in equation (3.7). Inst.Cum.Netbuy represents the trading imbalance on the announcing stock by the institutional investors as defined in equation (3.8).

investors from the institutions.

Upon separating the trading volume by investor legal types, I find that individual investors and institutional investors have drastically different behaviors around earnings announcements. In particular, I define net-buying trading volume from individuals and institutions in equations (3.7) and (3.8) respectively. These measures essentially track the order imbalances from each investor group.

The individual investors on average tend to exert net-buying pressure around announcements while institutions tend to be net sellers. In Figure (3.4), we can see that individual investors (green line) generate net buying volume, which rises continuously pre-announcement reaching about 100% daily trade volume and does not begin to taper off until 10 days post-announcement. Comparing this against the excess returns, this means that individual investors are on net capturing the premium in the pre-announcement window. However, because the average premium is eventually completely given up soon after the announcement and individual net-buying does not decrease immediately, individual investors as a group probably give up all of the gains as well.

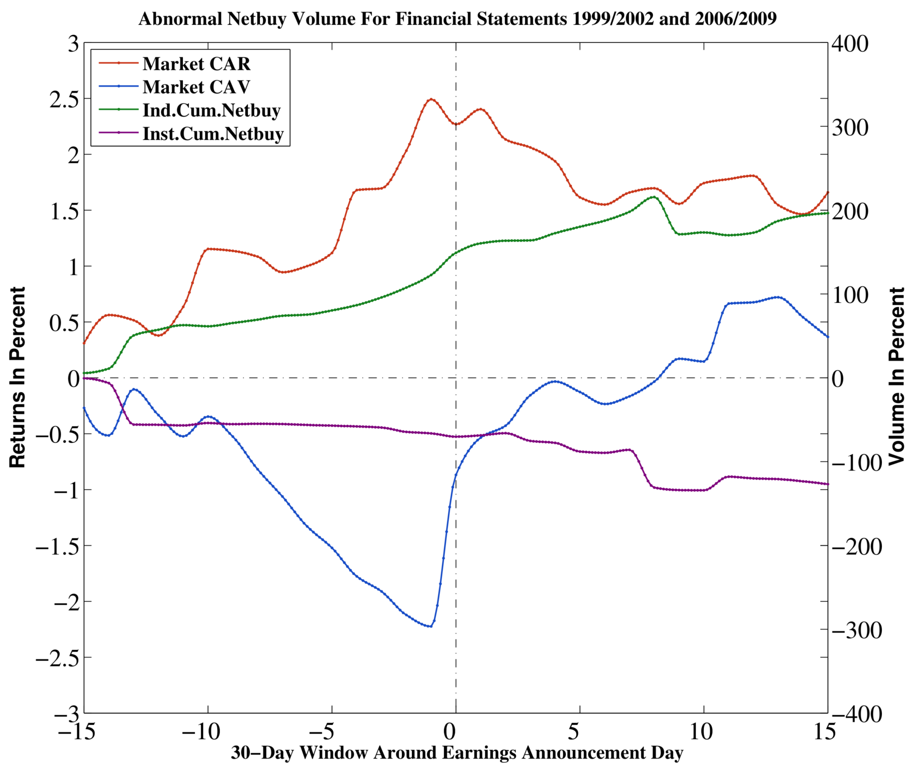
This pattern of individual investors net-buying vis-a-vis the announcement premium is consistent with the attention-grabbing hypothesis. The earnings announcement news grabs the attention of individual investors, who because of short-sale constraint exhibit as a group a net-buying bias. Their net-buying bids up the stock price. Institutions, being the more sophisticated investors, could have perceived that announcements on average do not generate good returns so are happy to accommodate the net-buying from individual investors.

Because the almost of all the announcement premium is earned over the financial announcements, we are naturally interested in seeing how the different investors groups behave specifically then. Figure (3.5) shows that similar to the case with all announcements, individual investors are net buyers around financial statements while institutions are net sellers. However, in this case because the announcement premium is persistent, the individuals investors as a group likely retain the excess returns.

3.6 Conclusion

In this paper, I investigate the earnings announcement premium in Finland on the Helsinki stock exchange. Looking at earnings announcement events between 1999-2002 and 2006-2009, I find that stocks with announcement do earn excess returns over non-announcement stock in the 2 week window before the announcements. However, these premiums are usually given up sooner after. Moreover, I find that the premium is signifi-

Figure 3.5: Average CAR and CAV Around Earnings Announcements By Announcement Types



This figure depicts the unconditional premium and volume around *financial statements*. Market CAR and Market CAV are the same CAR.fs and CAV.fs as in Figure(3.3) respectively. Ind.Cum.Netbuy represents the trading imbalance on the announcing stock by the individual investors as defined in equation (3.7). Inst.Cum.Netbuy represents the trading imbalance on the announcing stock by the institutional investors as defined in equation (3.8).

cantly higher and actually persistent through a 30 day window around the annual financial statement releases. I find no premium around the interim earnings report and in fact they accumulate losses.

I also assess the relationship between announcement premium and trading volume in this paper. Similar to other papers, which have examined the issue on international stock markets, I do not find evidence in support of the so-called volume hypothesis. In general, trading volume and the premium are negatively correlated around announcement dates. However, I do find some supportive evidence for the attention-grabbing hypothesis. I find a positive correlation between the announcement premium and the net-buying trading volume among individual investors, especially around the financial statements.

APPENDIX A

Chapter I Supporting Material

A.1 Mathematical Appendix

In this section, I will show that $A_r(\tau)$, $A_\beta(\tau)$ and $A_s(\tau)$ and $C(\tau)$ in (1.11) are deterministic functions of τ. In equilibrium, asset markets clear and we obtain (1.18). Most of what follows is basically the same as the solution in Greenwood and Vayanos (2014), differing by a scaling constant. The arbitrageurs' first order condition for bonds can be written as

$$\begin{aligned}
\mu_t^{(\tau)} - r_t = \sum_{i=r,\beta,s} A_i(\tau)\, a\sigma_i^2 \int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\,\beta_t\right) A_i(\tau)\, d\tau \\
- aA_r(\tau)\left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\,\beta_t\right) A_r(\tau)\, d\tau\right) \bar{x}_t^{(s)} \sigma_s \sigma_r \rho_{r,s} \\
- aA_r(\tau)\left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\,\beta_t\right) A_r(\tau)\, d\tau\right) \bar{x}_t^{(s)} \sigma_s^2 \\
- aA_r(\tau)\left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\,\beta_t\right) A_s(\tau)\, d\tau\right) \sigma_s \sigma_r \rho_{r,s} \\
- aA_s(\tau)\left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\,\beta_t\right) A_r(\tau)\, d\tau\right) \sigma_s \sigma_r \rho_{r,s}
\end{aligned} \tag{A.1}$$

where

$$\begin{aligned}
\mu_t^{(\tau)} =& A_r'(\tau)\, r_t + A_\beta'(\tau)\,\beta_t + A_s'(\tau)\, s_t + C'(\tau) \\
&- A_r(\tau)\,\kappa_r(\bar{r} - r_t) + A_\beta(\tau)\,\kappa_\beta \beta_t - A_s(\tau)(r_t + \sigma_s \xi_s) \\
&+ \frac{1}{2}A_r(\tau)^2 \sigma_r^2 + \frac{1}{2}A_\beta(\tau)^2 \sigma_\beta^2 + \frac{1}{2}A_s(\tau)^2 \sigma_s^2
\end{aligned} \tag{A.2}$$

The LHS of the equality is

$$
\begin{aligned}
LHS =& A_r^{'}(\tau) r_t + A_\beta^{'}(\tau) \beta_t + A_s^{'}(\tau) s_t + C^{'}(\tau) \\
& - A_r(\tau) \kappa_r (\bar{r} - r_t) + A_\beta(\tau) \kappa_\beta \beta_t - A_s(\tau)(r_t + \sigma_s \xi_s) \\
& + \frac{1}{2} A_r(\tau)^2 \sigma_r^2 + \frac{1}{2} A_\beta(\tau)^2 \sigma_\beta^2 + \frac{1}{2} A_s(\tau)^2 \sigma_s^2 - r_t
\end{aligned} \tag{A.3}
$$

The RHS of the equality is

$$
\begin{aligned}
RHS =& \sum_{i=r,\beta,s} A_i(\tau) a\sigma_i^2 \int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_i(\tau)\, d\tau \\
& - aA_r(\tau) \left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_r(\tau)\, d\tau\right) \bar{x}_t^{(s)} \sigma_s \sigma_r \rho_{r,s} \\
& - aA_r(\tau) \left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_r(\tau)\, d\tau\right) \bar{x}_t^{(s)} \sigma_s^2 \\
& - aA_r(\tau) \left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_s(\tau)\, d\tau\right) \sigma_s \sigma_r \rho_{r,s} \\
& - aA_s(\tau) \left(\int_0^T \left(\zeta_t^{(\tau)} + \theta(\tau)\beta_t\right) A_r(\tau)\, d\tau\right) \sigma_s \sigma_r \rho_{r,s}
\end{aligned} \tag{A.4}
$$

Collect r_t terms

$$A_r^{'}(\tau) + A_r(\tau)\kappa_r - 1 = A_s(\tau) \tag{A.5}$$

Collect s_t terms

$$A_s^{'}(\tau) = 0 \;\Rightarrow\; A_s(\tau) = Const. \tag{A.6}$$

Before we collect the β_t terms we note that the initial conditions, $A_r(0) = A_s(0) = A_\beta(0) = C(0) = 0$ so that $P_t(0) = 1$. In particular,

$$A_s(0) = 0 \;\Rightarrow\; A_s(\tau) = 0 \tag{A.7}$$

This simplifies the ODEs for $A_r(\tau)$ and $A_\beta(\tau)$ significantly. For $A_r(\tau)$,

$$A_r^{'}(\tau) + A_r(\tau)\kappa_r - 1 = 0 \tag{A.8}$$

$$\Rightarrow A_r(\tau) = \frac{1 - e^{-\kappa_r \tau}}{\kappa_r} \tag{A.9}$$

and for $A_\beta(\tau)$,

$$
\begin{aligned}
A_\beta^{'}(\tau)+A_\beta(\tau)\kappa_\beta =& A_r(\tau)\,a\sigma_r^2\int_0^T\theta(\tau)\,A_r(\tau)\,d\tau \\
&+A_\beta(\tau)\,a\sigma_\beta^2\int_0^T\theta(\tau)\,A_\beta(\tau)\,d\tau \\
&-aA_r(\tau)\left(\int_0^T\theta(\tau)\,A_r(\tau)\,d\tau\right)x_t^{(s)}\sigma_s\sigma_r\rho_{r,s} \\
&-aA_r(\tau)\left(\int_0^T\theta(\tau)\,A_r(\tau)\,d\tau\right)x_t^{(s)}\sigma_s^2
\end{aligned}
\tag{A.10}
$$

The solution to the $A_\beta(\tau)$. For convenience, define

$$
Z = a\sigma_r^2 I_r \tag{A.11}
$$

$$
I_r = \int_0^T\frac{1-e^{-\kappa_r\tau}}{\kappa_r}\theta(\tau)\,d\tau \tag{A.12}
$$

$$
A_\beta^{'}(\tau)+A_\beta(\tau)\left(\kappa_\beta-a\sigma_\beta^2\int_0^T A_\beta(\tau)\,\theta(\tau)\,d\tau\right)=A_r(\tau)\,Z-A_r(\tau)\,Z\frac{\sigma_s}{\sigma_r}x_t^{(s)}\rho_{r,s}-A_r(\tau)\,Z\frac{\sigma_s^2}{\sigma_r^2}x_t^{(s)} \tag{A.13}
$$

$$
=Z\left(\frac{1-e^{-\kappa_r\tau}}{\kappa_r}\right)\left(1-\frac{\sigma_s}{\sigma_r}\bar{x}_t^{(s)}\rho_{r,s}-\frac{\sigma_s^2}{\sigma_r^2}\bar{x}_t^{(s)}\right)
$$

Define

$$
\hat{\kappa}_\beta = \kappa_\beta-a\sigma_\beta^2\int_0^T A_\beta(\tau)\,\theta(\tau)\,d\tau \tag{A.14}
$$

$$
\hat{\lambda} = 1-\frac{\sigma_s}{\sigma_r}\bar{x}_t^{(s)}\rho_{r,s}-\frac{\sigma_s^2}{\sigma_r^2}\bar{x}_t^{(s)} \tag{A.15}
$$

So we have the simplified formulation

$$
A_\beta^{'}(\tau)+A_\beta(\tau)\,\hat{\kappa}_\beta = Z\hat{\lambda}\left(\frac{1-e^{-\kappa_r\tau}}{\kappa_r}\right) \tag{A.16}
$$

$$
A_\beta(\tau) = \frac{Z\hat{\lambda}}{\kappa_r}\left(\frac{1-e^{-\hat{\kappa}_\beta\tau}}{\hat{\kappa}_\beta}-\frac{e^{-\kappa_r\tau}-e^{-\hat{\kappa}_\beta\tau}}{\hat{\kappa}_\beta-\kappa_r}\right) \tag{A.17}
$$

Table A.1: Summary Statistics Of Key Variables

VARIABLES	Units	N	mean	sd	min	max
1Y Yield	percent	672	5.24	3.38	0.10	16.72
ACM 10 Year Term Premium	percent	667	1.65	1.20	-0.67	5.10
KW 10 Year Term Premium	percent	318	0.88	0.89	-0.85	2.84
CP 3 Year Term Premium	percent	612	1.23	2.23	-9.66	9.02
YC Slope (3 Year Minus 1 Year)	percent	667	0.42	0.53	-2.11	1.66
Stock-Bond Correlation (DCC)	decim.	672	0.10	0.15	-0.21	0.37
Stock-Bond Correlation (Rolling)	decim.	672	0.05	0.30	-0.54	0.54
MWI	decim.	670	0.36	0.17	0.09	0.85
WAM Issue	year	671	2.28	0.74	0.76	3.80
Short Share	decim.	671	0.68	0.13	0.45	0.99
WAM Stock	year	672	7.99	1.63	4.72	11.13
Debt-GDP Ratio	decim.	666	0.34	0.15	0.16	0.76

Note: 1Y Yield is the Treasury Constant Maturity 1 year zero coupon yield estimated by the Fed, which I identify as the nominal short rate; ACM is the Adrian, Crump and Moench (2013) bond risk premium; KW is the Kim and Wright (2005) bond risk premium; CP is the Cochrane and Piazzesi (2005) bond risk premium (Excess Return); MWI is the maturity-weighted sum of issuance to GDP ratio, which is the baseline supply measure; WAM issue is the weighted average maturity of the issuance over the following 12 months; Short share is the share of the debt with maturity under 1 year in the total issuance over 12 months, which I use as an alternative measure for maturity choice; WAM Stock is the weight average maturity of the entire stock of Treasuries outstanding at a given time; Debt-GDP ratio is ratio of the total face value of all marketable Treasuries to nominal GDP.

where $\hat{\kappa}_\beta$ solves the following expression

$$\hat{\kappa}_\beta = \kappa_\beta - a\sigma_\beta^2 \int_0^T \frac{Z\hat{\lambda}}{\kappa_r} \left(\frac{1 - e^{-\hat{\kappa}_\beta \tau}}{\hat{\kappa}_\beta} - \frac{e^{-\kappa_r \tau} - e^{-\hat{\kappa}_\beta \tau}}{\hat{\kappa}_\beta - \kappa_r} \right) \theta(\tau)\, d\tau \qquad \text{(A.18)}$$

A.2 Summary Statistics Table

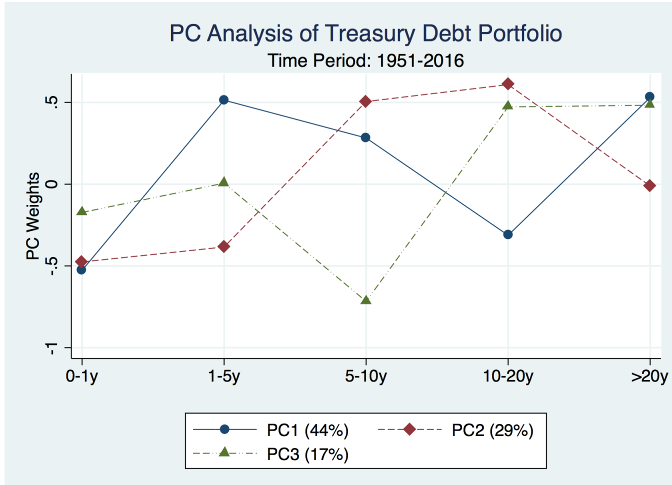
A.3 Plots

The following plot Figure A.7 is taken from Hou (2018). It describes in greater richness the dynamics of the US Treasury debt issuance policy. After encoding the issuance portfolio in 5 maturity bins, I do a principal component analysis of the maturity structure of the Treasury issuance. The first three principal components summarize about 90% of the portfolio variability. About 45% of the movements of the portfolio is between adjustments between the very short term (0-1year) and intermediate term (1-5year and 5-10year) and the adjustments between the long term (10-20year) and the ultra-long term (>20year). Another 30% of the variability comes from between short-medium term and long-ultra long term.

A.4 Tables of Results

The following table shows that the baseline results are not changed by using a simple moving window correlation. The share of short term debt is another measure of maturity of new issuances. Table A.5 presents the results from the time series regressions. The results are qualitatively very similar to those of WAM in table A.10. Since the higher the

Figure A.1: Principal Components of US Treasury Debt Portfolio

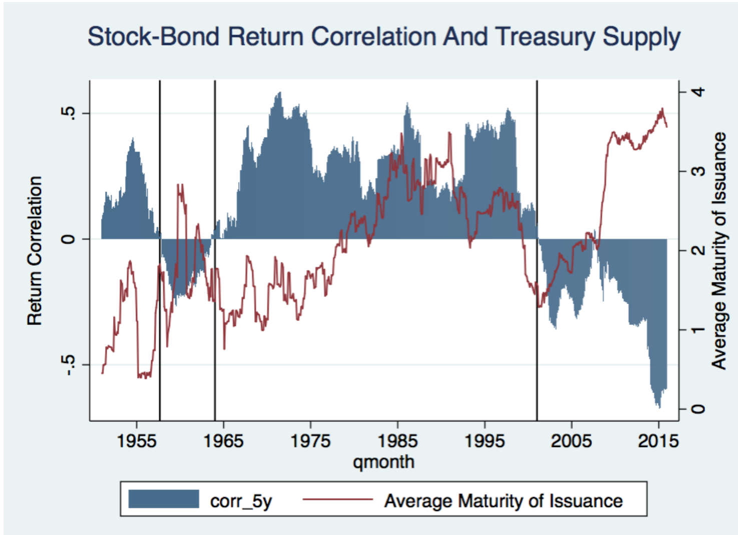


Note: I define five maturity bins: 0 to 1 year, 1 to 5 years, 5 to 10 years, 10 to 20 years and above 20 years. I describe the Treasury issuance portfolio by looking at the ratio of issuance in each maturity bin.

share of short term debt and smaller the weighted average maturity of issuance. Unless there is some kind of systematic "curvature" in issuance like short term debt is regularly issued in tandem with very long term debt as an alternative to medium term debt. In the appendix I do a principal component analysis of the maturity structure of issuance. About 52% of the all maturity structure choice is between maturity less than one year and above. The regression results appear to confirm this. While there is a conditional positive correlation between the term premium and WAM, there is similarly a conditional negative correlation between term premium and short share. When the share of short term debt goes from 0 to 100%, the term premium goes down by about 5 percent. Since the short share has a mean of 68% and a standard deviation of 12%, this represents an economically sizable effect.

The reason measures of maturity matter for term premium is that investors demand extra compensation for holding long term bonds. It would be therefore natural to test this hypothesis directly by regressing the term premium on the quantity of long term debt issued. Because the quantity of long term has a trend over decades, I normalize the quantity of new long term debt by nominal GDP. I define long term debt as Treasury having a maturity greater or equal to 5 years. If the term premium is compensation for holding long term bonds, we would expect positive coefficients on the long term debt quantity terms. Indeed that's what we find. For every percentage higher long term issuance as a share of

Figure A.2: Average Maturity of Issuance and the Stock-Bond Return Correlation: 1951-2016



The data comes from Global Financial Data. Both the stock and bond returns are monthly returns. The stock returns are total returns of the S&P 500 index and the bond returns are the holding period monthly returns computed from the 10 year Treasury Constant Maturity yields.

nominal GDP is associated with about 0.8 to 0.9 percent higher term premium.

$$LongQuant_t = \frac{\sum_{n\geq 5y} FVO_{i,t\leq s\leq t+12m}}{NGDP_t} \tag{A.19}$$

A.5 The Non-Market Drivers of the US Debt Issuance Policy

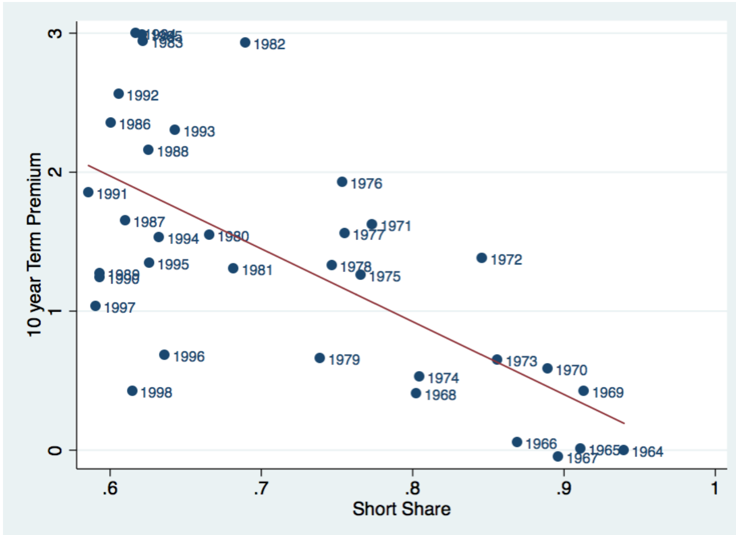
A.5.1 Overview

As seen in Figure 1.2, the portfolio has gone through significant evolution over the course of last century. Over time, the US federal government has taken on different levels of debt (measured as a share of GDP) and significantly different composition. In this paper, I am primarily focused on the maturity profile of the debt and am largely ignoring the policy choices such as callability and other option features[1] or indexation[2] Over time, the average maturity of government has significantly trended down while the absolute

[1]Until mid 1980s, the Treasury regularly issued callable bonds, which allows the Treasury to redeem the bond prior to maturity. This option feature apart from clearly having implications on the value of the debt, also means that the bond's effective maturity may be shorter than the stated value. Since the Treasury rarely actually exercised the call option on its debt, I have decided not to emphasize this particular feature.

[2]Treasury Inflation Protected Securities (TIPS), which are introduced in 1997, are offered in 5, 10 and 30 year maturities. The TIPS, which have grown significantly since inception, remain a small portion of the overall Treasury debt portfolio ($1.2 trillion out of $13.9 trillion marketable debt). While indexation affects the market value of the debt, it does not directly affect maturity of the debt.

Figure A.3: Short Share and Ten Year Term Premium



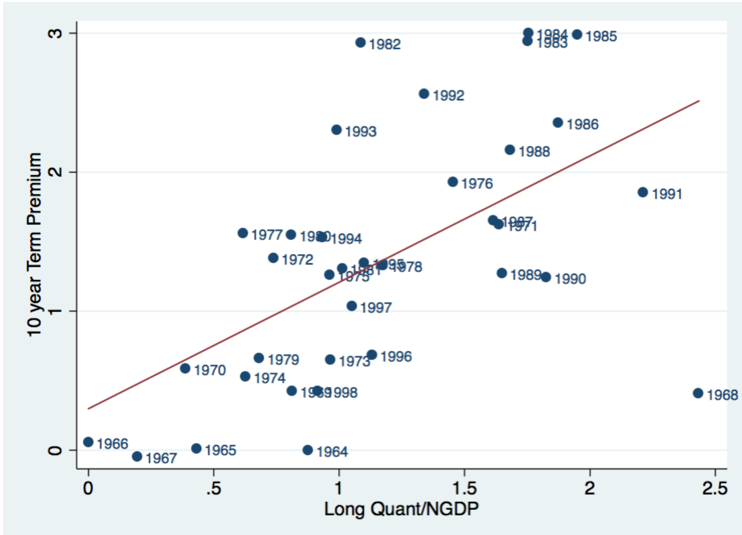
Short Share: 12 month ahead share of short term (maturity $\leq$ 1 year) debt; TP10: Current ten year term premium from Adrian, Crump and Moench (2013).

quantity of the debt has grown exponentially. There are distinctly two paradigms. Up until the end of world world two (or pre-war era henceforth), the US government debt was less regular or well-structured. It tends to consist mostly of one-off long term bonds to finance specific expenditures such as the war or the Panama canal project. Between 1917 and the end of world war two, Congress gradually delegated increasingly more borrowing power to the Treasury within the debt limit[3] Since the end of the war, the US Treasury debt management has gradually modernized and the portfolio too has stabilized. Because of the burgeoning and persistent borrowing need, the Treasury has come to increasingly rely on frequent auctions of short term debt[4]. Since the late 70s, the Treasury has also officially given up on tactical issuance and transitioned towards a policy of "regular and predictable", where the Treasury would conduct regular prescheduled auctions of debt securities, actively solicit market demand information and choreograph supply schedules. As can be seen in 1.2, the postwar Treasury debt portfolio tends to consist of substantially more short- and medium-term debt with relatively stable portfolio weights. Nevertheless there is still substantial and systematic variability in the debt portfolio over time. In fact, I will show that the debt issuance robustly responds to rollover risk and average maturity of the debt stock but not to market prices or expectation of market prices.

[3]While Congress has continued to set a limit or ceiling on the aggregate quantity of debt the Treasury can take on, it has also periodically raised that ceiling whenever it was about to be breached. Since 2001, the debt limit has been raised 15 times with intermittent political crisis threatening failure to raise the debt limit.

[4]Garbade, the Birth of a market

Figure A.4: Long Quant and Ten Year Term Premium



Long Quant: 12 month ahead sum of long term ($\geq$ 5 year) debt as a share of nominal GDP; TP10: Current ten year term premium from Adrian, Crump and Moench (2013).

A.5.2 Regression Analysis of Government Issuance Policy

I test the cost minimization model of debt management using predictive regressions. Specifically, I predict measures of Treasury issuance policy choice with contemporaneous variables. Because Treasuries of different maturities are auctioned on different schedules, in particular shorter maturity debt is auctioned more frequently than longer maturity debt, issuance policy stance can be only be accurately gauged from looking over a period of time. For this reason, a contemporaneous regression is not feasible: it's either regression on past or future information. I have chosen a predictive specification because I believe it best mimics the problem faced by policymakers at the US Treasury. This specification is equivalent to asking the Treasury officials to make a complete issuance schedule for the following year using current market and macro information. I begin by looking at weighted average maturity of new debt issues.

A.6 Alternative Measures of Maturity Structure

$$WAM_t = \frac{\sum_i^N FVO_{i,t\leq s\leq t+12m} \cdot \text{Maturity}_{i,t\leq s\leq t+12m}}{\sum_i^N FVO_{i,t\leq s\leq t+12m}} \tag{A.20}$$

Table A.2: Regression on MWI: Rolling Corr

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
MWI	1.348	2.385***	3.000***	3.083***	3.001***
	(0.910)	(0.753)	(0.512)	(0.502)	(0.523)
Stock-Bond Corr		1.908***	-1.205	-1.532	-1.396
		(0.585)	(0.969)	(1.079)	(1.133)
MWI x Corr			7.763***	6.788***	7.816***
			(1.857)	(2.034)	(1.870)
1Y Yield				0.081*	
				(0.044)	
Sign					0.107
					(0.368)
Constant	0.621**	0.153	0.075	-0.367	0.015
	(0.294)	(0.331)	(0.235)	(0.378)	(0.295)
Observations	655	655	655	655	655
Adjusted R-squared	0.07	0.35	0.50	0.53	0.50

Newey-West HAC standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TP5 is the 5 year statistical term premium from Adrian, Crump and Moench (2013); MWI is the maturity-weighted issuance to NGDP ratio; Stock-Bond Corr is the 5 Year moving correlation of month returns of the S&P 500 index and the 10 year Treasury bond index; 1Y Yield is the Treasury constant maturity 1 year nominal yield.

An alternative measure of maturity structure is looking at the share of short term debt in the total amount of debt issued in the following 12 months. I define short term debt as securities with a maturity less than a year.

$$ShortShare_t = \frac{\sum_{n\leq 1y} FVO_{i,t\leq s\leq t+12m}}{\sum_i FVO_{i,t\leq s\leq t+12m}} \tag{A.21}$$

Because the Treasury regularly rolls over maturing debts, new issuance is really a sum of maturing debt and new issuances financing new deficits. Since I am looking at issuances within a short horizon, most of the maturing debt will be either Treasury bills or highly illiquid long term bonds with very short time to maturity. Longer weighted average maturity of new issuances therefore also means greater amount of new long term bonds needs to be absorbed. The same goes for short term share.

I focus on the Treasury new issuances as measure of Treasury policy between 1951 and 2016. At the outset, because issuance maturity choice is highly multi-dimensional, it is not

Table A.3: 12-Month Overlapping Monthly Regressions: Short Share and Correlation

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
Short (0-1y) Share	-2.163*	-3.757***	-3.706***	-3.685***	-3.723***
	(1.233)	(0.837)	(0.719)	(0.672)	(0.748)
Stock-Bond Corr		2.026***	7.400***	6.188***	7.192***
		(0.544)	(1.823)	(2.080)	(1.837)
Short Share x Corr			-8.557***	-7.432**	-8.871***
			(2.877)	(3.143)	(3.017)
TCM 1Y				0.054	
				(0.044)	
Sign					0.261
					(0.326)
Constant	2.585***	3.573***	3.670***	3.376***	3.538***
	(0.938)	(0.601)	(0.530)	(0.543)	(0.559)
Observations	655	655	655	655	655
Adjusted R-squared	0.09	0.41	0.49	0.51	0.49

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). Short_sh is the sum (by face value) of securities with maturity less or equal to 1 year as a share of all new securities issued in the following 12 months. I express short share in decimals so that an increment of 1 is 100%. I have kept it in this somewhat awkward unit to make the coefficients more readily comparable to that of the sign of the stock-bond return correlation. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

clear which empirical measures should be used. For example, when the government wants to issue more net debt to finance a certain deficit, it could issue uniformly across maturities or let a certain amount of short term debt mature while issuing some long term debt or it could even let a certain amount of short term debt and maturing long term debt mature and issue a certain amount of medium term debt. In order to capture the dynamics of the vectors of portfolio weights, I apply a principal component analysis to the bond issuance. I divide up the issuance into five maturity bins: 0 to 1 year, 1 to 5 years, 5-10 years, 10-20 years and more than 20 years. I define the issuance shares on a monthly basis by the shares of new debt securities issued within a given maturity bin as a share of total amount

Table A.4: 12-Month Overlapping Monthly Regressions: Short Share and Sign of Correlation

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
Short Share	-1.836	-5.702***	0.084	-0.661	-0.422
	(1.247)	(1.048)	(1.143)	(1.300)	(1.008)
Short Share x Sign Dummy			-5.786***	-4.604***	-4.582***
			(1.542)	(1.743)	(1.129)
TCM 1 Year				0.063	0.036
				(0.048)	(0.031)
Sign of Stock-Bond Corr			4.884***	3.800***	3.896***
			(1.141)	(1.344)	(0.934)
Constant	2.329**	5.433***	0.549	0.876	0.803
	(0.947)	(0.859)	(0.745)	(0.781)	(0.579)
Observations	667	426	667	667	55
Adjusted R-squared	0.06	0.47	0.47	0.49	0.41

Newey-West HAC standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). Short_sh is the sum (by face value) of securities with maturity less or equal to 1 year as a share of all new securities issued in the following 12 months. I express short share in decimals so that an increment of 1 is 100%. I have kept it in this somewhat awkward unit to make the coefficients more readily comparable to that of the sign of the stock-bond return correlation. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

of debt issued in the next 12 months. I use 12 months[5] because that is a long enough of a time period for every maturity to have a chance to be issued. The results are displayed in figure A.7. The PCA results are not as easily interpretable as the PC analysis of the term structure of interest rates, where components can be readily interpreted as “level”, “slope” and “curvature”. Nevertheless, we can derive some significant insights. The first principal component (PC) explains about 52% of variations in the issuance vectors. There is a significant negative weight on 0-1 year and there are positive weights on all bins except the medium long term bin (10-20 years). I interpret this as saying that about 50% of the issuance policy is about trading off between very short term debt and long term debt. This can be roughly interpreted as a “slope” factor between short (0-1 year) and long term debt (>1 year) or a “level” factor for >1year debt. The second PC explains 21% of the issuance vectors. There are significant weights on 5-10 years and 10-20 years. I interpret this as a

[5] I vary this time span to 6 month and 24 months, which I include in the appendix. The results remain qualitatively unchanged.

Table A.5: 12-Month Overlapping Monthly Regressions: Short Share

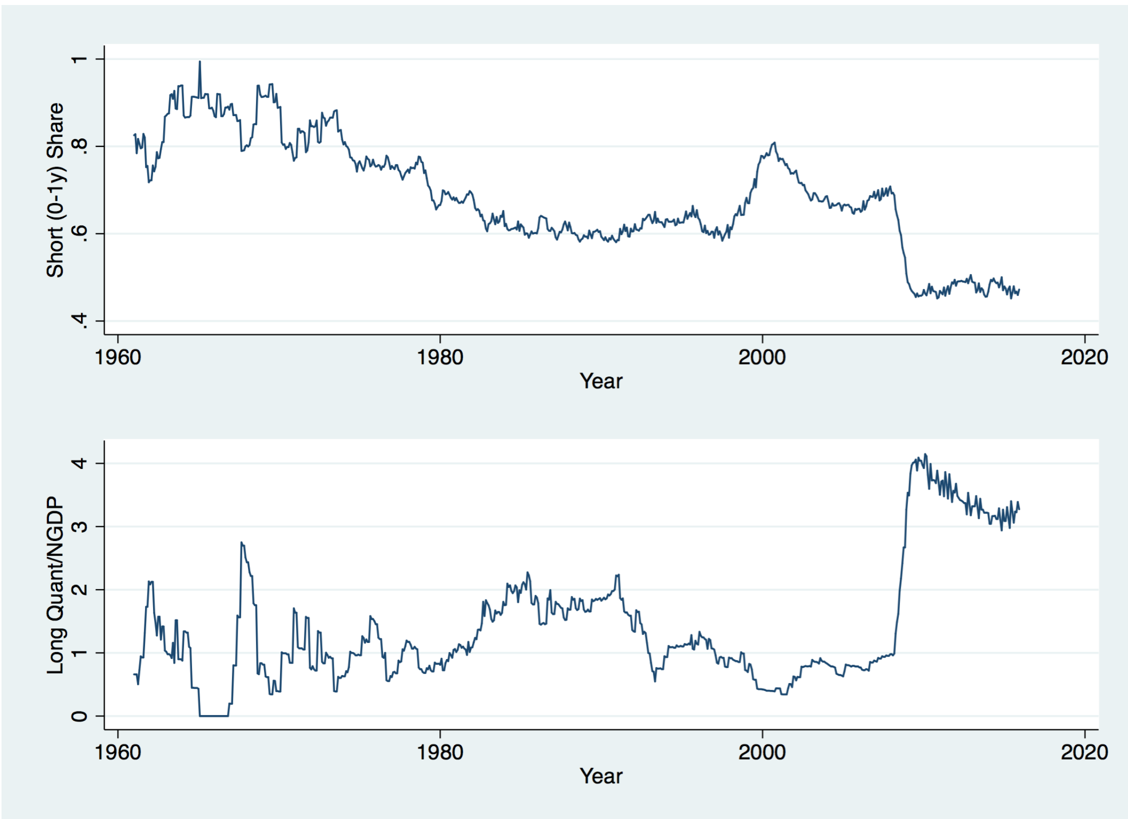
VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5	(6) TP5
(first) short_sh	-2.163*	-3.747***	-0.227	-1.226	-0.970	-0.811
	(1.233)	(0.794)	(1.098)	(1.646)	(1.256)	(0.955)
Short_sh x Stock-Bond Corr Sign			-5.475***	-3.975*	-4.303**	-4.194***
			(1.509)	(2.337)	(1.713)	(1.068)
Sign of Stock-Bond Corr			4.639***	3.100	3.569***	3.609***
			(1.116)	(1.990)	(1.323)	(0.890)
(first) corr_5y_nocrash		1.902***		0.980		
		(0.458)		(0.913)		
TCM 1 Year					0.062	0.036
					(0.049)	(0.031)
Constant	2.585***	3.557***	0.794	1.722	1.120	1.091**
	(0.938)	(0.574)	(0.704)	(1.212)	(0.738)	(0.532)
Observations	655	655	655	655	655	54
Adjusted R-squared	0.09	0.44	0.47	0.48	0.49	0.41

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). Short_sh is the sum (by face value) of securities with maturity less or equal to 1 year as a share of all new securities issued in the following 12 months. I express short share in decimals so that an increment of 1 is 100%. I have kept it in this somewhat awkward unit to make the coefficients more readily comparable to that of the sign of the stock-bond return correlation. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

trade-off between a choice between issuing intermediate versus the very long term debt. This can be interpreted roughly as a slope factor within the long (>1 year) debt. The third PC explains 15% of the variations and has negative weights on 1-5year and >20year bins and positive weights on 5-10year and 10-20year bins. The trade-off here is between very short/ultra-long term debt and the intermediate/long-term debt. This factor resembles a "curvature" factor for the long term (>1 year) debt where the Treasury could try to push (or do the opposite) maturity towards the center (5-20) by issuing more in the middle and less on the "edges" (1-5 and >20). The three factors taken together suggest that the Treasury apart from deciding how much very short term debt (bills) to issue also tries to manipulate the issuance patterns to achieve a certain maturity target. This exercise confirms that it is reasonable to capture the Treasury's debt policy by either looking at short debt shares or the average maturity of debt issuance and potentially the higher order moments such as the variance of issuance maturities.

Figure A.5: Plots of Short Share and Long Quant



The short share is the share of the new issuances with maturity less or equal to 1 year to the total amount of new issuances in the next 12 months. The long_quant is the ratio between the total face value of long term debt with maturity greater than 5 years as a share of the nominal GDP.

Table A.6: 12-Month Overlapping Monthly Regressions: Long Quant and Correlation

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
Long_quant	0.083	0.278**	0.585***	0.587***	0.590***
	(0.148)	(0.139)	(0.119)	(0.113)	(0.125)
Stock-Bond Corr		1.768***	-0.872	-1.276	-1.258
		(0.624)	(0.851)	(0.901)	(1.214)
Long_quant x Corr			1.709***	1.542***	1.740***
			(0.424)	(0.423)	(0.442)
TCM 1Y				0.076	
				(0.047)	
Sign of Corr					0.215
					(0.457)
Constant	0.986***	0.619**	0.370**	-0.024	0.244
	(0.242)	(0.274)	(0.188)	(0.357)	(0.308)
Observations	655	655	655	655	655
Adjusted R-squared	0.01	0.24	0.41	0.44	0.41

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). Long_quant is the sum of securities with maturity greater than 5 year as a share of nominal GDP. I express long_quant in percents. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

Table A.7: 12-Month Overlapping Monthly Regressions: Long Quant and Sign of Correlation

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
Long_quant	0.046	0.954***	-0.037	0.065	0.061
	(0.147)	(0.264)	(0.129)	(0.157)	(0.105)
Long_quant x Sign Dummy			0.991***	0.806***	0.804***
			(0.294)	(0.297)	(0.190)
TCM 1 Year				0.084	0.064
				(0.054)	(0.053)
Sign of Stock-Bond Corr			-0.449	-0.567	-0.453***
			(0.382)	(0.398)	(0.149)
Constant	1.014***	0.227	0.676**	0.300	0.365
	(0.243)	(0.263)	(0.284)	(0.445)	(0.378)
Observations	665	426	665	665	55
Adjusted R-squared	0.00	0.32	0.37	0.41	0.35

Newey-West HAC standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). Long_quant is the sum of securities with maturity greater than 5 year as a share of nominal GDP. I express long_quant in percents. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

Table A.8: 12-Month Overlapping Monthly Regressions: WAM of Issuance and Correlation

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
WAM	0.360	0.505***	0.530***	0.525***	0.529***
	(0.227)	(0.182)	(0.127)	(0.124)	(0.132)
Stock-Bond Corr		1.697***	-2.325*	-2.422*	-2.807**
		(0.561)	(1.191)	(1.267)	(1.412)
WAM x Corr			1.584***	1.438***	1.630***
			(0.406)	(0.444)	(0.413)
TCM 1Y				0.050	
				(0.050)	
Sign					0.233
					(0.383)
Constant	0.286	-0.132	-0.094	-0.336	-0.223
	(0.460)	(0.460)	(0.324)	(0.434)	(0.345)
Observations	655	655	655	655	655
Adjusted R-squared	0.08	0.33	0.45	0.47	0.46

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). WAM is the average maturity (weighted by face value) of the new securities issued in the following 12 months with units in years. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

Table A.9: 12-Month Overlapping Monthly Regressions: WAM of Issuance and Sign of Correlatioin

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5
WAM	0.303	0.931***	-0.154	-0.059	-0.110
	(0.230)	(0.192)	(0.184)	(0.228)	(0.158)
WAM x Sign Dummy			1.085***	0.927***	0.932***
			(0.265)	(0.304)	(0.164)
TCM 1 Year				0.053	0.023
				(0.053)	(0.039)
Sign of Stock-Bond Corr			-1.656***	-1.541**	-1.421***
			(0.598)	(0.635)	(0.315)
Constant	0.383	-0.671*	0.985**	0.634	0.841*
	(0.465)	(0.373)	(0.482)	(0.677)	(0.508)
Observations	667	426	667	667	55
Adjusted R-squared	0.06	0.43	0.45	0.46	0.38

Newey-West HAC standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (5) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). WAM is the average maturity (weighted by face value) of the new securities issued in the following 12 months with units in years. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

Table A.10: 12-Month Overlapping Monthly Regressions: WAM of Issuance

VARIABLES	(1) TP5	(2) TP5	(3) TP5	(4) TP5	(5) TP5	(6) TP5
WAM	0.360	0.495***	-0.109	-0.050	-0.015	-0.047
	(0.227)	(0.177)	(0.183)	(0.254)	(0.229)	(0.160)
WAM x Sign Dummy			1.040***	0.943***	0.884***	0.868***
			(0.264)	(0.356)	(0.305)	(0.160)
Sign			-1.592***	-1.605***	-1.473**	-1.303***
			(0.604)	(0.613)	(0.643)	(0.315)
Corr		1.596***		0.429		
		(0.469)		(0.802)		
TCM 1 Year					0.052	0.024
					(0.054)	(0.038)
Constant	0.286	-0.116	0.921*	0.907*	0.572	0.721
	(0.460)	(0.444)	(0.490)	(0.530)	(0.692)	(0.519)
Observations	655	655	655	655	655	54
Adjusted R-squared	0.08	0.35	0.44	0.44	0.45	0.37

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The data ranges between 1961 and 2015. Column 1-4 are overlapping monthly regressions. Column (6) is nonoverlapping annual regressions. The dependent variable is the five year zero coupon term premium from Adrian, Crump and Moench (2013). WAM is the average maturity (weighted by face value) of the new securities issued in the following 12 months with units in years. The sign of the stock-bond return correlation is derived from the 5 year returns correlations. It takes the value of 1 if the correlation is positive. This corresponds to roughly between 1965-2000. TCM 1 year is the Treasury constant maturity 1 year yield from the Federal Reserve.

Table A.11: Quarterly Issuance Regressions: 1961Q1-2015Q4 Using 2 Year Correlation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES		Short (0-1y) Share				Average Maturity of Issuance		
10Y Term Premium	-0.038	-0.048***	-0.062***	-0.062***	0.207	0.251**	0.303***	0.304***
	(0.024)	(0.018)	(0.017)	(0.018)	(0.132)	(0.114)	(0.113)	(0.113)
TCM 1 Year			0.014*	0.014*			-0.051	-0.051
			(0.007)	(0.007)			(0.046)	(0.046)
Sign of Stock-Bond Corr		0.130***	0.072*	0.072*		-0.588**	-0.375	-0.375
		(0.044)	(0.043)	(0.043)		(0.276)	(0.281)	(0.281)
Tax Season Dummy				0.030***				-0.265***
				(0.011)				(0.091)
Constant	0.755***	0.679***	0.671***	0.656***	1.879***	2.225***	2.257***	2.389***
	(0.052)	(0.050)	(0.047)	(0.048)	(0.286)	(0.309)	(0.305)	(0.308)
Observations	218	218	218	218	218	218	218	218
Adjusted R-squared	0.10	0.27	0.32	0.33	0.07	0.16	0.18	0.19

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

LHS variables are respectively one quarter forward the share of short term debt (maturity 1 year or less) and the face value weighted average maturity of new debt issued. The regressors are contemporaneous observations. Ten year term premium is from Adrian, Crump and Moench (2013). Treasury constant maturity 1 year interest rate is used to proxy for the level of nominal interest rate. The sign of stock and bond returns is taken from the sign of the 5 year moving average correlation between monthly stock returns and monthly bond returns. The tax season dummy is one for the second and fourth quarters, when personal and corporate income tax receipts come into the Treasury.

Table A.12: Quarterly Regressions of Issuance Maturity: 1961Q1-2015Q4 Using 5 Year Correlation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES		Short (0-1y) Share				Average Maturity of Issuance		
10Y Term Premium	-0.038	-0.055***	-0.063***	-0.064***	0.207	0.275**	0.315***	0.316***
	(0.024)	(0.019)	(0.017)	(0.017)	(0.132)	(0.119)	(0.113)	(0.113)
TCM 1 Year			0.010	0.011			-0.049	-0.050
			(0.008)	(0.008)			(0.052)	(0.052)
Sign of Stock-Bond Corr		0.150***	0.102*	0.102*		-0.594*	-0.371	-0.365
		(0.051)	(0.058)	(0.058)		(0.322)	(0.377)	(0.377)
Tax Season Dummy				0.029***				-0.262***
				(0.011)				(0.091)
Constant	0.755***	0.680***	0.671***	0.657***	1.879***	2.181***	2.220***	2.349***
	(0.052)	(0.049)	(0.047)	(0.047)	(0.286)	(0.308)	(0.304)	(0.306)
Observations	218	218	218	218	218	218	218	218
Adjusted R-squared	0.10	0.32	0.34	0.35	0.07	0.16	0.17	0.19

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

LHS variables are respectively one quarter forward the share of short term debt (maturity 1 year or less) and the face value weighted average maturity of new debt issued. The regressors are contemporaneous observations. Ten year term premium is from Adrian, Crump and Moench (2013). Treasury constant maturity 1 year interest rate is used to proxy for the level of nominal interest rate. The sign of stock and bond returns is taken from the sign of the 5 year moving average correlation between monthly stock returns and monthly bond returns. The tax season dummy is one for the second and fourth quarters, when personal and corporate income tax receipts come into the Treasury.

Table A.13: Monthly and Annual Regressions of Issuance Maturity Measures: 1961 Jan-2015 Dec Using 5 Year Correlation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Short (0-1y) Share				Average Maturity of Issuance			
	Monthly Overlapping			Annual	Monthly Overlapping			Annual
10Y Term Premium	-0.037**	-0.056***	-0.064***	-0.056***	0.201*	0.278***	0.316***	0.281***
	(0.018)	(0.015)	(0.015)	(0.012)	(0.105)	(0.097)	(0.097)	(0.078)
TCM 1 Year			0.010				-0.046	
			(0.007)				(0.045)	
Sign of Stock-Bond Corr		0.151***	0.106**	0.153***		-0.640**	-0.432	-0.643***
		(0.040)	(0.048)	(0.031)		(0.256)	(0.316)	(0.198)
Constant	0.748***	0.674***	0.665***	0.674***	1.931***	2.245***	2.285***	2.231***
	(0.039)	(0.037)	(0.036)	(0.029)	(0.221)	(0.236)	(0.238)	(0.183)
Observations	655	655	655	54	655	655	655	54
Adjusted R-squared	0.12	0.40	0.43	0.39	0.10	0.25	0.27	0.23

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

LHS variables are respectively 12 months forward the share of short term debt (maturity 1 year or less) and the face value weighted average maturity of new debt issued. Column 4 and column 8 are non-overlapping annual regressions using fiscal years (Oct). Results are not qualitatively similar to using calendar years. The regressors are contemporaneous observations. Ten year term premium is from Adrian, Crump and Moench (2013). Treasury constant maturity 1 year interest rate is used to proxy for the level of nominal interest rate. The sign of stock and bond returns is taken from the sign of the 5 year moving average correlation between monthly stock returns and monthly bond returns.

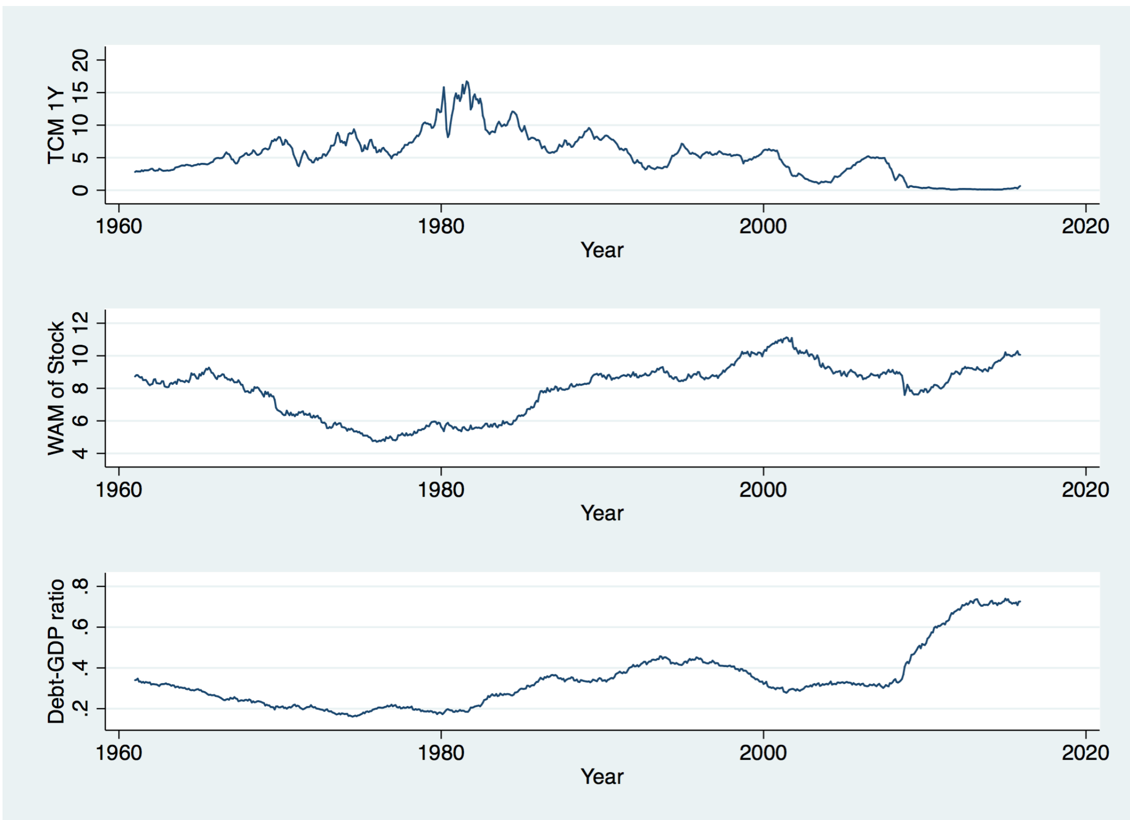
Table A.14: Predictive Regression of WAM of Issuance: 1951-2016, Face Value of Debt Stock

	(1)	(2)	(3)	(4)
	Year 1951-2016	Year 1951-1983	Year 1983-2016	Year 1951-2016 Non-OL
VARIABLES	WAM of Issuance	WAM of Issuance	WAM of Issuance	WAM of Issuance
TCM 1 Year	0.394***	0.290***	0.217**	0.386***
	(0.095)	(0.094)	(0.088)	(0.086)
DGDP	0.869***	1.025***	0.609***	0.863***
	(0.088)	(0.279)	(0.071)	(0.078)
WAM Stock	-0.246***	-0.470***	-0.437***	-0.247***
	(0.094)	(0.136)	(0.091)	(0.083)
Constant	2.152***	1.962***	2.498***	2.153***
	(0.068)	(0.137)	(0.067)	(0.058)
Observations	759	369	402	63
Adjusted R-squared	0.69	0.46	0.80	0.66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

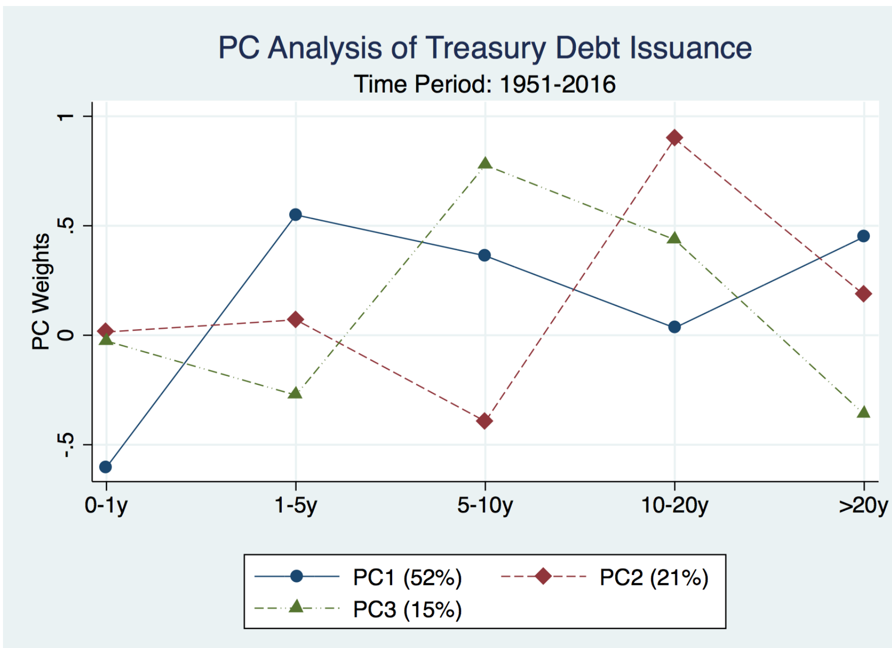
The baseline regressions (column 1-3) are overlapping monthly predictive regressions. The dependent variable is the weighted average maturity of debt issued in the following 12 months. The independent variables are the current nominal interest rate (Treasury constant maturity 1 year), standardized marketable debt (face value) to GDP ratio, standardized weighted average maturity of all outstanding debt. Because overlapping regressions induce autocorrelation, I use Newey-West HAC standard errors. As a further check, I run a non-overlapping annual regression. There are 12 ways of running an annual regression. I display here the results from using fiscal year or Oct to Oct. Results from using calendar year are very similar.

Figure A.6: Plots of Ancillary Time Series Variables



TCM1Y is the one year Treasury constant maturity yield estimated by the Federal Reserve; WAM_Stock is the weighted average maturity of the stock of marketable debt outstanding; the debt to GDP ratio is the ratio between the total face va value of the marketable debt and the nominal GDP.

Figure A.7: Principal Components of US Treasury Debt Portfolio



I describe the Treasury debt issuance by first dividing new issues into five bins by maturity: 0 to 1 year, 1 to 5 years, 5 to 10 years, 10 to 20 years and above 20 years. I then calculate the quantity issued in each bin as a share of the total quantity issued in the previous 12 months. The first three principal components summarize about 90% of the portfolio variability. The first component (52% of issuance movements) consists of a choice between very short term debt and medium or long term debt. The second component (21%) consists of a choice between medium term (5-20 year) debt and short- or ultra-long term debt.

APPENDIX B

Chapter II Supporting Material

B.1 Data Treatment

B.1.1 Mistakes and Missing Entries

The CRSP database contains, especially between 1955 and 1960, numerous instances of errors, missing entries and other mistakes. I manually verify the CRSP datasets against the MSPD records and manually correct any mistakes or missing entries. Furthermore, I extend the CRSP Treasury database forward to 1919 by manually inputting the quantity and other issue information of marketable Treasury securities from the MSPD. Old bond prices prior to the start of the CRSP database or missing from the it are obtained from the archival records of the *Wall Street Journal*.

The issuance dates are missing for many short-term securities such as Treasury bills, tax-anticipation or cash-management bills. I recover the issuance dates by subtracting duration (in days) from the maturity date wherever possible. And when the duration is missing, I use the first quotation date in which the security appears.

The CRSP database/MSPD have some quirky data recording methodology. Because the MSPD report is recorded at the end of each month, sometimes a new security issued at the beginning of the next month is recorded in the previous month with a quantity of zero. There are other times, when a security is mysteriously dropped a month before its maturing month. I manually correct these.

B.1.2 Reopening Identification

In a security reopening, the Treasury issues additional amounts of of a previously issued, typically long maturity, security. The reopening has the same maturity date and coupon rate as that of the original security. Securities are sometimes reopened because the

Treasury wants to add to some recently issued ultra-long-maturity securities and sometimes to support the market liquidity of these securities. Either way, reopenings reflect the Treasury's issuance decisions and should be properly identified. Because reopenings are not separately reported in the database, I detail how I identify them here.

Because I do not have complete record of when the Treasury has done how much reopenings, I must infer it from the history of quantity outstanding. If a security is not reopened, the quantity outstanding should stay constant over the entire lifetime of a bond. In other words, if quantity outstanding increases significantly during the course of a bond's lifetime, it must be due to reopening. I identify a reopening whenever the quantity outstanding in a given period is more than 10% greater than the previous period. In practice, I find that most of the increments are much bigger than 10%. I identify reopenings as new individual securities. Sometimes, a single security has multiple reopenings and each is a separate security as well. I checked that of the reopenings for which there is record since 2002, the identified reopened securities have a match rate of about 99%.

B.2 Empirical Analysis

B.2.1 VAR Analysis of Issuance Maturity

In this section I explain in detail the setup of the VAR model behind Figure (2.7). The goal of the model is to estimate the dynamic response of the issuance maturity to the two sources of funding needs, i.e., maturing debt-GDP ratio and the deficit-GDP ratio. In the baseline, let

$$y_t = \begin{bmatrix} (\text{MLD/GDP})_t \\ (\text{Def/GDP})_t \\ \text{WAM}_t \end{bmatrix} \tag{B.1}$$

denote the time t value of the three variables: maturing debt to GDP ratio, deficit to GDP ratio and the weighted average maturity of issuance. The VAR model can be stated as follows.

$$A\left(I_3 - A_1 L - A_2 L^2 - \cdots - A_p L^p\right) y_t = A\varepsilon_t = Be_t \tag{B.2}$$

where L is the lag operator and p is the number of lags. in the baseline, I assume $p = 2$ or a lag order of 2. A, B, and $A_1, \ldots, A_p$ are 3×3 matrices of parameters. ε_t is a 3×1 vector of innovations with $\varepsilon_t \sim N(\mathbf{0}, \Sigma)$ and $E\left[\varepsilon_t \varepsilon_s^{'}\right] = \mathbf{0}_3$ for all $s \neq t$. e_t is a 3×1 vector of orthogonalized disturbances, that is $e_t \sim N(\mathbf{0}, \mathbf{I}_3)$ and $E\left[e_t e_s^{'}\right] = \mathbf{0}_3$ for all $s \neq t$.

I obtain identification by imposing Cholesky restrictions on the VAR system by applying equality constraints with the constraint matrices $\mathbf{A}$ and $\mathbf{B}$ defined as follows.

$$A = \begin{bmatrix} 1 & 0 & 0 \\ \cdot & 1 & 0 \\ \cdot & \cdot & 0 \end{bmatrix}, \; B = \begin{bmatrix} \cdot & 0 & 0 \\ 0 & \cdot & 0 \\ 0 & 0 & \cdot \end{bmatrix} \tag{B.3}$$

In the baseline, these structural restrictions represent the assumption that 1) the maturing debt/GDP ratio does not respond contemporaneously to either the deficit/GDP ratio or the weighted average maturity of issuance; 2) the deficit/GDP ratio may respond to the maturing debt/GDP ratio but does not respond contemporaneously to the weighted average maturity of issuance; and 3) the weighted average maturity of issuance may respond contemporaneously to both the maturing debt/GDP ratio and the deficit/GDP ratio. The responses of the weighted average maturity of issuance are reported in Figure (2.7) and the variables' dynamic responses to own shocks are reported below in Figure (B.1).

I conduct a couple robustness checks of the VAR results. First, because the ordering of the first two variables is admittedly somewhat arbitrary, I consider two separate models: model a has the baseline ordering and model b swaps the ordering of the first two variables. Specifically,

$$y_t^A = \begin{bmatrix} (\text{MLD/GDP})_t \\ (\text{Def/GDP})_t \\ \text{WAM}_t \end{bmatrix}, \; y_t^B = \begin{bmatrix} (\text{Def/GDP})_t \\ (\text{MLD/GDP})_t \\ \text{WAM}_t \end{bmatrix} \tag{B.4}$$

The results are presented in the first two columns of Figure (B.2). There is no visible difference from using either ordering. Secondly, in the baseline the VAR model is estimated with 2 lags. Given the autocorrelation structure or persistence in the WAM and the deficit variables, I reestimate the model using 4 lags. The results are presented in the third column of Figure (B.2), denoted as model C.

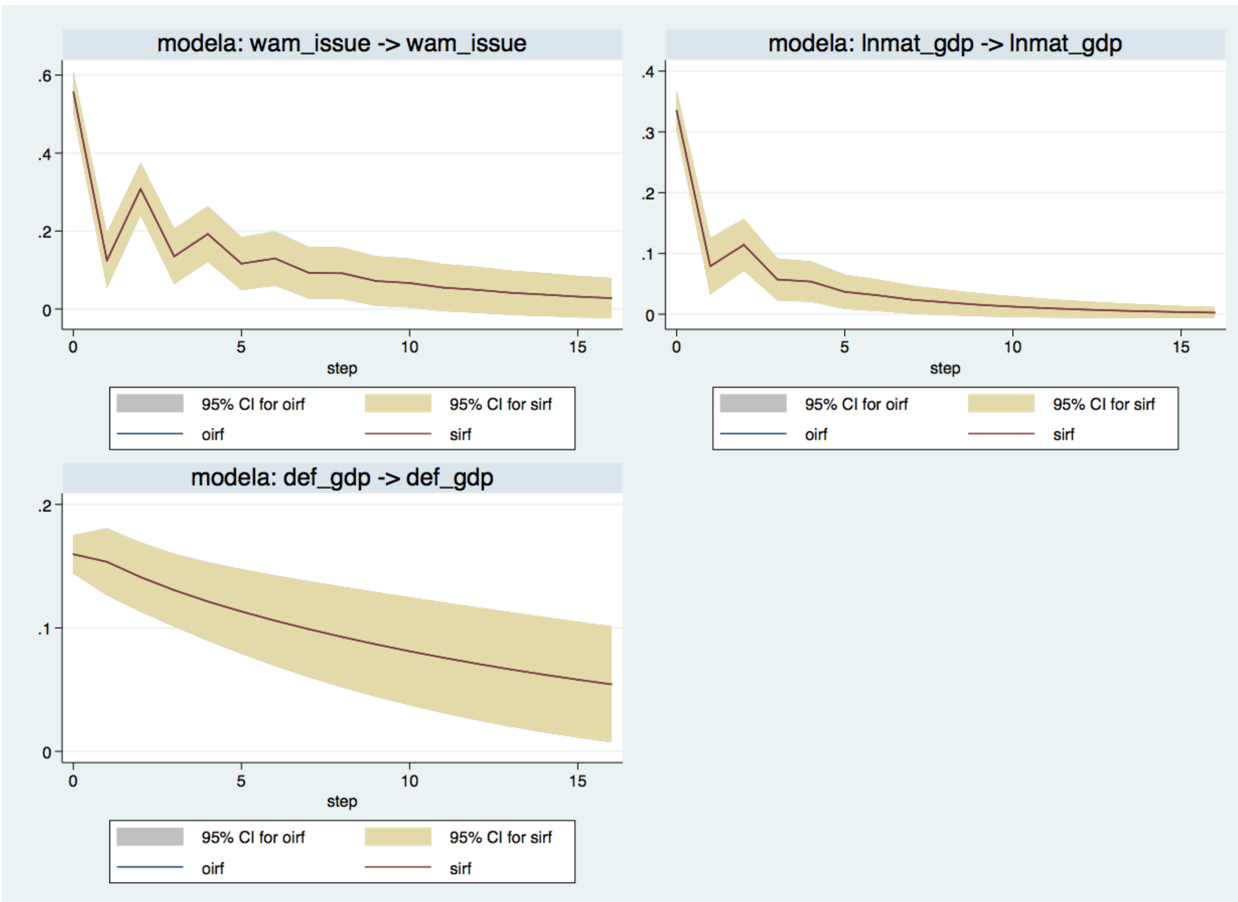
B.3 Mathematical Appendix

B.3.1 Solution of The Model

1. The risk-neutral case.

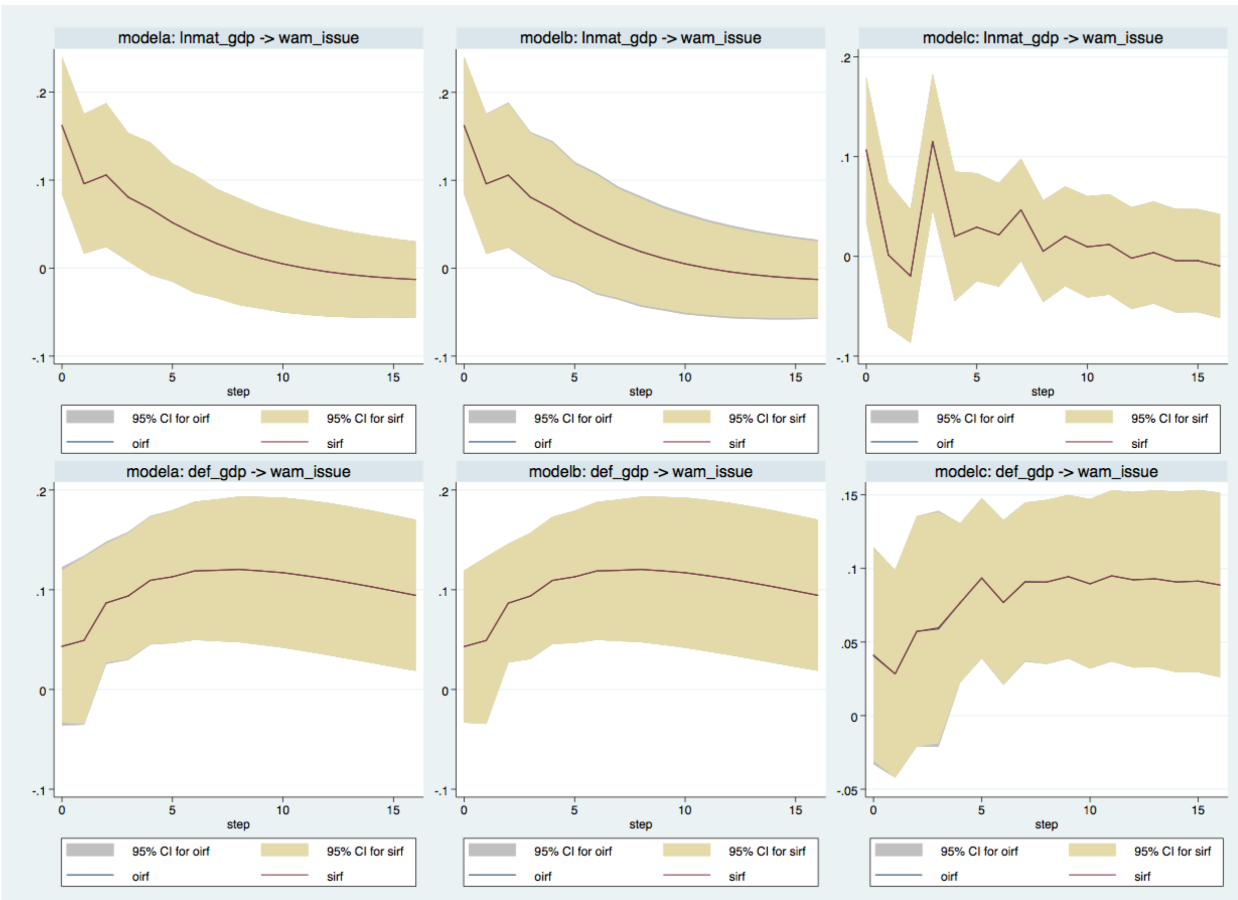
   If $\gamma = 0$, as $\bar{y}_1 < \bar{y}_2$ and $0 < \psi < 1$, cost of short-term borrowing is strictly lower. then

Figure B.1: Impulse Responses to Own Shocks



This set of figures show the impulse responses of the three variables to their own shocks. Each step is a quarter.

Figure B.2: Robust Checks of the VAR Results



This set of figures show the results from a couple robustness checks. The first two columns show the impulse responses of the weighted average maturity of issuance to shocks to maturing debt/GDP and to deficit/GDP shocks in two different model specifications. The first column depicts the results from model A ordering and the second column depicts results from model B ordering. There is no visible difference between the two models. The third column shows the results of from using 4 lags instead of the baseline 2 lags as in model A in the first column. Each step is a quarter.

$s^* \equiv 1$.

2. The "perfectly elastic demand" case.

   If $\gamma > 0$ and $\bar{L} \equiv \infty$ or if $1 - s < \ell$, then $\phi_2(s) \equiv 0$. So the objective function becomes

$$\min_s s(\bar{y}_1 - h(\delta)) + (1-s)(\bar{y}_2 - \psi h(\delta)) + \gamma d \frac{(s-a)^2}{2} \cdot \mathbf{1}\{s > a\} \tag{B.5}$$

   where

$$y_1 = \bar{y}_1 - h(\delta) \tag{B.6}$$

$$y_2 = \bar{y}_2 - \psi h(\delta), \ \psi \in (0,1) \tag{B.7}$$

   Note that the $s^* \geq a$. This is because if $s^* < a$, interest rate costs can be reduced by borrowing more short term debt without incurring any rollover risk disutility. If $s^* \geq a$, (issue more short-term debt at the expense of greater roll-over risk) the objective function is

$$V_2 = s(\bar{y}_1 - h(\delta)) + (1-s)(\bar{y}_2 - \psi h(\delta)) + \gamma d \frac{(s-a)^2}{2} \tag{B.8}$$

   And the optimal amount of short term debt is

$$s^* = \frac{(\bar{y}_2 - \psi h(\delta)) - (\bar{y}_1 - h(\delta))}{\gamma d} + a \tag{B.9}$$

3. The downward-sloping demand case.

   In this case $\bar{L} < D < \infty$. Assume further that $0 < a < 1 - \ell$. So in this case, the demand curve for long-term bonds is downward-sloping.

$$\min_s s y_1 + (1-s) y_2 + \gamma d \frac{(s-a)^2}{2} \tag{B.10}$$

$$y_1 = \bar{y}_1 - h(\delta) \tag{B.11}$$

$$y_2 = \bar{y}_2 + \phi_2(1 - s - \ell) \cdot \mathbf{1}\{1 - s > \ell\} \cdot d - \psi h(\delta) \tag{B.12}$$

   The downward-sloping demand curve only kicks in if we issue more than $1 - s > \ell$ amount of long-term debt or less than $s < 1 - \ell$ amount of short-term debt. Therefore the following has to hold for the downward-sloping demand curves to matter.

$$\ell < 1 - a - \frac{(\bar{y}_2 - \bar{y}_1) + h(\delta)(1-\psi)}{\gamma d} \tag{B.13}$$

If the long-term debt trigger is too high, it wouldn't bind. The downward-sloping demand curve binds only if sufficiently small. Therefore, assume the above is true, so the new objective function is

$$s\left(\bar{y}_1 - h\left(\delta\right)\right) + \left(1-s\right)\left(\bar{y}_2 + \phi_2\left(1-s-\ell\right)d - \psi h\left(\delta\right)\right) + \gamma d\frac{\left(s-a\right)^2}{2} \tag{B.14}$$

And the solution then becomes

$$s^* = \frac{\left(\bar{y}_2 - \psi h\left(\delta\right)\right) - \left(\bar{y}_1 - h\left(\delta\right)\right)}{\left(2\phi_2 d + \gamma d\right)} + \frac{\phi_2\left(1-\ell\right) + \phi_2 + \gamma a}{\left(2\phi_2 + \gamma\right)} \tag{B.15}$$

When $\phi_2 = 0$, s^* reduces to the perfectly elastic case. Let's quickly verify that this is indeed bigger than the short-term debt share under the perfectly elastic demand case.

$$\frac{\left(\bar{y}_2 - \psi h\left(\delta\right)\right) - \left(\bar{y}_1 - h\left(\delta\right)\right)}{\left(2\phi_2 d + \gamma d\right)} + \frac{\phi_2\left(1-\ell\right) + \phi_2 + \gamma a}{\left(2\phi_2 + \gamma\right)} > \frac{\left(\bar{y}_2 - \psi h\left(\delta\right)\right) - \left(\bar{y}_1 - h\left(\delta\right)\right)}{\gamma d} + a \tag{B.16}$$

$$\iff \ell < 2\left(1 - a - \frac{\left(\bar{y}_2 - \psi h\left(\delta\right)\right) - \left(\bar{y}_1 - h\left(\delta\right)\right)}{\gamma d}\right) \tag{B.17}$$

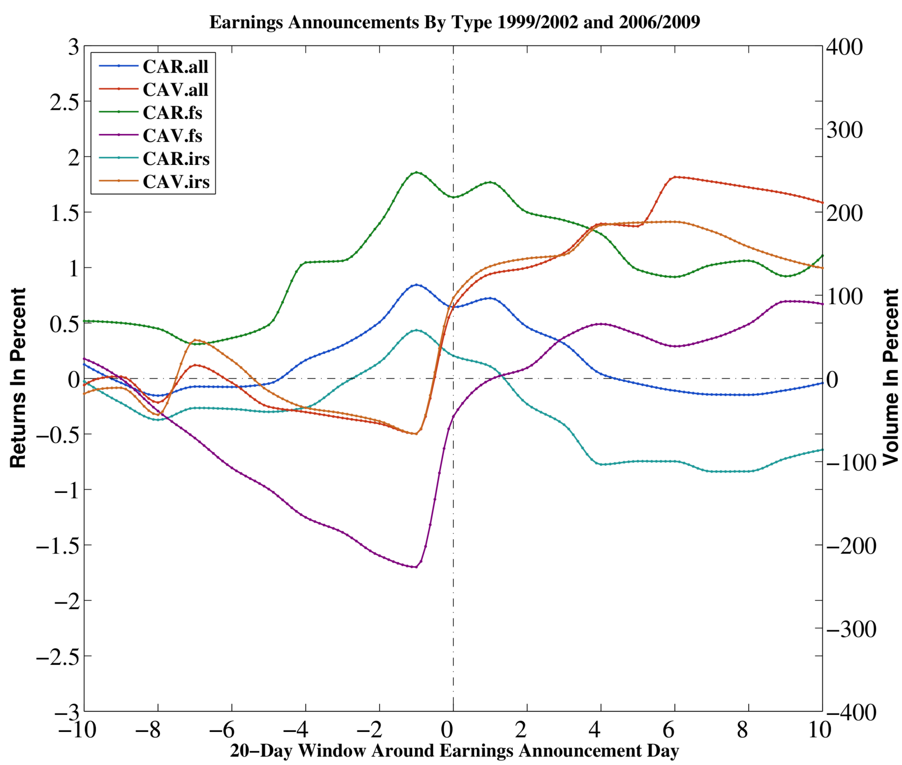
which is indeed the case.

APPENDIX C

Chapter III Supporting Material

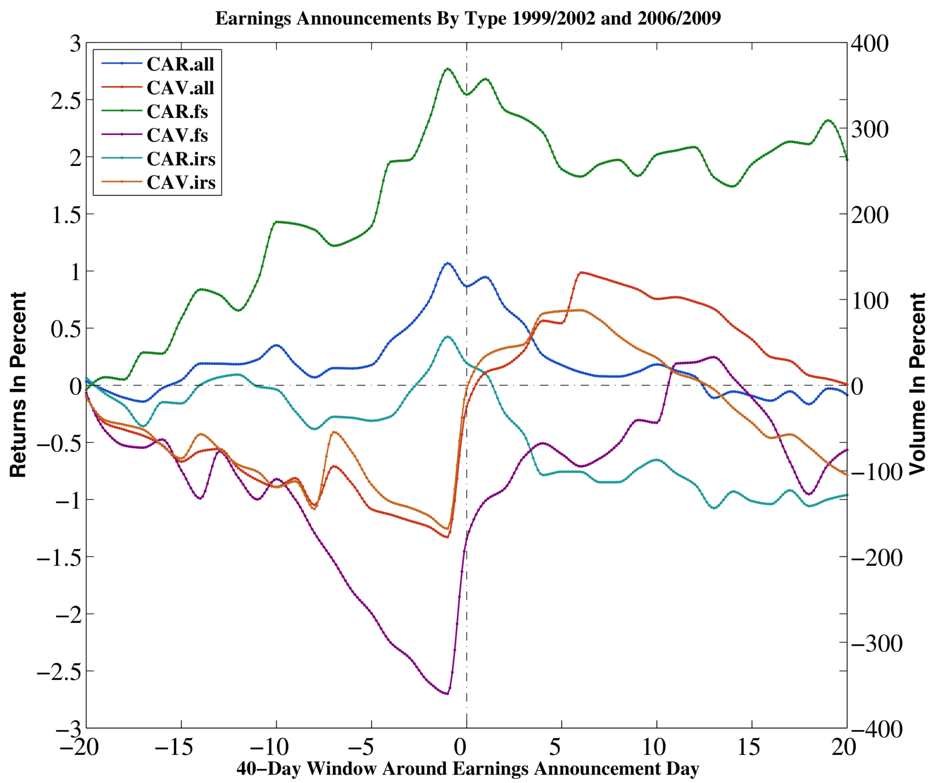
C.1 Figures

Figure C.1: Average CAR and CAV Around Earnings Announcements By Announcement Types



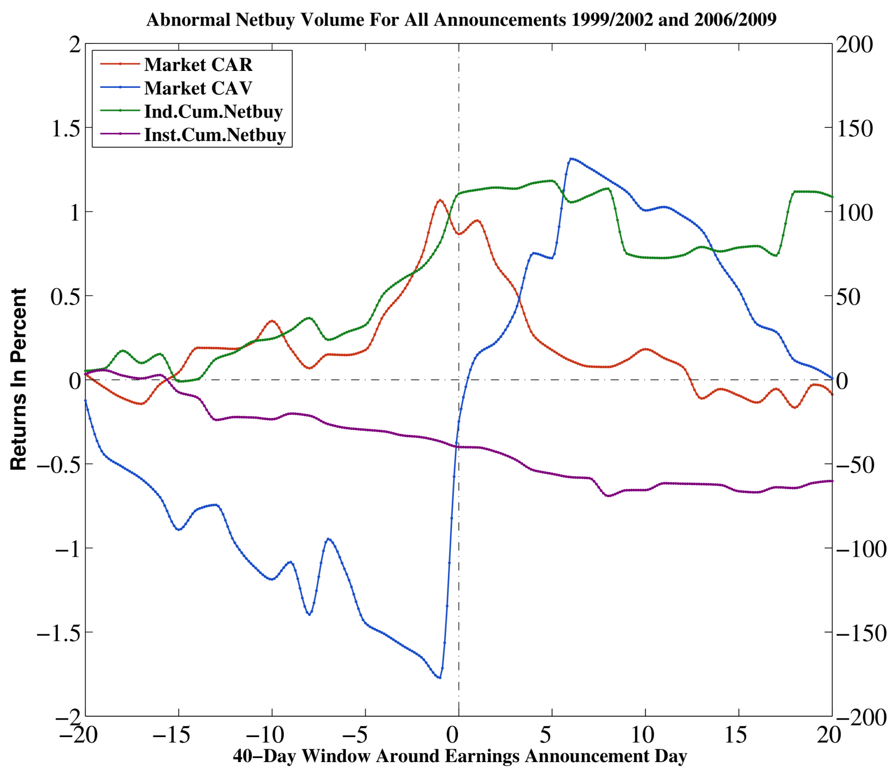
This figure shows the cumulative abnormal returns and cumulative abnormal volume by different types of earnings announcements in a 20-day window. As mentioned in section (3.3.1), in Finland each stock has four main earnings announcements in a year. One (annual) financial statement release and three (quarterly) interim earnings reports. CAR.all and CAV.all repeat the unconditional premium and volume as in Figure (3.1). CAR.fs and CAV.fs represent the return and volume averaged over only financial statement events. CAR.irs and CAV.irs represent the return and volume averaged over only interim report events. Volume and return are in percent.

Figure C.2: Average CAR and CAV Around Earnings Announcements By Announcement Types



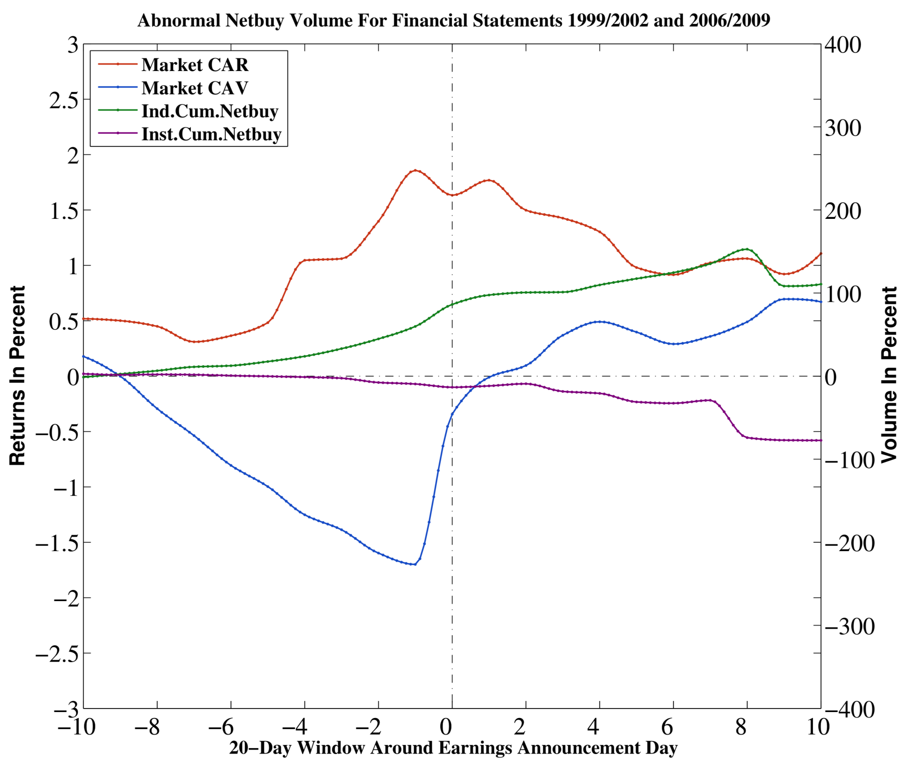
This figure shows the cumulative abnormal returns and cumulative abnormal volume by different types of earnings announcements in a 40-day window. As mentioned in section (3.3.1), in Finland each stock has four main earnings announcements in a year. One (annual) financial statement release and three (quarterly) interim earnings reports. CAR.all and CAV.all repeat the unconditional premium and volume as in Figure (3.1). CAR.fs and CAV.fs represent the return and volume averaged over only financial statement events. CAR.irs and CAV.irs represent the return and volume averaged over only interim report events. Volume and return are in percent.

Figure C.3: Average CAR and CAV Around Earnings Announcements By Announcement Types



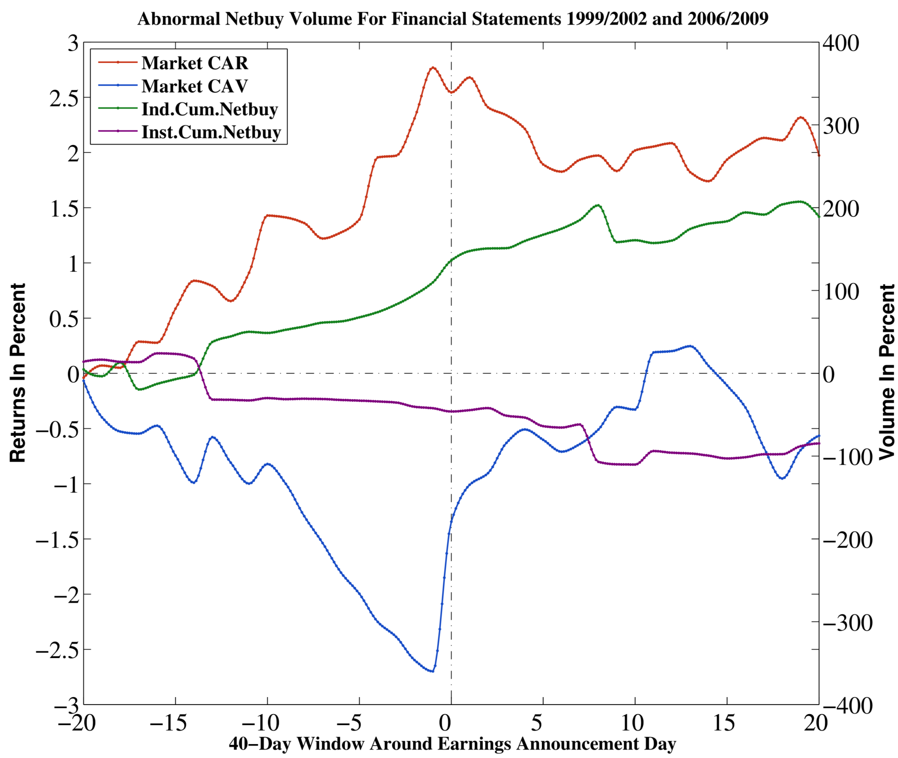
This figure depicts the unconditional premium and volume around all earnings announcements in a 40-day window. Market CAR and Market CAV are the same CAR.fs and CAV.fs as in Figure(3.3) respectively. Ind.Cum.Netbuy represents the trading imbalance on the announcing stock by the individual investors as defined in equation (3.7). Inst.Cum.Netbuy represents the trading imbalance on the announcing stock by the institutional investors as defined in equation (3.8).

Figure C.4: Average CAR and CAV Around Earnings Announcements By Announcement Types



This figure depicts the unconditional premium and volume around *financial statements* in a 20-day window. Market CAR and Market CAV are the same CAR.fs and CAV.fs as in Figure(3.3) respectively. Ind.Cum.Netbuy represents the trading imbalance on the announcing stock by the individual investors as defined in equation (3.7). Inst.Cum.Netbuy represents the trading imbalance on the announcing stock by the institutional investors as defined in equation (3.8).

Figure C.5: Average CAR and CAV Around Earnings Announcements By Announcement Types



This figure depicts the unconditional premium and volume around *financial statements* in a 40-day window. Market CAR and Market CAV are the same CAR.fs and CAV.fs as in Figure(3.3) respectively. Ind.Cum.Netbuy represents the trading imbalance on the announcing stock by the individual investors as defined in equation (3.7). Inst.Cum.Netbuy represents the trading imbalance on the announcing stock by the institutional investors as defined in equation (3.8).

C.2 Statistical Tables

Table C.1: T-stats For CAR and CAV Around Earnings Announcements

Day	AR	t-stat	CAR	tstat.car	AV	t-stat	CAV	tstat.cav
-15	0.07	1.08	0.07	1.08	-19.38	-3.82	-19.38	-3.82
-14	0.14	1.83	0.22	2.10	12.15	0.35	-7.23	-0.21
-13	0.00	-0.02	0.21	1.77	2.67	0.21	-4.56	-0.12
-12	0.00	-0.07	0.21	1.52	-22.50	-4.00	-27.07	-0.72
-11	0.04	0.44	0.25	1.51	-13.75	-1.42	-40.82	-1.06
-10	0.13	1.61	0.38	2.05	-8.04	-0.73	-48.87	-1.22
-9	-0.17	-2.39	0.21	1.07	10.28	0.42	-38.59	-0.82
-8	-0.12	-1.93	0.09	0.46	-31.23	-10.63	-69.82	-1.48
-7	0.08	1.25	0.18	0.82	44.97	0.74	-24.86	-0.32
-6	0.00	-0.06	0.17	0.78	-20.99	-3.23	-45.84	-0.59
-5	0.03	0.41	0.20	0.86	-29.03	-4.68	-74.88	-0.97
-4	0.21	2.25	0.41	1.64	-6.31	-0.54	-81.19	-1.04
-3	0.13	1.64	0.55	2.07	-7.11	-1.46	-88.30	-1.13
-2	0.21	3.15	0.76	2.77	-6.86	-0.68	-95.16	-1.20
-1	0.34	5.31	1.09	3.89	-12.19	-3.51	-107.35	-1.36
0	-0.20	-1.85	0.89	2.96	152.29	14.84	44.95	0.56
1	0.08	1.15	0.97	3.14	39.72	7.38	84.66	1.06
2	-0.26	-3.13	0.71	2.23	7.59	1.15	92.26	1.15
3	-0.15	-1.59	0.56	1.69	17.61	1.71	109.87	1.36
4	-0.27	-2.87	0.29	0.84	35.15	2.78	145.02	1.77
5	-0.09	-1.24	0.20	0.57	-2.93	-0.60	142.10	1.73
6	-0.06	-1.07	0.14	0.39	59.09	0.89	201.18	1.90
7	-0.03	-0.55	0.10	0.29	-5.46	-1.01	195.72	1.85
8	0.00	-0.05	0.10	0.28	-6.93	-1.09	188.79	1.78
9	0.04	0.56	0.14	0.38	-7.26	-0.55	181.53	1.70
10	0.06	0.72	0.21	0.54	-11.06	-2.00	170.47	1.59
11	-0.05	-0.67	0.15	0.39	2.07	0.12	172.54	1.59
12	-0.05	-0.83	0.10	0.26	-5.41	-0.71	167.13	1.54
13	-0.19	-3.28	-0.09	-0.21	-8.29	-1.74	158.84	1.46
14	0.06	1.01	-0.03	-0.07	-19.82	-5.49	139.02	1.28
15	-0.04	-0.65	-0.07	-0.16	-15.80	-2.66	123.22	1.13

CAR,CAV For All Announcements: Key Statistics From T=30

Table C.2: T-stats For CAR and CAV Around Only Financial Statements

Day	AR	t-stat	CAR	tstat.car	AV	t-stat	CAV	tstat.cav
-15	0.31	1.93	0.31	1.93	-35.94	-4.37	-35.94	-4.37
-14	0.25	1.16	0.56	2.08	-32.87	-3.89	-68.81	-5.84
-13	-0.05	-0.30	0.52	1.66	55.09	1.11	-13.72	-0.27
-12	-0.14	-1.02	0.38	1.11	-30.81	-2.84	-44.53	-0.85
-11	0.26	1.27	0.63	1.61	-25.39	-2.04	-69.93	-1.30
-10	0.52	2.84	1.15	2.65	23.70	0.56	-46.23	-0.68
-9	-0.02	-0.12	1.14	2.47	-23.94	-2.79	-70.17	-1.02
-8	-0.05	-0.39	1.08	2.27	-38.96	-5.74	-109.13	-1.57
-7	-0.14	-1.00	0.94	1.90	-32.50	-2.58	-141.63	-2.01
-6	0.06	0.41	1.00	1.94	-35.74	-4.35	-177.36	-2.50
-5	0.12	0.72	1.12	2.07	-25.50	-2.08	-202.87	-2.82
-4	0.56	2.79	1.68	2.91	-34.00	-5.87	-236.86	-3.28
-3	0.01	0.09	1.69	2.82	-18.02	-2.13	-254.88	-3.51
-2	0.34	2.37	2.03	3.29	-28.10	-4.81	-282.99	-3.88
-1	0.46	3.50	2.49	3.95	-13.62	-1.72	-296.60	-4.04
0	-0.22	-0.98	2.27	3.38	180.74	11.97	-115.86	-1.55
1	0.14	0.89	2.40	3.49	44.54	4.06	-71.32	-0.94
2	-0.27	-1.56	2.13	3.00	14.10	1.08	-57.22	-0.74
3	-0.07	-0.36	2.06	2.79	36.49	1.75	-20.73	-0.26
4	-0.12	-0.62	1.94	2.53	16.23	1.34	-4.49	-0.06
5	-0.32	-2.31	1.61	2.08	-12.52	-2.29	-17.01	-0.21
6	-0.06	-0.58	1.55	1.97	-14.31	-1.68	-31.32	-0.39
7	0.11	0.77	1.66	2.08	9.22	0.58	-22.09	-0.27
8	0.04	0.30	1.70	2.10	17.47	0.79	-4.62	-0.05
9	-0.14	-0.87	1.56	1.89	27.34	0.68	22.71	0.24
10	0.19	1.18	1.74	2.08	-3.22	-0.23	19.49	0.20
11	0.04	0.19	1.78	2.07	69.05	1.00	88.54	0.75
12	0.03	0.21	1.81	2.08	1.55	0.15	90.09	0.76
13	-0.26	-2.11	1.54	1.76	6.01	0.42	96.10	0.81
14	-0.08	-0.74	1.46	1.65	-23.91	-3.54	72.19	0.60
15	0.20	1.80	1.66	1.86	-23.48	-1.79	48.71	0.41

CAR,CAV For Financial Statements: Key Statistics From T=30

Table C.3: T-stats For CAR and CAV Around Only Interim Earnings Reports

Day	AR	t-stat	CAR	tstat.car	AV	t-stat	CAV	tstat.cav
-15	-0.01	-0.13	-0.01	-0.13	-14.85	-2.06	-14.85	-2.06
-14	0.16	1.73	0.15	1.22	28.34	0.50	13.49	0.24
-13	0.07	0.83	0.22	1.48	-17.03	-3.40	-3.55	-0.06
-12	0.02	0.26	0.24	1.40	-18.68	-2.48	-22.22	-0.39
-11	-0.10	-0.89	0.14	0.66	-7.94	-0.56	-30.17	-0.51
-10	-0.03	-0.27	0.11	0.48	-18.28	-3.54	-48.45	-0.81
-9	-0.19	-2.13	-0.08	-0.33	6.99	0.21	-41.46	-0.61
-8	-0.15	-2.00	-0.24	-0.91	-32.38	-8.93	-73.83	-1.08
-7	0.11	1.32	-0.13	-0.47	89.78	0.88	15.95	0.13
-6	-0.01	-0.12	-0.14	-0.49	-24.27	-3.77	-8.32	-0.07
-5	-0.03	-0.27	-0.16	-0.55	-37.11	-4.36	-45.43	-0.37
-4	0.04	0.35	-0.13	-0.40	-19.92	-3.43	-65.35	-0.53
-3	0.21	2.02	0.09	0.26	-6.70	-1.01	-72.05	-0.58
-2	0.20	2.32	0.28	0.82	-9.48	-1.05	-81.53	-0.66
-1	0.29	3.70	0.57	1.63	-15.17	-3.72	-96.70	-0.78
0	-0.23	-1.54	0.34	0.89	163.43	10.66	66.73	0.53
1	-0.09	-1.03	0.25	0.63	37.92	5.48	104.65	0.84
2	-0.34	-3.22	-0.09	-0.23	9.34	1.11	113.99	0.91
3	-0.18	-1.71	-0.28	-0.66	4.19	0.62	118.18	0.94
4	-0.36	-2.94	-0.64	-1.45	35.86	2.39	154.04	1.22
5	0.03	0.31	-0.61	-1.35	3.06	0.43	157.10	1.24
6	0.00	-0.01	-0.61	-1.34	0.97	0.09	158.07	1.24
7	-0.09	-1.19	-0.70	-1.51	-11.18	-2.29	146.89	1.15
8	0.00	0.01	-0.70	-1.49	-18.96	-4.30	127.92	1.00
9	0.12	1.24	-0.58	-1.22	-14.74	-0.99	113.19	0.88
10	0.08	0.62	-0.51	-1.02	-10.69	-1.57	102.49	0.80
11	-0.12	-1.17	-0.62	-1.23	-17.57	-2.92	84.92	0.66
12	-0.10	-1.25	-0.72	-1.41	-7.31	-0.63	77.61	0.60
13	-0.21	-2.82	-0.93	-1.80	-11.82	-2.39	65.79	0.51
14	0.15	1.93	-0.78	-1.50	-21.34	-4.27	44.46	0.34
15	-0.08	-1.09	-0.87	-1.64	-17.65	-2.63	26.81	0.21

CAR,CAV For Interim Report Statements: Key Statistics From T=30

Table C.4: T-stats For Cumulative Net-Buy Around Earnings Announcements

Day	Netbuy.ind	tstat.ind	cum.netbuy.ind	tstat.cnb.ind	Netbuy.inst	tstat.inst	cum.netbuy.inst	tstat.cnb.inst
-15	-16.29	-0.81	-16.29	-0.81	-10.18	-1.21	-10.18	-1.21
-14	1.34	0.37	-14.94	-0.73	-3.19	-2.31	-13.37	-1.57
-13	12.07	0.81	-2.87	-0.11	-13.33	-1.33	-26.70	-2.02
-12	3.94	1.69	1.07	0.04	1.71	1.38	-24.99	-1.89
-11	6.48	3.53	7.54	0.29	-0.28	-0.29	-25.27	-1.90
-10	1.61	0.44	9.15	0.35	-1.04	-0.53	-26.31	-1.96
-9	5.02	2.74	14.17	0.55	3.37	0.62	-22.94	-1.58
-8	7.19	4.84	21.36	0.82	-1.24	-2.41	-24.18	-1.67
-7	-12.87	-0.96	8.49	0.29	-5.00	-2.02	-29.17	-1.98
-6	4.51	2.39	13.00	0.44	-2.36	-2.27	-31.53	-2.14
-5	4.26	1.86	17.26	0.59	-1.03	-1.31	-32.56	-2.21
-4	18.85	1.51	36.11	1.13	-0.96	-0.75	-33.52	-2.26
-3	8.59	3.26	44.69	1.40	-2.39	-2.80	-35.91	-2.42
-2	6.63	1.31	51.32	1.58	-1.06	-0.52	-36.97	-2.47
-1	14.99	4.47	66.31	2.03	-2.45	-1.92	-39.42	-2.62
0	28.98	2.55	95.29	2.76	-3.37	-2.07	-42.79	-2.83
1	2.34	0.94	97.63	2.82	-0.25	-0.24	-43.04	-2.84
2	1.33	0.59	98.97	2.85	-2.59	-1.43	-45.63	-2.99
3	-0.67	-0.18	98.29	2.82	-4.42	-1.75	-50.05	-3.23
4	3.36	0.85	101.66	2.90	-6.52	-1.26	-56.58	-3.47
5	1.30	0.35	102.96	2.92	-2.14	-0.75	-58.71	-3.54
6	-12.71	-0.91	90.25	2.38	-2.02	-1.89	-60.73	-3.66
7	4.00	1.70	94.25	2.48	-0.61	-0.31	-61.34	-3.67
8	4.09	0.77	98.34	2.56	-10.57	-1.43	-71.90	-3.94
9	-38.58	-1.77	59.76	1.35	3.44	0.83	-68.46	-3.66
10	-2.42	-0.90	57.34	1.30	0.06	0.05	-68.41	-3.65
11	-0.25	-0.07	57.09	1.29	4.07	0.76	-64.34	-3.30
12	1.65	0.53	58.74	1.32	-0.28	-0.25	-64.61	-3.30
13	4.92	2.13	63.65	1.43	-0.24	-0.26	-64.85	-3.31
14	-2.64	-0.79	61.01	1.37	-0.48	-0.56	-65.32	-3.33
15	2.31	1.10	63.32	1.42	-3.77	-1.55	-69.10	-3.50

Individual and Institutional Netbuy For All Announcements: Key Statistics From T=30

Table C.5: T-stats For Cumulative Net-Buy Around Only Financial Statements

Day	Netbuy.ind	tstat.ind	cum.netbuy.ind	tstat.cnb.ind	Netbuy.inst	tstat.inst	cum.netbuy.inst	tstat.cnb.inst
-15	5.69	2.16	5.69	2.16	-0.67	-0.70	-0.67	-0.70
-14	5.32	1.55	11.01	2.55	-5.62	-2.58	-6.28	-2.65
-13	39.55	0.66	50.56	0.84	-49.50	-1.20	-55.79	-1.35
-12	6.80	1.68	57.36	0.95	-0.28	-0.18	-56.07	-1.35
-11	5.47	1.32	62.84	1.04	-0.77	-0.42	-56.84	-1.37
-10	-1.35	-0.25	61.48	1.01	2.85	0.86	-53.99	-1.30
-9	3.85	1.09	65.34	1.07	-1.36	-0.50	-55.34	-1.33
-8	3.96	1.50	69.30	1.14	0.51	0.56	-54.83	-1.31
-7	4.67	2.01	73.96	1.21	-0.35	-0.29	-55.19	-1.32
-6	1.41	0.60	75.38	1.23	-1.08	-0.58	-56.27	-1.35
-5	4.95	1.06	80.33	1.31	-0.81	-0.58	-57.08	-1.37
-4	6.34	1.61	86.67	1.41	-0.98	-0.58	-58.06	-1.39
-3	9.18	2.27	95.85	1.56	-1.30	-0.80	-59.36	-1.42
-2	11.72	1.69	107.57	1.74	-5.16	-1.59	-64.52	-1.54
-1	15.08	4.15	122.65	1.98	-1.74	-1.54	-66.27	-1.58
0	26.46	3.84	149.10	2.39	-3.98	-1.20	-70.25	-1.67
1	11.32	2.10	160.43	2.56	1.64	0.60	-68.61	-1.63
2	3.04	0.61	163.47	2.60	2.53	0.78	-66.08	-1.56
3	0.44	0.04	163.91	2.56	-9.22	-1.31	-75.30	-1.75
4	8.64	1.19	172.55	2.68	-2.30	-0.96	-77.60	-1.81
5	7.56	2.49	180.12	2.79	-10.35	-1.00	-87.95	-1.99
6	7.28	2.03	187.40	2.90	-1.60	-1.02	-89.54	-2.02
7	10.64	2.75	198.03	3.06	3.64	0.50	-85.91	-1.92
8	17.60	0.99	215.64	3.21	-45.08	-1.50	-130.99	-2.43
9	-44.50	-1.51	171.14	2.33	-2.99	-0.47	-133.97	-2.46
10	2.27	0.41	173.41	2.36	-0.26	-0.09	-134.24	-2.47
11	-3.32	-0.27	170.09	2.28	16.30	0.76	-117.94	-2.02
12	2.95	0.34	173.04	2.30	-2.09	-1.01	-120.03	-2.05
13	14.03	2.86	187.06	2.49	-0.87	-0.38	-120.90	-2.06
14	6.39	1.41	193.46	2.57	-2.64	-1.71	-123.54	-2.11
15	2.87	0.71	196.33	2.60	-3.36	-1.32	-126.90	-2.16

Individual and Institutional Netbuy For Financial Statements: Key Statistics From T=30

Table C.6: T-stats For Cumulative Net-Buy Around Interim Earnings Reports

Day	Netbuy.ind	tstat.ind	cum.netbuy.ind	tstat.cnb.ind	Netbuy.inst	tstat.inst	cum.netbuy.inst	tstat.cnb.inst
-15	-30.73	-0.91	-30.73	-0.91	-16.26	-1.15	-16.26	-1.15
-14	6.43	3.19	-24.30	-0.72	-0.64	-0.68	-16.90	-1.19
-13	4.98	1.80	-19.32	-0.57	-1.84	-1.93	-18.74	-1.32
-12	1.85	0.56	-17.48	-0.51	1.30	1.10	-17.43	-1.22
-11	7.86	3.33	-9.62	-0.28	-0.10	-0.08	-17.53	-1.22
-10	5.79	1.97	-3.83	-0.11	0.20	0.22	-17.33	-1.21
-9	4.15	1.77	0.33	0.01	7.21	0.82	-10.13	-0.60
-8	7.95	3.82	8.28	0.24	-1.71	-2.38	-11.84	-0.70
-7	-25.86	-1.14	-17.58	-0.43	-8.67	-2.12	-20.51	-1.18
-6	4.35	2.93	-13.23	-0.32	-2.51	-1.71	-23.02	-1.32
-5	5.18	1.85	-8.05	-0.19	-1.34	-1.29	-24.36	-1.40
-4	8.23	4.02	0.18	0.00	0.01	0.01	-24.35	-1.39
-3	6.56	1.77	6.75	0.16	-3.49	-2.97	-27.85	-1.59
-2	9.61	3.03	16.36	0.39	-2.29	-1.76	-30.14	-1.72
-1	9.53	3.39	25.89	0.62	-3.27	-1.66	-33.41	-1.89
0	30.86	1.66	56.75	1.24	-1.16	-0.75	-34.57	-1.95
1	-1.65	-0.49	55.11	1.20	-2.34	-1.79	-36.91	-2.08
2	1.79	0.60	56.90	1.24	-5.24	-1.90	-42.15	-2.34
3	-0.44	-0.15	56.47	1.22	-0.96	-1.19	-43.11	-2.39
4	-2.51	-0.47	53.96	1.16	2.07	1.39	-41.04	-2.27
5	-0.38	-0.06	53.58	1.14	-1.34	-2.08	-42.38	-2.34
6	-1.61	-0.36	51.97	1.11	-2.47	-1.71	-44.85	-2.47
7	4.29	1.31	56.26	1.19	-2.61	-2.16	-47.46	-2.61
8	-0.22	-0.09	56.04	1.19	-0.79	-0.69	-48.24	-2.65
9	-45.59	-1.32	10.45	0.18	6.83	1.06	-41.42	-2.14
10	-4.15	-1.15	6.31	0.11	0.67	0.42	-40.75	-2.10
11	2.23	0.95	8.54	0.15	-0.10	-0.07	-40.85	-2.10
12	1.97	0.56	10.51	0.18	0.38	0.31	-40.46	-2.08
13	2.33	0.74	12.84	0.22	-0.13	-0.12	-40.59	-2.08
14	-6.30	-1.21	6.54	0.11	-0.29	-0.24	-40.88	-2.09
15	1.73	0.66	8.27	0.14	-0.46	-0.30	-41.34	-2.11

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