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The Risk and Return Characteristics of the U.S. Treasury Basis Trade

by

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Master Thesis

MSc in Finance and MSc in Business with Major in Finance

ABSTRACT

We conduct an analysis of the risk and return characteristics of the U.S. Treasury basis trade by regressing the strategy returns of the 2-year, 5-year and 10-year futures contracts on a variety of bond and equity market risk factors. We find that over the full sample period from January 1, 1992 to March 31, 2023, the 5-year strategy generates a positively significant alpha without loading on any risk factors, whereas the 2-year strategy generates no significant alpha, and the 10-year strategy generates a negatively significant alpha, with little explanatory power even though they load on some risk factors. In the more recent sample period from August 31, 2007 to March 31, 2023, the 2-year strategy and the 5-year strategy generated highly significant alphas, which coincides with hedge fund interest in the basis trade. Further we cannot rule out that the significant alphas observed in the 2-year or 5-year contracts might stem from limits to arbitrage.

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1 Introduction and motivation

We conduct an analysis of the risk and return characteristics of the U.S. Treasury basis trade. Specifically, we investigate whether the basis trade generates returns in excess of equity and bond market factors.

The 26th of November 1975, the Commodity Futures Trading Commission (CFTC) approved the first futures contract on U.S. government debt – the Chicago Mercantile Exchange (CME) 90-day U.S. Treasury bill futures contract (CFTC, n.d.). The commencement of the Treasury futures market sparked a new area of research – the efficiency of the Treasury futures market, starting with Puglisi's (1978) article in the Journal of Portfolio Management, where he concluded that the Treasury futures market was inefficient. Following Puglisi (1978), Elton et al. (1984) conducted direct tests of market efficiency by using intraday prices and concluded that the Treasury futures market was inefficient with respect to pure arbitrage. If the futures market were to be perfectly efficient, there would be no arbitrage opportunities in the basis trade. However, Barth and Kahn (2021) document the presence of near-arbitrage opportunities in the basis trade, nearly four decades later.

Highly leveraged relative value hedge funds constitute the main participants in the basis trade. Barth and Kahn (2021) report that in 2019, hedge funds they categorize as large basis traders had a mean leverage of 21 with a standard deviation of 17.6 (Barth and Kahn, 2021, p. 29). On March 17, 2020, Bloomberg reported that a significant increase in the Treasury basis spread had prompted leveraged investors to unwind their positions, resulting in a liquidity crisis in another corner of the market and a $5 trillion Federal Reserve promise to calm markets (Spratt, 2020).

In a post-mortem analysis of the March 2020 Treasury market illiquidity episode, Barth and Kahn (2021) concluded that while basis trades were unlikely to be the primary cause of stress, had the Federal Reserve not intervened, a liquidity spiral might have resulted as hedge funds would likely have amplified the stress through Treasury markets, leading to "unparallelled stress in the world's most important asset market" (Barth and Kahn, 2021, p. 4). Recently the basis trade has drawn scrutiny from regulators, as they are concerned with the low, or even zero-margin funding available to hedge funds in the trade (Basak et al., 2023). On May 31, 2023, 2023, Bloomberg reported that the basis trade had rebounded to 2018-2019 levels, where CFTC data showed that leveraged funds had amassed a record short position of about $500 billion worth of the 10-year Treasury note (Bolingbroke, 2023).

Barth and Kahn (2021) point out that at its peak, the basis trade accounted for more than 60% of hedge funds' total Treasury exposure, more than 70% of their repo borrowing, and more than a quarter of dealers' repo lending (Barth and Kahn, 2021, p. 2). Taking the potential financial stability threat, the economic magnitude, recent regulatory scrutiny, and resurgence of the trade, an investigation into the risk and return characteristics of the U.S. Treasury basis trade is warranted.

To the best of our knowledge, no other papers have investigated the risk and return characteristics of the U.S. Treasury basis trade. Duarte et al. (2007) investigate the risk and return characteristics of five different fixed income arbitrage strategies, but not the basis trade. Fleckenstein and Longstaff (2020) investigate whether intermediary balance sheet rental costs explain the *funding basis*.[1] We contribute with our analysis in that we 1) investigate the risk and return characteristics of the basis trade with respect to both bond and equity market risk factors, and 2) use recent data.

We generate time series of monthly excess returns of the basis trade for the nearby 2-year, 5-year, and 10-year futures contracts, and subsequently perform OLS regressions to see if either the underlying CRSP Fama maturity portfolio, log changes in the MOVE bond volatility index, the up-minus-down, market, small-minus-big, high-minus-low, or S&P bank stock index excess returns explain the strategy returns. Using White's test for heteroscedasticity and the Breusch-Godfrey test for autocorrelation, we detect both heteroscedasticity and autocorrelation in the residuals, and hence apply Newey-West's autocorrelation and heteroscedasticity consistent standard errors. We divide the full sample of the strategy into two subsamples, to account for time-varying risk premia, and also test the strategy at three different thresholds to observe if reducing

[1] The difference between the implied repo rate and the repo rate

noise in the signal improves the strategy returns. Further, we compare the OLS regression results when using either the federal funds rate as a proxy for the repo rate or the GCF repo rate to observe the magnitude of the positive bias by using a proxy rate.

We obtain Treasury spot data from CRSP, Treasury futures price data for the nearby contract on the 2-year, 5-year, and 10-year Treasury note futures contracts provided by the CME from the Bloomberg system, the federal funds effective rate provided by the Board of governors of the Federal Reserve System (US) from Fred, Federal Reserve Bank of St. Louis, the Treasury GCF Weighted Average repo rate from the DTCC, the Fama 2-year, 5-year, and 10-year maturity portfolios from the CRSP Treasury database, and the up-minus-down, market, small-minus-big, and high-minus-low excess returns from Kenneth French's online data library. The final sample ends up covering the period from January 1, 1992 to March 31, 2023.

We reject the null-hypothesis of there being no significant alpha for the 5-year strategy, as we observe significant alpha in both the full sample and the subsample. As for the 2-year strategy, we fail to reject the null-hypothesis for the full sample, but it is rejected in the second half of the subsample, as the alpha is significant for the last 15 years. The 10-year strategy is significantly negative in all samples. Further we cannot rule out that the significant alphas observed in the 2-year or 5-year contracts might stem from limits to arbitrage. These results imply that if the alphas of the 2-year and 5-year contracts are not due to limits to arbitrage, but rather due to mispricing or a differential habitat premium (Chow and Brophy, 1982), there seem to be a profitable basis trade in the 5-year Treasury note, that is not explained by neither bond or equity market factors. Further, the 2-year Treasury note seems to offer alpha, but it is significantly associated with bond and equity market factors.

2 Literature review

2.1 Treasury futures market efficiency

Puglisi (1978) specifies a model for pricing Treasury bill futures contracts and tests whether the returns of a bills-futures less a bills-only strategy are significantly different from zero, also conducting a sign test on the number of times the bills-only strategy returned less than the bills-futures strategy. Puglisi uses daily closing prices of Treasury futures contracts and asked prices on Treasury bills, which he obtains from the Wall Street Journal (WSJ). Puglisi finds that the bills-futures strategy would have resulted in higher returns than with the bills-only strategy for four out of seven contracts. Further, Puglisi points out that for six out of seven contracts, the sign test implies that the return difference is significantly different from zero. Based on these results, Puglisi concludes that the Treasury bill futures market is inefficient, and as Chow and Brophy (1982) point out, the conclusion is without providing a satisfactory explanation (Chow and Brophy, 1982, p. 26).

Capozza and Cornell (1979) derive an arbitrage condition connecting the Treasury bill spot market and the Treasury futures market by comparing futures rates with implied forward rates. In this model, arbitrage opportunities will exist if the implied forward rate is not equal to the futures rate at every point in time. They use weekly data on futures and Treasury bill spot rates from the WSJ, covering the period from January 6, 1979 through June 1978. Capozza and Cornell find that even though the average deviation is generally small for the near contract, it tends to grow with increased maturity, and therefore conclude that the arbitrage condition is violated. As Rendleman and Carabini (1979) point out, none of these discrepancies could have been arbitraged directly due to the cost of shorting the Treasury spot bill required to establish the position (Rendleman and Carabini, 1979, p. 896), which in turn, as pointed out by Kolb and Gay (1985), implies that the Treasury futures market is efficient (Kolb and Gay, 1985, p. 157).

Rendleman and Carabini (1979) determine the equilibrium price of futures contracts on the basis of arbitrage relationships between Treasury spot bills and corresponding futures contracts, and further examine the relationship between actual International Monetary Market (IMM) Index values and the theoretical values given by the equilibrium model. If the two markets are in equilibrium, no pure- or quasi arbitrage opportunities can exist. They define pure arbitrage as “shorting a security or portfolio to fund a position in an economically equivalent security or portfolio at a lower price”, and quasi arbitrage as “selling securities from an existing portfolio to fund an economically equivalent position at a lower price” (Rendleman and Carabini, 1979, p. 896).

Rendleman and Carabini get daily futures data from the CME, and bid and asked bankers’ discount yields of Treasury bills from the Federal Reserve Bank of New York, covering the time period from January 6, 1976 to March 31, 1978. They find that the Treasury bill futures market appears to have been highly efficient with respect to pure arbitrage opportunities given an annualized shorting cost of 50 basis points, assumed from Capozza and Cornell (1979). Further, they find that many quasi arbitrage opportunities have existed in the Treasury bill futures market, and that the market appeared to become less efficient over time.

Vignola and Dale (1979) follow the model of Puglisi (1978), comparing bills-only returns with bills-futures returns. They get closing bid and ask prices for spot market Treasury bills from the Federal Reserve Bank of New York, and daily settlement prices for futures contracts from the Chicago Mercantile Exchange (CME). Utilizing a sign test on the bills-only less the bills-futures returns, Vignola and Dale find that the differential return is significantly different from zero at the five-percent level or better for six of the eight contracts on the ask side and for four contracts on the bid side, which indicates that the Treasury bill market has remained inefficient. Further, they find that there are time series trends in the arbitrage returns as there is significant autocorrelation in each contract, and hence they conclude that the futures market is inefficient not only with respect to arbitrage, but also due to the arbitrage returns not being distributed randomly over time.

Vignola and Dale (1980) empirically test two alternative model specifications for pricing Treasury bill futures contracts and testing the efficiency of the futures market, derived from 1) the theory of storage costs, and 2), the expectations hypothesis of forward rates implied by the term structure. To test the two different models, they compare equilibrium prices from the two alternative model specifications with actual futures prices. Their data sample includes daily observations of the federal funds rate, closing prices on Treasury bill futures contracts, and Treasury spot bills covering the time period from January 6, 1976 through December 1978.

Vignola and Dale argue that the repo rate is the most representative rate for the financing of Treasury bills due to the popularity of entering a reverse repo and selling the security instead of outright shorting it. Due to the overnight repo rate not being available, they use the federal funds rate as a proxy. Vignola and Dale find that the futures market seems efficient with respect to pure arbitrage, but not with respect to quasi arbitrage. They further conclude that the overnight cost-of-carry model is better for explaining Treasury futures prices, and that the question of futures market efficiency reduces to the question of the use of appropriate financing costs.

Chow and Brophy (1982) analyze quasi arbitrage opportunities from the perspective of different prospective and actual Treasury bill owners, classifying the market participants into 12 groups. They use daily data on Treasury bill futures contracts from the CME over the time period from January 6, 1976 to March 22, 1979. Chow and Brophy succeed in replicating other authors' results, including Capozza and Cornell (1979), Rendleman and Carabini (1979), and Vignola and Dale (1980) by applying their approximations to their own formulas. They find that the daily marking-to-market effect of futures contracts makes a negligible contribution to the explanation of the discrepancy between futures and implicit forward yields, and that a *differential habitat premium*, which they consider a natural generalization of the habitat preference theory, is required to explain the yield discrepancy.

Chow and Brophy define the differential habitat premium as "the yield premium that an investor demands or is willing to sacrifice, for reasons other than default risk and tax, in order to participate in the futures market instead of the corresponding spot market" (Chow and Brophy, 1982, p. 27). They point out that lower transaction costs and the ability to achieve high leverage are some of the advantages that the futures market might offer over the spot market.

Kawaller and Koch (1984) examine the relationship between actual Treasury bill futures and forward rates constructed using different assumed financing rates in the arbitrage trade, with either assumed term financing or overnight financing. First, they duplicate previous work by testing for equality of nearby futures rates and corresponding implied forward rates, which they point out is equivalent to testing whether term repo financing can explain the discrepancy between forward and futures rates. Next, they substitute a compounded overnight repo rate for the term repo rate to construct adjusted forward rates, and retest for equality.

Kawaller and Koch point out that in their model, a difference of zero provides evidence that the futures contract is priced according to the cash-and-carry arbitrage. They use daily closing quotations on Treasury spot bills from the Bank of America and futures rates from the Chicago Mercantile Exchange, covering the time period from September 1977 through June 1982. Kawaller and Koch use mean difference t-tests to show that futures rates calculated on the basis of compounded overnight repo rates do not significantly differ from observed futures rates on nearby contracts, and thus conclude that the nearby futures market is efficient.

Elton et al. (1984) use intraday prices to examine the efficiency of the Treasury bill futures market with respect to pure arbitrage, which allows them to carefully match the trades in futures and spot markets in time such that they can make more realistic assumptions about the prices at which the trades could have taken place. They point out that the profits from the analyzed strategies do not depend on an assumption of an equilibrium model, such that the tests are direct tests of market efficiency rather than a joint test of equilibrium and efficiency.

Elton et al. use intraday bid and ask quotes on Treasury spot bills from the Federal Reserve Bank of New York and Treasury bill futures prices from the CME, covering the time period from January 6, 1978 to December 22, 1982. They find that the Treasury bill futures market is not perfectly efficient with respect to pure arbitrage, as buying either the cash or synthetic Treasury bill and selling the other instrument short when the anticipated profit is larger than transaction costs leads to positive profits. These results are robust to both immediate and delayed execution.

Hegde and Branch (1985) examine the arbitrage potential between the 90-day Treasury bill futures contract and the Treasury bill spot market, where they assume that an arbitrageur compares the price of the nearby futures contract with the corresponding implied forward price. Hegde and Branch also point out that margin maintenance costs are difficult to estimate as they depend upon daily movements in futures rates (Hegde and Branch, 1985, p. 411). Hegde and Branch use a data sample consisting of closing quotations on spot and futures data collected from the WSJ, covering the time period between March 24, 1976 and December 16, 1981. They find that the nearby Treasury bill futures contract frequently has been overpriced relative to the corresponding implied forward price.

Further, Hegde and Branch observe that the extent of overpricing rarely has been enough to meet pure arbitrage costs prior to October 1979, even though it has allowed for profitable quasi arbitrage opportunities, but that since then the number of pure arbitrage opportunities has increased markedly. They point out that the observed differences are too large to be accounted for adequately by margin costs, and that the remaining difference may be due to what Chow and Brophy (1982) coined the *differential habitat premium*, which arises from various advantages associated with futures trading.

Allen and Thurston (1988) derive arbitrage conditions for the cash-and-carry trade and calculate the spread between implied forward rates obtained from this model and corresponding futures rates, and further perform an OLS regression to measure the forecasting power of borrowing spreads on the forward-futures differential. They get repo rates from the Interactive Data Corporation (IDC), and Treasury spot bill and futures prices from the New York Times (NYT), WSJ, and Washington Post. Allen and Thurston find that the forward-futures rate differential is overwhelmingly positive, and that this differential persists because of dealers' financing rates not being low enough to allow them to completely arbitrage it away. They conclude that even if it is true that most arbitrage activity involves overnight repo, IDC's term repo data performs better as a predictor of the implied repo rate than a compound overnight rate of the same term, referring to Kawaller and Koch (1984).

2.2 Limits to arbitrage

Fleckenstein and Longstaff (2020) examine whether intermediary balance sheet costs explain the basis between five-year Treasury cash notes and Treasury note futures, where they define the difference between the implied repo rate and the repo rate as the *funding basis*. They find that throughout the entire sample period of 1991-2018, the funding basis is directly associated with the cost of balance sheet usage by financial intermediaries, and that this is not simply an effect of capital regulation like the Dodd Frank Act and the Basel III framework following the financial crisis. Further, Fleckenstein and Longstaff find that the funding basis increases when intermediaries are required to hold more regulatory capital, and that in the period before the financial crisis the funding basis is closely associated with debt-overhang costs whereas, in the post-crisis period, capital regulation becomes the dominant factor associated with balance sheet usage costs. Fleckenstein and Longstaff also point out that the repo rate, and not the implied repo rate, is usually what causes the funding basis to spike in times of crisis.

Barth and Kahn (2021) document the rise and fall of the basis trade among hedge funds. They derive arbitrage conditions and show that these are frequently violated, and that the deviations are extremely persistent and correlated with stressed market conditions, which suggests the importance of limits to arbitrage. Barth and Kahn find that 1) hedge funds' financing costs are positively associated with the cash-futures disconnect, 2) the amount of Treasuries on dealer balance sheets is associated with the disconnect, and 3) Treasury volatility measures are associated with larger deviations due to increased margin risk. They conclude that these results point toward margin risk and funding costs as important limits to arbitrage in the Treasury futures and cash markets.

2.3 Regression model

Duarte, Longstaff, and Yu (2007) examine the risk and return characteristics of five different fixed income arbitrage strategies, where they regress the excess returns of the various strategies on a set of different equity and bond portfolios.

They include the CRSP Fama two-year, five-year, and ten-year bond portfolios to account for bond market risk. To account for equity market risk, they include the momentum (UMD or WML), Fama-French (1993) market, small-minus-big (SMB), and high-minus-low (HML), and S&P bank sector equity index excess returns. To account for indirect default risk, Duarte et al. include A/BBB-rated industrial bond and bank sector bond portfolios.

3 Methodology

3.1 Hypothesis

There is conflicting evidence with regards to the efficiency of the Treasury futures market, as demonstrated in the previous chapter. Elton et al. (1984), however, differ from the rest of the literature on Treasury market efficiency in that they are the only ones to conduct a direct test of market efficiency by using intraday price data, in contrast to relying on equilibrium models, like Rendleman and Carabini (1979), Capozza and Cornell (1979), and Vignola and Dale (1979), among others. Elton et al. (1984) find that the Treasury futures market is inefficient with respect to pure arbitrage, and these results are robust to both immediate and delayed execution. Fleckenstein and Longstaff (2020) find that the funding basis is very persistent. Barth and Kahn (2021) document near-arbitrage opportunities in the basis trade, and that the deviations from arbitrage are extremely persistent. With these studies in mind, we hypothesize that there is a significant positive alpha in excess of any bond or equity market risk factors, which leads us to our null and alternative hypotheses:

$$H_0 : \alpha = 0$$

$$H_1 : \alpha \neq 0$$

Further, Fleckenstein and Longstaff (2020) find that throughout the sample period of 1991-2018, the funding basis is directly associated with the cost of balance sheet usage by financial intermediaries, and that it increases when intermediaries are required to hold more regulatory capital. Barth and Kahn

(2021) find that hedge funds' funding costs, Treasury market volatility, and the amount of Treasuries on dealers' balance sheets are all associated with deviations from arbitrage. The findings of Fleckenstein and Longstaff (2020), and Barth and Kahn (2021) implies that limits to arbitrage have to be considered as a potential explanation in the case of the null hypothesis being rejected.

3.2 Excess returns

The basis of a Treasury futures contract and a corresponding Treasury note can be mathematically defined as

$$B = P - F \times C \tag{3.1}$$

where B is the basis, P is the spot price per \$100 face value, F is the futures price per \$100 face value of the contract, and C is the conversion factor for the Treasury futures contract (Burghardt and Belton, 2005, p. 4).

We compute the conversion factor for each Treasury note in accordance with Chicago Board of Trade (CBOT) regulation, outlined in appendix A1.[2] The CBOT uses a conversion factor to increase the deliverable set of Treasuries by placing Treasuries that differ in remaining time to maturity and coupon rates on roughly equal footing (Burghardt and Belton, 2005, p. 6).[3] We include both callable and non-callable notes in the analysis.[4]

When the spot price is higher than the product of the futures price with the corresponding conversion factor, the basis is positive, and vice versa. The strategy involves a short position in the higher priced of the two, and a long position in the other, as by no arbitrage the spot price has to converge to the futures price at the delivery date of the futures contract. When a long basis position is taken, a short futures position is taken in combination with a long position in the spot Treasury note financed with a repurchase agreement (repo),

[2] When computing the conversion factor we account for the fact that the formula provided by the CBOT was 20 basis points higher than the current rate of 6% before March 2000 (CFTC, 2005)

[3] For the CBOT regulations of Treasuries eligible for delivery into the futures contract, see appendix A2.

[4] The two differ in how the conversion factor is calculated with respect to the remaining time to maturity, outlined in appendix A1

i.e. a Treasury note is purchased in the spot market and delivered into the repo transaction as collateral in exchange for the cash price, where the trader agrees to buy the Treasury back at a higher price (Veronesi, 2010, p. 15).When a short basis position is taken, a long futures position is taken in combination with a reverse repo transaction, where the Treasury note received is subsequently sold outright in the market, and the trader agrees to sell it back at a lower price.

The difference between the initial price and the price which the security is either bought or sold back at is called a *haircut*. In addition, the trader pays the repo rate on the initial price less the haircut (Veronesi, 2010, p. 16). For simplification purposes in the analysis, we assume that there is no haircut in the repo transaction. Considering this, and that as mentioned further down that we do not estimate margin maintenance cost, no risk-free rate is subtracted from the strategy returns to get the excess returns, as there is no initial cash outlay. This is not too unreasonable, as in reality the haircut is quite small, and hedge funds can in the most extreme cases achieve a leverage of 50 to 1. Barth and Kahn (2021) point out that in 2019, hedge funds they classified as basis traders had a mean leverage of 21, with a standard deviation of 17.6 (Barth and Kahn, 2021, p. 29).

When calculating the basis in equation 3.1, we account for the fact that a specific Treasury note will be the least expensive to deliver in the short-futures position, which is referred to as the cheapest-to-deliver (CTD) security. We follow Burghardt and Belton (2005) in identifying the CTD, which is to select the security with the highest implied repo rate (IRR), which can be understood as the security that offers the highest theoretical return relative to the futures in a long basis position Burghardt and Belton (2005, p. 15). When computing the implied repo rate, it is necessary to account for whether there is an intervening coupon payment in the holding period or not. To account for intervening coupons, we emulate a coupon schedule for all deliverable Treasuries based on the information of the first coupon date, issue date, and number of coupon payments per year contained in the spot market data obtained from CRSP. Equation 3.2 shows the equation for the IRR in the case of no intervening coupon payment, and equation 3.3 shows the equation for the IRR with an intervening coupon payment (Burghardt and Belton, 2005, pp. 15-16).

$$IRR = \left(\frac{Invoice\,Price}{Purchase\,Price} - 1\right) \times \frac{360}{n} \tag{3.2}$$

$$IRR = \frac{(Invoice\,Price + \frac{c}{2} - Purchase\,Price) \times 360}{(Purchase\,Price \times n) - (\frac{c}{2} \times n_2)} \tag{3.3}$$

Where C is the annual coupon, n is the number of days to delivery, n_2 is the number of days from the coupon date to delivery, $Invoice\,Price$ and $Purchase\,Price$ are defined as

$$Invoice\,Price = Futures \times Conversion\,Factor + Accrued\,Interest$$

$$Purchase\,Price = Quoted\,Price + Accrued\,Interest$$

The basis trade has two sources of profit: changes in the basis, and carry. The carry consists of, depending on whether the basis trader enters a long (short) position, coupon income (expense) and financing cost (income). The carry is calculated as the coupon leg net of the financing leg. As in the case of the IRR, one must account for any intervening coupon payment in the holding period. Equation 3.4 and 3.5 show the case of coupon income and financing cost, respectively, with no intervening coupon payment. Equation 3.6 and 3.7 show the same, but with an intervening coupon payment (Burghardt and Belton, 2005, p. 235).

$$Coupon\,Income = \frac{c}{2} \times \frac{D}{DCOUP1} \tag{3.4}$$

$$Financing\,Cost = (P + ACC) \times \left(\frac{RP}{100}\right) \times \left(\frac{D}{360}\right) \tag{3.5}$$

$$Coupon\,Income = \left(\frac{c}{2}\right) \times \left[\left(\frac{D1}{DCOUP1}\right) + \left(\frac{D2}{DCOUP2}\right)\right] \tag{3.6}$$

$$
\begin{aligned}
Financing\,Cost = (P + ACC) \times \left(\frac{RP}{100}\right) \times \left(\frac{D1}{360}\right) \\
+ P \times \left(\frac{RP}{100}\right) \times \left(\frac{D2}{360}\right)
\end{aligned} \tag{3.7}
$$

Where c is the annual coupon, P is the clean price of the note, ACC is the accrued interest on the note, RP is the term repo in percentage, D is the actual number of days for which carry is computed, $D1$ is the number of days from the purchase of the bond to the coupon payment date, $D2$ equals $D - D1$, $DCOUP1$ is the actual number of days between the most recent coupon payment date and the upcoming coupon payment, and $DCOUP2$ is the number of days in the next coupon period.

With regards to the appropriate funding rate, it would have been desirable to use the Delivery-versus-Payment (DVP) overnight repo rate from the Fixed Income Clearing Corporation (FICC), as hedge funds participate in the DVP through the sponsorship service (Barth and Kahn, 2021, p. 30). However, we are unable to find a repo rate with a sufficiently long time period for the main analysis. Hence, we follow (Vignola and Dale, 1980) in that we use the federal funds rate as a proxy for the overnight repo rate. As (Vignola and Dale, 1980) point out, the federal funds rate is usually higher than the overnight repo rate, as the federal funds rate is the rate on an overnight unsecured loan, whereas the repo rate is the rate on an overnight collateralized loan. Due to the strategy in our analysis taking mostly short basis positions, we expect this to introduce a positive bias into the analysis.

As we were able to obtain the GCF repo rate from the Depository Trust & Clearing Corporation (DTCC), even though it only covers the time period from January 3, 2005 to December 30, 2022, we follow Barth and Kahn (2021) in using the GCF repo rate as a proxy for the DVP repo rate in our additional analysis, comparing the results from the strategy with the federal funds effective rate with the strategy using the GCF repo rate. As the GCF repo rate is an interdealer rate, it will be slightly higher than the DVP sponsored rate, as the sponsor has to guarantee for the trades of the entities it sponsors (Barth and

Kahn, 2021, p. 31). We assume this effect to be negligible.

Equation 3.4, 3.5, 3.6, and 3.7 above estimate the total carry for the whole period, assuming that a term repo is utilized. However, since we in our analysis employ an overnight rate, we need to make some adjustments to the equations. We calculate daily profit and losses from the coupon, funding, and change in basis, and subsequently sum them up for the month. In this case, the equations become as equation 3.8 and 3.9 up until the intervening coupon payment (or for the whole period if there is none), and as 3.10 and 3.11 after the coupon payment.

$$Coupon\, Income = \left(\frac{c}{2}\right) \times \left(\frac{1}{DCOUP1}\right) \tag{3.8}$$

$$Financing\, Cost = (P + ACC) \times \left(\frac{RP}{100}\right) \times \left(\frac{1}{360}\right) \tag{3.9}$$

$$Coupon\, Income = \left(\frac{c}{2}\right) \times \left(\frac{1}{DCOUP2}\right) \tag{3.10}$$

$$Financing\, Cost = P \times \left(\frac{RP}{100}\right) \times \left(\frac{1}{360}\right) \tag{3.11}$$

Throughout the time series of the excess returns, we compute the carry and the change in basis for each trading day, which is then subsequently summed up to monthly observations. Additionally, to account for transaction costs, we use the monthly mean bid-ask spread of the Treasury note for the respective month. Hence, the daily profit and loss is computed as in equation 3.12.

$$P\&L_t = \Delta Basis_t + Carry_t - BA_t \tag{3.12}$$

Since the profit and loss is computed at \$100 par-value at all stages, we can consider the profit and loss as how much the strategy yields per \$100, meaning that it becomes our monthly excess return series by dividing the summed profit and loss by 100, as in equation 3.13.

$$r_t = \frac{P\&L_t}{100} \tag{3.13}$$

We base the strategy on a monthly holding period – taking a position based on the direction of the basis at the beginning of each month, and unwinding it at the end of the month. A quarterly holding period might seem reasonable given that the nearby futures contract expires on a quarterly basis. In reality, however, such a long holding period might prove infeasible due to margin risk and leverage. For simplification purposes, we do not attempt to estimate margin maintenance costs, because, as Hegde and Branch (1985) point out, they are difficult to estimate as they depend upon daily movements in the futures rates (Hegde and Branch, 1985, p. 411).

3.3 Regression

3.3.1 Model specification

To investigate the risk and return characteristics of the basis trade, we will perform OLS multivariate regressions on the strategy excess returns from the 2-year, 5-year and 10-year futures contracts on a set of different bond and equity market portfolios. The rationale for including equity market factors, as Duarte et al. (2007) point out, is that there are common risk factors that drive returns in both equity and bond markets. We take Duarte et al.'s (2007) model for investigating fixed income arbitrage strategies as a starting point. They include the excess returns of the CRSP Fama 2-year, 5-year, and 10-year bond portfolios to account for bond market risk. To account for equity market risk, Duarte et al. (2007) include the excess returns of the up-minus-down (UMD), and the Fama-French (1993) market, small-minus-big (SMB), and high-minus-low (HML) portfolios. To account for default risk, they include the excess returns of A/BBB-rated general industrial bond and A/BBB-rated bank sector bond portfolios provided by Merrill Lynch.

Due to data limitations, we were not able to retrieve the sector specific corporate bond index portfolios of Duarte et al. (2007) Hence, we resort to a proxy, using a BBB-rated general corporate bond index.[5] Further, we include the log changes in the Merill Lynch Volatility Estimate (MOVE) index, a bond market volatility index, as Barth and Kahn (2021) point out that deviations from arbitrage is

[5]The ICE BofA BBB US Corporate Index Total Return

highly correlated with volatility in financial markets (Barth and Kahn, 2021, p. 21). To account for time-varying risk premia, we split the full sample into two subsamples, to see if there are any structural changes in the risk and return characteristics of the basis trade.

We end up with a different model than Duarte et al. (2007). This is in the first instance due to multiple of the independent variables having a high degree of correlation, which might pose itself as a problem when subsampling as it can lead to problems of multicollinearity. This is confirmed by calculating the variance inflation factors (VIF) of the independent variables, see appendix A6. Brooks (2019) points out that as a rule of thumb, if the VIF is below 5, multicollinearity can be assumed to be negligible, whereas if it is equal to 5 or higher, the problem must be addressed (Brooks, 2019, p. 215). With near multicollinearity, the regression becomes sensitive to even small changes in the model specification and the standard errors will be high, thus making it difficult to make proper inferences (Brooks, 2019, p. 215). Hence, we drop any variables with a VIF equal to or larger than 5.

The CRSP Fama 2-year, 5-year, and 10-year bond portfolios have extremely high correlations, which is also revealed to be an issue after calculating the VIFs. We end up, after excluding independent variables with a high degree of near multicollinearity, with the following model:

$$R_{i,t} = \alpha + \beta_1 R_{NOTE,t} + \beta_2 MOVE_t + \beta_3 R_{M,t} + \beta_4 SMB_t + \beta_5 HML_t + \beta_6 UMD_t + \beta_7 R_{SPB,t} + \epsilon_t \quad (3.14)$$

Where R_{NOTE} is the excess returns of the underlying CRSP Fama bond portfolio, i.e. either the 2-year, 5-year or 10-year portfolio. We include this to see if the strategy loads on bond market risk from the underlying note. MOVE is the log change in the MOVE index, which is the implied volatility of Treasury options. We include this to account for financial market volatility, as Barth and Kahn (2021) point out that deviations from arbitrage are highly correlated with volatility in financial markets (Barth and Kahn, 2021, p. 21). To account for equity market risk, we include the Fama and French (1993) market, SMB and HML factor, the UMD factor, and the S&P bank stock index excess returns.

SMB is the excess returns of the small-minus-big factor, which Duarte et al. (2007) point out is correlated with corporate defaults, and hence contains some default risk. HML is the excess returns of the high-minus-low factor. UMD is the excess returns of the up-minus-down, or momentum, factor. R_{SPB} is the excess returns of the S&P bank stock index portfolio. Duarte et al. (2007) point out that this captures the risk of major financial events.

3.3.2 Diagnostic tests

We use White's test to test for heteroscedasticity in the residuals. If heteroscedasticity is ignored, the standard errors could be wrong, and thus any inferences made could be misleading (Brooks, 2019, p. 188). If we detect heteroscedasticity in the residuals, we apply White's heteroscedasticity consistent standard errors. We utilize the Breusch Godfrey test to test for autocorrelation in the residuals. If autocorrelation in the residuals is ignored the standard errors could be inappropriate, and hence the wrong inferences could be made (Brooks, 2019, p. 200). A challenge when employing the Breusch Godfrey test is how to determine the number of lags when estimating the auxiliary regression. Brooks (2019) suggests considering the frequency of the data to decide how many lags to use in the test (Brooks, 2019, p. 276), which would suggest using 12 months in our case as we are dealing with monthly data. However, we use 3 lags, as we expect that the residuals would be related to those in the most recent quarter, due to the quarterly basis of the futures contract. If autocorrelation is detected, we use Newey-West's heteroscedasticity and autocorrelation consistent standard errors to avoid making wrong inferences.

4 Data

4.1 Data collection

We obtain a comprehensive dataset of daily observations of all Treasury securities from the Center for Research in Security Prices (CRSP) over the time period June 14, 1969 to March 31, 2023. These contain the type of issue, maturity date, coupon, accrued interest, first coupon date, issue date, first callable date, and bid-, ask-, and nominal prices. The daily spot data is fairly comprehensive with more than 100 million data points. We obtain the Treasury futures price data for the nearby contract on the 2-year, 5-year, and 10-year Treasury note futures contracts provided by the Chicago Mercantile Exchange (CME) from the Bloomberg system.[6] The futures price data dates back to June 22, 1990 for the 2-year contract, to June 2, 1988 for the 5-year contract, and May 3, 1982 for the 10-year contract, which leaves us with 99, 105, and 123 contracts, respectively. We follow Barth and Kahn (2021) by beginning the sample January 1, 1992, as they point out that the 2-year and 5-year futures contracts were very thinly traded in the beginning (Barth and Kahn, 2021, p. 13).

We obtain the federal funds effective rate, provided by the Board of Governors of the Federal Reserve System (US) from FRED, Federal Reserve Bank of St. Louis.[7] We obtain the Treasury GCF Weighted Average repo rate from the Depository Trust & Clearing Corporation (DTCC).[8] We get the Fama 2-year, 5-year, and 10-year maturity portfolios from the CRSP Treasury database with quarterly updates.[9]. We get the up-minus-down, the Fama and French (1993) market, small-minus-big, and high-minus-low excess returns from Kenneth French's online data library. Our final sample covers the period from January 1, 1992 to March 31, 2023.

4.2 Preliminary analysis

Table 4.1: January 1, 1992 - March 31, 2023, summary statistics

	N	S	L	μ	σ	Min	Med.	Max	Skew	Kurt
2Y	375	356	19	-0.034	0.696	-1.122	0.018	0.727	-1.346	5.688
5Y	375	307	68	1.090	1.591	-1.211	0.043	2.318	1.120	4.556
10Y	375	359	16	-1.432	1.687	-2.349	0.009	1.489	-1.311	2.721

Where 2Y is the 2-year, 5Y is the 5-year, 10Y is the 10-year, N is the number of trades, S is the number of times short, L is the number of times long, μ is the annual mean, σ is the annual standard deviation, and Kurt is the excess kurtosis.

[6] The tickers in the Bloomberg system for these are TU1COMB, FV1COMB, and TY1COMB

[7] Board of Governors of the Federal Reserve System (US) (2023)

[8] Depository Trust & Clearing Corporation (2023)

[9] The 2-year portfolio includes Treasuries of between 18 and 24 months maturity, the 5-year between 48 and 60 months, and the 10-year between 60 and 120 months

In the past three decades, our trading strategy, spanning 375 trades, has primarily favored short positions across 2-Year, 5-Year, and 10-Year Contracts. Despite the common preference for shorts, contracts showed distinct behaviors - negative mean returns for the 2-Year and 10-Year Contracts and positive for the 5-Year, with the least volatility for the 2-Year Contract. The return distributions across all contracts were leptokurtic. Although short trades remained popular throughout, a recent shift towards long positions is noticeable. The variability in annual returns and risk profiles, coupled with a recent surge in excess kurtosis, highlights evolving opportunities and risks.

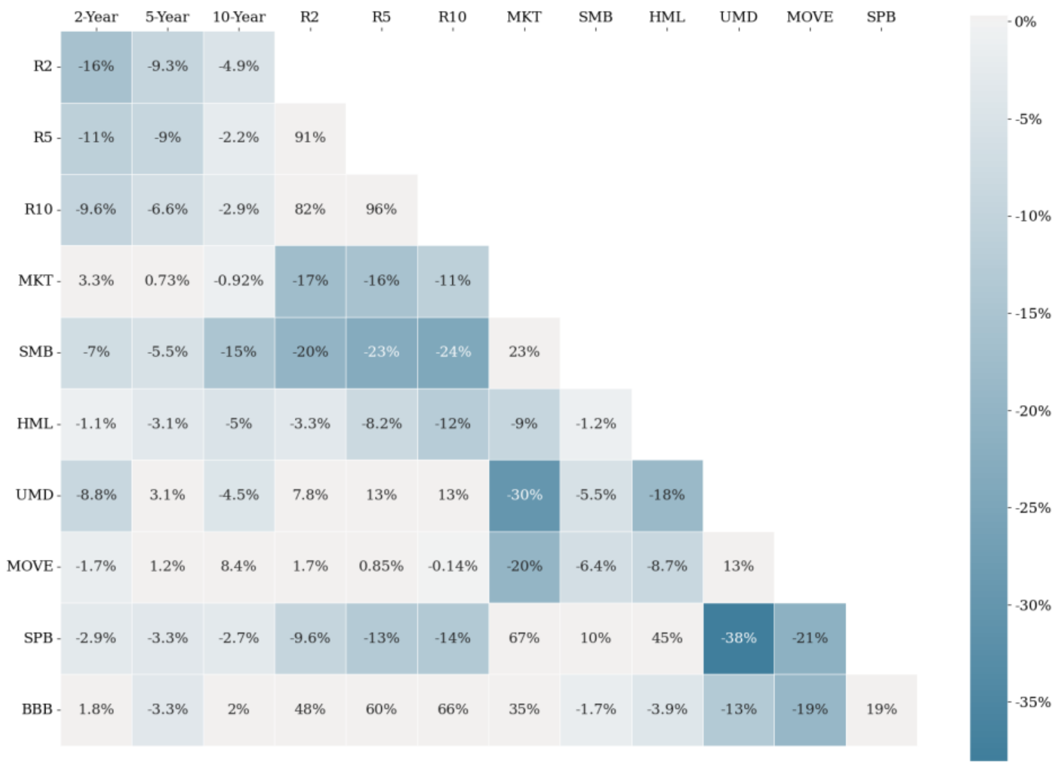

Figure 4.1: Correlation matrix of dependent and independent variables, before exclusion of variables with VIF greater than 5

5 Results and analysis

5.1 Full sample analysis

Table 5.1 shows the strategy regression results of the 2-year, 5-year, and 10-year Treasury futures contract. We observe that the alpha is insignificant for the 2-year contract, significantly positive at the 1% level for the 5-year contract, and significantly negative at the 1% level for the 10-year contract. Even though the alpha is insignificant, the 2-year is negatively associated with the underlying 2-year maturity portfolio, SMB, UMD, and the S&P bank sector index excess returns, which indicates that the 2-year futures contract strategy loads to some degree on both bond and equity market risk. As observed, the model is only able to explain 5.42% of the strategy returns, and we conclude that the 2-year in the full sample generates no significant alpha, with little degree of bond and equity market risk.

Table 5.1: January 1, 1992 - March, 31 2023 regression result, 0bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0002	1.7695	0.0011	4.0745	-0.0009	-4.2355
R_{NOTE}	-0.0801	-2.4474	-0.0455	-1.6416	-0.0227	-0.9607
R_M	0.0057	1.6391	0.0073	0.9714	0.0030	0.3416
R_{SMB}	-0.0080	-2.2419	-0.0126	-1.7207	-0.0261	-2.5928
R_{HML}	0.0033	0.9507	0.0009	0.1091	-0.0077	-0.8089
R_{UMD}	-0.0039	-2.1284	0.0028	0.7185	-0.0061	-1.3795
R_{SPB}	-0.0049	-1.9728	-0.0049	-0.9077	-0.0012	-0.2286
$MOVE$	-0.0002	-0.4596	0.0002	0.1215	0.0023	1.3925
R^2	0.0542		0.0191		0.0376	
R^2 *adj.*	0.0362		0.0004		0.0192	
N	375		375		375	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

The 5-year futures contract strategy yields a monthly alpha at 0.11%, which is significant at the 1% level of significance. Further, we observe that it does not load significantly on any of the bond or equity market risk factors. The 10-year futures contract strategy yields a negative alpha which is significant at the 1% level, combined with a significant loading on the SMB factor. However, as the model is only able to explain 3.76% of the variation in the strategy returns, the strategy gives a negative alpha without being explained by risk market factors. This might be due to the 10-year Treasury notes having higher duration, hence leading to sudden divergence of the basis.

5.1.1 Threshold analysis

We also test the strategies at different signal thresholds to see if reducing noise from the basis improves the returns, see table A3.1 and A3.2. By increasing the signal threshold to 10bps, the first observation is that it reduces the explanatory power of the model for each trade. Further increasing it to 20bps, the R^2 increases again, but does not exceed the levels observed at 0bps. For the 2-year futures contract strategy, the significance and magnitude of the alpha remains the same at the 10bps signal threshold, but at 20bps it yields a monthly alpha of 0.03%, which is significant at the 1% level. Further, the significance of the SMB factor decreases with increasing the signal threshold. The 10-year futures contract strategy is unaffected by changing the signal threshold, but there is a marginal change in the magnitude of each coefficient. When increasing it to the 20bps threshold, it yields an alpha of 0.03%. Increasing the threshold has little effect on the risk loadings for the 5-year Treasury note futures contract, but the magnitude of the alpha decreases. For the full sample, increasing the threshold improves the results in the 2-year and 10-year strategy, but reduces the alpha of the 5-year. However, what the threshold analysis demonstrates, is that the alpha is persistent across the contracts.

5.2 Subsample analysis

To address whether there are time-varying risk premia, we divide the full sample into two subsamples of equal length. Starting with the first sample (1992-2007), see table 5.2 the 2-year strategy has no factor loadings for the first 15 years, and no significant alpha. The 5-year strategy does not load on any of the independent variables, but generates a positively significant alpha, whereas the 10-year strategy generates a significantly negative alpha of -0.10%, lower than in the full sample. For all three strategies, the R^2 is very low, ranging from 2.47% to 4.31%.

Table 5.2: January 1, 1992 - August 31, 2007 regression result, 0bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	-0.0001	-0.5280	0.0011	2.5060	-0.0010	-3.0322
R_{NOTE}	-0.0476	-0.9422	-0.0548	-1.2306	-0.0029	-0.0904
R_M	0.0070	1.0827	0.0147	1.1226	0.0041	0.2250
R_{SMB}	-0.0106	-1.6764	-0.0130	-1.1310	-0.0137	-0.9638
R_{HML}	0.0062	1.0220	0.0055	0.4074	0.0089	0.5966
R_{UMD}	-0.0053	-1.5981	0.0073	1.3686	-0.0069	-0.9948
R_{SPB}	-0.0045	-0.8857	-0.0023	-0.2367	0.0020	0.1751
$MOVE$	-0.0003	-0.2612	0.0029	1.2119	0.0018	0.6778
R^2	0.0431		0.0271		0.0247	
R^2 *adj.*	0.0059		-0.0107		-0.0132	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

For the second sample period (2008 to 2023), see table 5.3 we observe some changes in both the 2-year and 10-year strategy, but remaining characteristically the same for the 5-year strategy. During this sample period, the 2-year generates a significant alpha of 0.05% per month at the 1% significance level, with the underlying bond portfolio and the S&P bank stock index loading significantly negative. Additionally, the model's explanatory power increases to 23.71%. The 5-year contract changes in that the magnitude of the alpha is reduced. The 10-year contract still yields a significantly negative alpha of the same magnitude as the previous sample, but now significantly loads on the SMB factor.

Table 5.3: September 30, 2007 - March, 31 2023 regression result, 0bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0005	6.4297	0.0009	3.7743	-0.0010	-3.3525
R_{NOTE}	-0.1132	-4.0844	-0.0450	-1.4164	-0.0499	-1.7037
R_M	0.0046	1.4327	0.0028	0.3333	0.0047	0.5588
R_{SMB}	0.0033	1.2800	-0.0118	-1.2006	-0.0358	-2.4699
R_{HML}	-0.0000	-0.0147	0.0016	0.1859	-0.0254	-1.5578
R_{UMD}	-0.0015	-1.0711	-0.0036	-0.7929	-0.0098	-1.8562
R_{SPB}	-0.0052	-2.4184	-0.0091	-1.5331	-0.0007	-0.1114
$MOVE$	-0.0001	-0.3900	-0.0021	-1.9192	0.0023	1.0246
R^2	0.2371		0.0496		0.0927	
R^2 *adj.*	0.2072		0.0125		0.0572	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

5.2.1 Threshold analysis

Regardless of signal threshold, the 2-year see no changes in the first subsample. However, for the last 15 years the alpha suffers with increasing threshold, but it improves the exposure to the underlying bond portfolio, pushing it closer to zero. However, increasing the threshold also increases the strategy to more negative exposure towards the bank sector whilst adding positive exposure towards the market portfolio. Increasing the signal to 10bps for the 5-year, it does not change the purity of the alpha but the increase reduces the magnitude, similarly to how it reduces the alpha of the full sample. Increasing it further it simply follows the same pattern in the first subsample, but for the second sample we see some structural changes. From 2008-2023 the increasing bps effectively extinguishes the alpha, making it insignificant, and simultaneously introducing an inverse exposure to the banking sector. The alpha of the 10-year benefits from increasing the signal threshold for the first subsample, making it increasingly less negative. With respect to risk exposure, increasing the signal strength to 10bps completely diminishes the risk exposure to SMB for the second subsample. At 20bps the alpha keeps getting less negative, though the SMB exposure reappears at greater strength than initially.

What these thresholds demonstrate is that the performance of the strategy and how it is employed is highly sensitive to the levels of the signal thresholds. For the 10-year it clearly benefits from higher thresholds, suggesting that its performance may improve at a higher level than those we have tested for. But for the 5-year, increasing the threshold has negative effects on its performance, having the opposite effect than it has for the 10-year. Lastly, for the 2-year the threshold functions more like a gauge for "refining" the exposures but at the cost of diminishing alpha.

5.3 GCF versus federal funds effective rate

We also investigate to what degree changing the financing rate from the federal funds effective rate to the GCF repo rate impacts the results. Thus far, we have utilized the federal funds effective rate. As discussed in an earlier section, since the GCF repo rate is the rate on a collateralized loan, whereas the federal funds rate is the rate on an overnight unsecured loan, the federal funds effective rate is usually higher. As the strategies predominantly takes short basis positions, this introduces a positive bias into the financing income. The mean spread between the federal funds effective rate and the GCF repo rate is 0.0056%, with a standard deviation of 0.1778%. Figure 5.1 plots the two and the spread. We conclude that the impact of using the federal funds effective rate in the full sample analyses does not significantly impact our estimates, such that the bias is minimal.

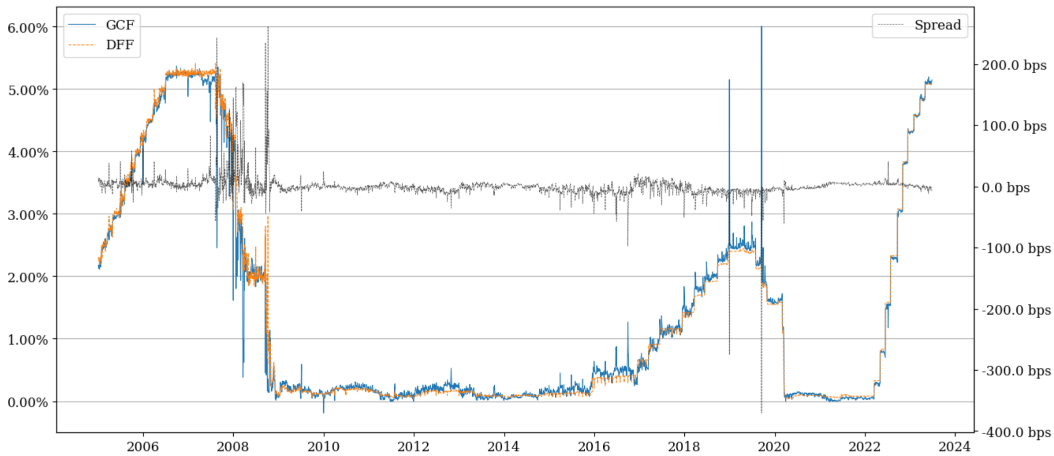

Figure 5.1: January 31, 2005 - March 31, 2023, Federal funds effective rate, GCF repo rate, and the spread

Switching from the federal funds effective rate to the GCF repo rate impacts the regression results marginally, as can be observed in table 5.4 and 5.5. However, we can see a slight increase in the R^2 when using the GCF rate instead, which might indicate that the strategy excess returns are marginally better explained when using an actual repo rate instead of the federal funds effective rate.

Table 5.4: January 31, 2005 - March 31, 2023 regression result with GCF repo, 0bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0004	6.2326	0.0007	3.4669	-0.0008	-3.1672
R_{NOTE}	-0.1119	-4.2272	-0.0419	-1.4903	-0.0502	-1.8166
R_M	0.0047	1.3950	0.0029	0.3325	0.0074	0.8910
R_{SMB}	0.0030	1.2665	-0.0110	-1.2613	-0.0312	-2.3609
R_{HML}	-0.0003	-0.0936	-0.0010	-0.1213	-0.0217	-1.4143
R_{UMD}	-0.0014	-1.0138	-0.0038	-0.8065	-0.0079	-1.4938
R_{SPB}	-0.0050	-2.2829	-0.0080	-1.2575	-0.0024	-0.3993
$MOVE$	-0.0003	-0.7810	-0.0018	-1.8470	0.0025	1.2930
R^2	0.2367		0.0448		0.0830	
R^2 *adj.*	0.2113		0.0131		0.0526	
N	219		219		219	

Regression results from analysis using the GCF repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table 5.5: January 31, 2005 - March 31, 2023 regression result with FFR, 0bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0004	6.3949	0.0007	3.5152	-0.0008	-3.1759
R_{NOTE}	-0.1079	-4.3017	-0.0409	-1.4586	-0.0500	-1.8157
R_M	0.0042	1.3349	0.0024	0.2887	0.0068	0.8359
R_{SMB}	0.0030	1.2928	-0.0108	-1.2462	-0.0313	-2.3665
R_{HML}	-0.0002	-0.0776	-0.0009	-0.1013	-0.0217	-1.4135
R_{UMD}	-0.0013	-0.9359	-0.0037	-0.7768	-0.0078	-1.4814
R_{SPB}	-0.0049	-2.2890	-0.0079	-1.2471	-0.0022	-0.3754
$MOVE$	-0.0003	-0.8374	-0.0018	-1.8717	0.0025	1.2778
R^2	0.2296		0.0443		0.0829	
R^2 *adj.*	0.2041		0.0126		0.0525	
N	219		219		219	

Regression results from analysis using the federal funds effective rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

To summarize, in the full sample the basis trade strategy with the 2-year futures contract generates no significant alpha but is negatively associated with the underlying bond portfolio, the SMB factor, the UMD factor, and the S&P bank stock index excess returns, but these loadings only account for 5.42% of the return variation. The 5-year strategy generates a significantly positive alpha of 0.11% while not loading on any of the factors. The 10-year strategy generates a significantly negative monthly alpha of -0.09%, and is negatively associated with the SMB factor, with an R^2 of only 3.76%.

In the first subsample, the significance and sign of the alphas remain as in the full sample, but the magnitudes change, and the model is still not able to explain much of the variation in returns. In the second subsample, the 2-year strategy alpha becomes significant and positive, and is negatively associated with the underlying bond portfolio and the S&P bank stock index excess returns, with the model explaining 23.71% of the return variation. The 10-year strategy, however, remains yielding a significantly negative alpha.

An inherent weakness of our strategy is that we for simplification purposes assumed away the repo haircut and the margin maintenance costs. The haircut is less impactful, but we expect that the margin maintenance costs would have given a better picture into the strategy risk and return performance during volatile times in the Treasury markets.

6 Conclusion

We investigate the risk and return characteristics of the basis trade, and see whether it generates returns in excess of any bond or equity market risk factors. We find that in the full sample, the strategy for the 2-year futures contract yields no significant alpha with a marginally negative correlation to the equity market risk factors. The 5-year strategy generates a significant positive alpha without factor loadings. Dividing our sample into two equal subsamples, we find that the 2-year strategy generates significant and positive alpha for the last 15 years, accompanied by negative loadings on both bond and equity market risk factors where the model have a relatively high ability to explain the variations in the strategy return variation (23.71%). For the 10-year strategy, it is significantly negative in all samples.

In conclusion, we reject the null-hypothesis for the 5-year as we do observe significant alpha in both the full sample and the subsample. As for the 2-year, we fail to reject the null-hypothesis for the full sample, but it is rejected in the second half of the subsample, as the alpha is significant for the last 15 years. Further we cannot rule out that the significant alphas observed in the 2-year or 5-year contracts might stem from limits to arbitrage. Our analysis is limited by the fact that we do not account for haircuts on repo transactions or margin maintenance costs.

We believe that future research should extend the analysis by including both repo haircuts and margin maintenance costs, and also use intraday prices like Elton et al. (1984) to conduct a direct test of market efficiency with more realistic prices. Using closing prices might not be granular enough, as the basis trade without leverage is marginal in size, and hence can be sensitive to small price differences. More realistic trading prices while including futures margin maintenance costs might therefore give a better indication of the true profitability and riskiness of this trade.

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Appendix

A1 Conversion factor

CME Group defines a Treasury securities conversion factor as (CME, 2023):

$$factor = a \times \left[\left(\frac{coupon}{2}\right) + c + d\right] - b$$

$$v = \begin{cases} z, & \text{if z} < 7 \\ 3, & \text{if z} \geq 7 \text{ (for 30-year and 10-year)} \\ (z-6) & \text{if z} \geq 7 \text{ (for 2-year, 3-year, and five-year)} \end{cases}$$

$$a = \frac{1}{1.03^{\frac{v}{6}}}$$

$$b = \left(\frac{coupon}{2}\right) \times \frac{6-v}{6}$$

$$c = \begin{cases} \frac{1}{1.03^{2n}}, & \text{if z} < 7 \\ \frac{1}{1.03^{2n+1}}, & \text{if otherwise} \end{cases}$$

$$d = \frac{coupon}{0.06} \times (1-c)$$

- Where $factor$ is rounded to four decimal places, and
- $coupon$ is the bond's annual coupon in decimals.
- n is the number of whole years from the first day of the delivery month to the maturity (or call) date of the bond or note.
- z is the number of whole months between n and the maturity (or call) date rounded down to the nearest quarter for the 10-year U.S. Treasury note and 30-year U.S. Treasury bond futures contracts, and to the nearest month for the 2-year, 3-year, and 5-year U.S. Treasury note futures contracts.

A2 Regulations

Table A2.1

Contract	Original maturity	Remaining maturity
2-year note	$\leq$ 5 years, 3 months	$\geq$ 1 year, 9 months $\leq$ 2 years
5-year note	$\leq$ 5 years, 3 months	$\geq$ 4 years, 2 months
10-year note	$\leq$ 10 years	$\geq$ 6 years, 6 months $\leq$ 10 years

Where remaining maturity of the actual note is calculated in complete one-month increments from the first day of the corresponding delivery month to the maturity date of the note (CME, 2023).

A3 Regression results

Table A3.1: January 1, 1992 - March, 31 2023 regression result, 10bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0002	1.9281	0.0009	3.5273	-0.0008	-3.9599
R_{NOTE}	-0.0576	-1.8787	-0.0372	-1.3761	-0.0216	-0.9746
R_M	0.0070	2.1068	0.0048	0.6767	0.0050	0.6596
R_{SMB}	-0.0052	-1.6251	-0.0118	-1.7499	-0.0212	-2.6037
R_{HML}	0.0033	1.0588	-0.0018	-0.2354	-0.0066	-0.7418
R_{UMD}	-0.0027	-1.8866	0.0011	0.2839	-0.0029	-0.6832
R_{SPB}	-0.0042	-1.7255	-0.0020	-0.3695	-0.0038	-0.7923
$MOVE$	-0.0000	-0.1019	0.0005	0.4120	0.0010	0.5846
R^2	0.0428		0.0143		0.0275	
R^2 *adj.*	0.0246		-0.0045		0.009	
N	375		375		375	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.2: January 1, 1992 - March, 31 2023 regression result, 20bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0003	3.9739	0.0007	3.1095	-0.0006	-3.2948
R_{NOTE}	-0.0578	-2.5587	-0.0358	-1.4702	-0.0284	-1.3458
R_M	0.0045	1.3081	0.0050	0.7673	0.0024	0.3415
R_{SMB}	-0.0012	-0.6175	-0.0044	-0.8320	-0.0200	-2.6685
R_{HML}	0.0030	0.9340	-0.0034	-0.5586	-0.0032	-0.3860
R_{UMD}	-0.0003	-0.1910	0.0012	0.3813	-0.0024	-0.6083
R_{SPB}	-0.0026	-1.1431	-0.0024	-0.4867	-0.0044	-0.9046
$MOVE$	0.0000	0.0528	0.0012	1.0603	0.0003	0.2026
R^2	0.0505		0.0162		0.0295	
R^2 *adj.*	0.0323		-0.0026		0.0110	
N	375		375		375	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.3: January 1, 1992 - August 31, 2007 regression result, 10bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	-0.0001	-0.2800	0.0010	2.1759	-0.0008	-2.5672
R_{NOTE}	-0.0230	-0.4974	-0.0503	-1.1029	-0.0096	-0.3174
R_M	0.0064	1.0372	0.0085	0.6777	0.0097	0.6600
R_{SMB}	-0.0054	-0.9505	-0.0149	-1.4037	-0.0149	-1.4053
R_{HML}	0.0047	0.8760	0.0012	0.0929	0.0070	0.5224
R_{UMD}	-0.0039	-1.5643	0.0031	0.6073	-0.0020	-0.3046
R_{SPB}	-0.0012	-0.2626	0.0003	0.0326	-0.0053	-0.5752
$MOVE$	0.0002	0.1638	0.0041	1.6458	0.0006	0.2363
R^2	0.0289		0.03		0.0132	
R^2 *adj.*	-0.0089		-0.0077		-0.0252	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.4: January 1, 1992 - August 31, 2007 regression result, 20bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0002	1.7015	0.0010	2.5870	-0.0007	-2.4647
R_{NOTE}	-0.0393	-1.1693	-0.0496	-1.2528	-0.0199	-0.6932
R_M	-0.0020	-0.3792	-0.0002	-0.0176	0.0141	1.0507
R_{SMB}	0.0010	0.3122	-0.0064	-0.7176	-0.0176	-1.8423
R_{HML}	0.0007	0.1474	-0.0083	-0.7247	0.0084	0.6436
R_{UMD}	-0.0000	-0.0167	0.0043	0.9091	0.0003	0.0589
R_{SPB}	0.0045	1.4306	0.0064	0.8067	-0.0111	-1.3355
$MOVE$	0.0001	0.1001	0.0039	1.6609	0.0013	0.5544
R^2	0.0326		0.0306		0.0197	
R^2 *adj.*	-0.005		-0.0071		-0.0185	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.5: September 30, 2007 - March, 31 2023 regression result, 10bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0004	6.0744	0.0007	3.2477	-0.0009	-3.2268
R_{NOTE}	-0.1002	-3.3760	-0.0296	-1.1382	-0.0395	-1.3471
R_M	0.0068	2.2276	0.0025	0.3080	0.0044	0.4955
R_{SMB}	0.0023	0.9947	-0.0051	-0.5843	-0.0274	-1.8711
R_{HML}	0.0017	0.6077	-0.0017	-0.2145	-0.0208	-1.3117
R_{UMD}	-0.0015	-1.1473	-0.0019	-0.3778	-0.0067	-1.3285
R_{SPB}	-0.0059	-2.8071	-0.0060	-0.9141	-0.0019	-0.3120
$MOVE$	-0.0003	-0.9799	-0.0019	-1.9124	0.0010	0.4670
R^2	0.2344		0.028		0.0642	
R^2 *adj.*	0.2044		-0.01		0.0276	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.6: September 30, 2007 - March, 31 2023 regression result, 20bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0003	4.8163	0.0003	1.7529	-0.0005	-2.3360
R_{NOTE}	-0.0933	-3.0691	-0.0301	-1.1828	-0.0396	-1.3473
R_M	0.0076	2.5469	0.0071	1.0459	-0.0030	-0.3976
R_{SMB}	0.0018	0.7502	0.0019	0.3955	-0.0286	-2.0607
R_{HML}	0.0027	0.9682	-0.0004	-0.0769	-0.0102	-0.8349
R_{UMD}	-0.0016	-1.1337	-0.0039	-1.1744	-0.0067	-1.3936
R_{SPB}	-0.0065	-3.0990	-0.0100	-2.1731	-0.0012	-0.2033
$MOVE$	-0.0003	-0.8221	-0.0009	-1.0173	-0.0004	-0.1954
R^2	0.2248		0.0489		0.0592	
R^2 *adj.*	0.1945		0.0117		0.0225	
N	187		187		187	

Regression results from analysis using the federal funds effective rate as a proxy for the repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.7: January 31, 2005 - March 31, 2023 regression result with GCF repo, 10bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0004	5.9633	0.0006	3.1418	-0.0008	-3.1866
R_{NOTE}	-0.0970	-3.4575	-0.0277	-1.0574	-0.0388	-1.3953
R_M	0.0067	2.1081	0.0022	0.2596	0.0062	0.7252
R_{SMB}	0.0016	0.7507	-0.0053	-0.6495	-0.0231	-1.7441
R_{HML}	0.0011	0.3962	-0.0041	-0.5076	-0.0181	-1.2182
R_{UMD}	-0.0016	-1.1995	-0.0022	-0.4355	-0.0052	-1.0610
R_{SPB}	-0.0055	-2.4986	-0.0047	-0.6837	-0.0031	-0.5443
$MOVE$	-0.0003	-0.9909	-0.0016	-1.7523	0.0011	0.5897
R^2	0.2254		0.0247		0.0555	
R^2 *adj.*	0.1997		-0.0076		0.0242	
N	219		219		219	

Regression results from analysis using the GCF repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.8: January 31, 2005 - March 31, 2023 regression result with GCF repo, 20bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0003	4.8032	0.0002	1.6132	-0.0005	-2.3087
R_{NOTE}	-0.0896	-3.1014	-0.0287	-1.1330	-0.0380	-1.3635
R_M	0.0075	2.3926	0.0065	0.9841	-0.0011	-0.1529
R_{SMB}	0.0009	0.4053	0.0006	0.1241	-0.0238	-1.9017
R_{HML}	0.0021	0.7541	-0.0026	-0.4857	-0.0087	-0.7396
R_{UMD}	-0.0017	-1.1951	-0.0043	-1.2608	-0.0052	-1.1156
R_{SPB}	-0.0060	-2.7673	-0.0086	-1.7272	-0.0021	-0.3654
$MOVE$	-0.0002	-0.6812	-0.0006	-0.9091	-0.0001	-0.0347
R^2	0.2132		0.0442		0.0482	
R^2 *adj.*	0.1871		0.0125		0.0166	
N	219		219		219	

Regression results from analysis using the GCF repo rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.9: January 31, 2005 - March 31, 2023 regression result with FFR, 10bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0004	6.0923	0.0006	3.1827	-0.0008	-3.1898
R_{NOTE}	-0.0928	-3.4711	-0.0268	-1.0254	-0.0387	-1.3949
R_M	0.0063	2.0877	0.0018	0.2149	0.0057	0.6732
R_{SMB}	0.0017	0.8199	-0.0052	-0.6276	-0.0232	-1.7523
R_{HML}	0.0012	0.4343	-0.0039	-0.4841	-0.0181	-1.2166
R_{UMD}	-0.0015	-1.1087	-0.0021	-0.4109	-0.0052	-1.0605
R_{SPB}	-0.0054	-2.5259	-0.0046	-0.6736	-0.0030	-0.5150
$MOVE$	-0.0003	-1.1426	-0.0016	-1.7894	0.0011	0.5811
R^2	0.2167		0.0243		0.0555	
R^2 *adj.*	0.1907		-0.0081		0.0241	
N	219		219		219	

Regression results from analysis using the federal funds effective rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

Table A3.10: January 31, 2005 - March 31, 2023 regression result with FFR, 20bps threshold

	2-Year		5-Year		10-Year	
	b	t-stat	b	t-stat	b	t-stat
α	0.0003	4.9208	0.0003	1.6539	-0.0005	-2.2854
R_{NOTE}	-0.0854	-3.0959	-0.0278	-1.1015	-0.0379	-1.3621
R_M	0.0071	2.3834	0.0061	0.9499	-0.0015	-0.2181
R_{SMB}	0.0010	0.4661	0.0008	0.1561	-0.0239	-1.9063
R_{HML}	0.0022	0.8102	-0.0024	-0.4586	-0.0088	-0.7445
R_{UMD}	-0.0016	-1.1147	-0.0042	-1.2325	-0.0052	-1.1138
R_{SPB}	-0.0059	-2.7912	-0.0086	-1.7283	-0.0019	-0.3426
$MOVE$	-0.0002	-0.8341	-0.0006	-0.9643	-0.0001	-0.0470
R^2	0.204		0.0433		0.0487	
R^2 *adj.*	0.1776		0.0115		0.0171	
N	219		219		219	

Regression results from analysis using the federal funds effective rate. R_{NOTE} is the underlying CRSP Fama bond portfolio.

A4 Figures

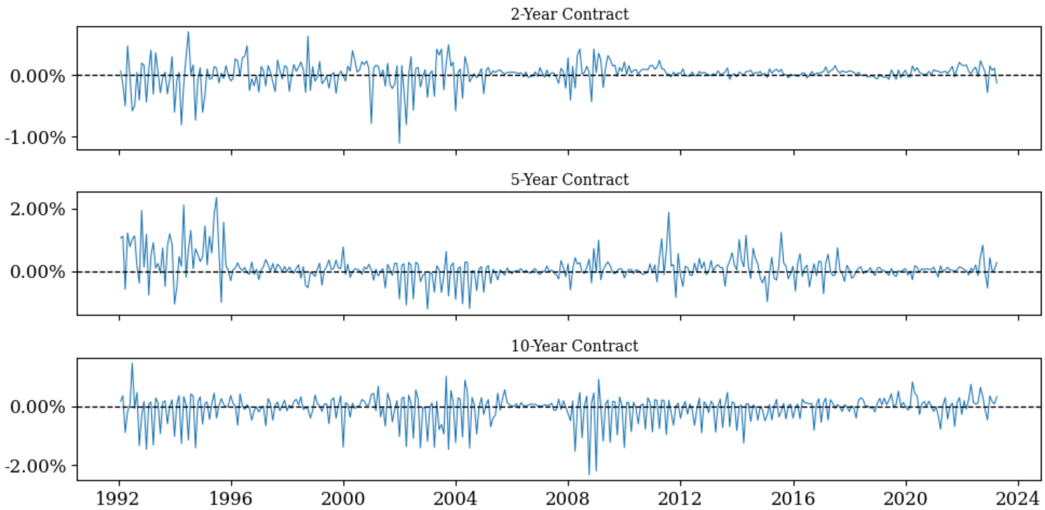

Figure A4.1: January 1, 1992 - March 31, 2023 strategy returns

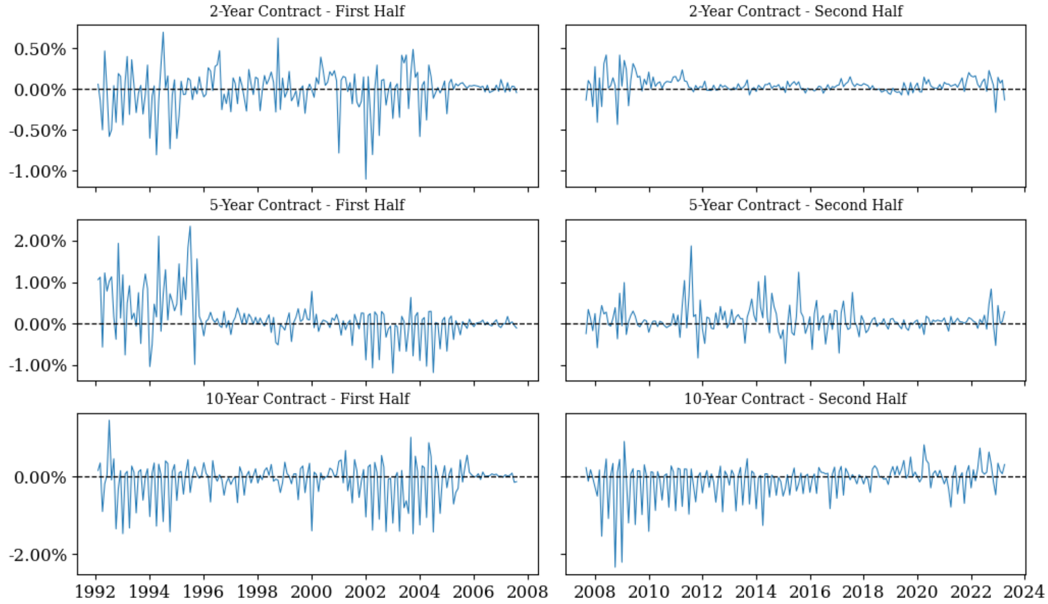

Figure A4.2: January 1, 1992 - August 31, 2007 and September 30, 2007 - March 31, 2023 monthly strategy returns

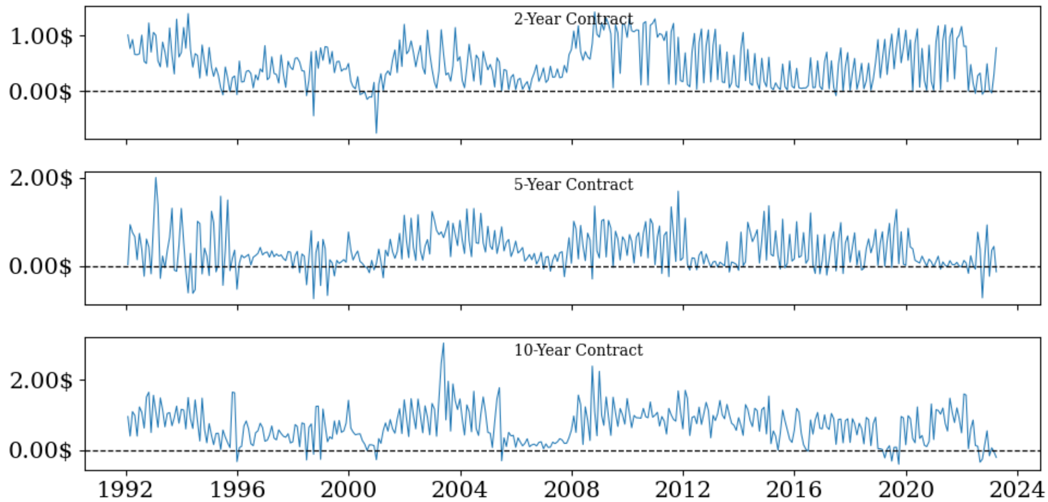

Figure A4.3: January 1, 1992 - March 31, 2023 Basis

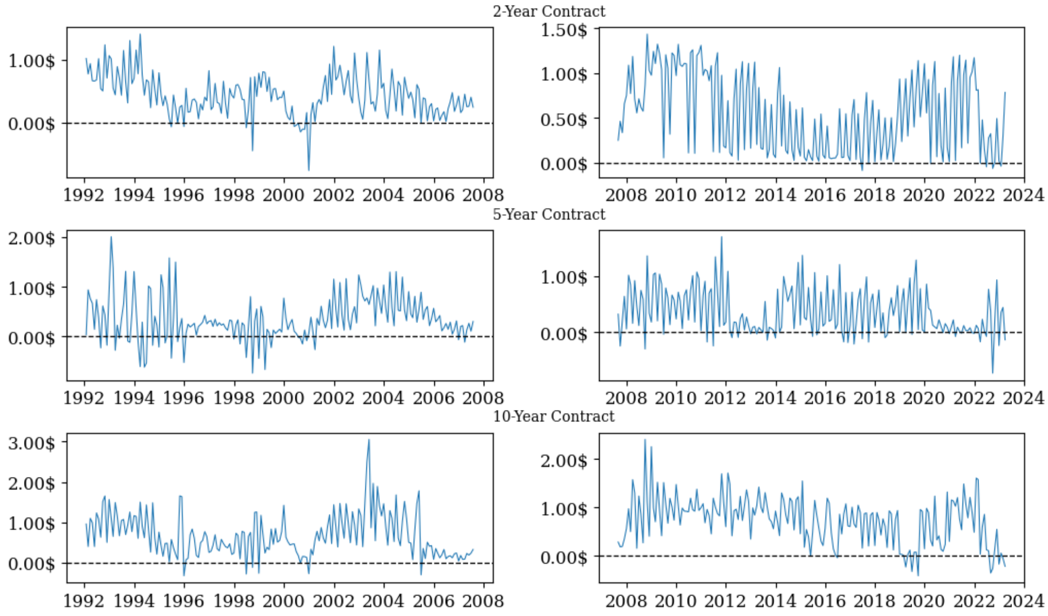

Figure A4.4: January 1, 1992 - August 31, 2007 and September 30, 2007 - March 31, 2023 Basis

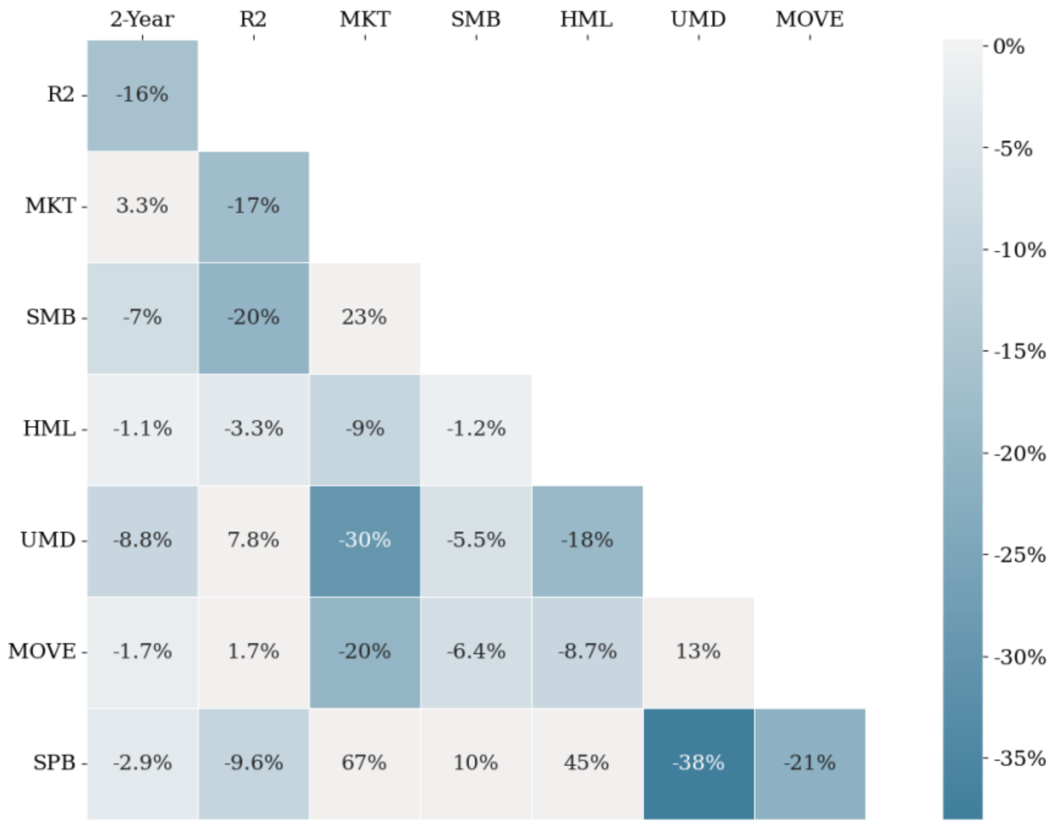

Figure A4.5: Correlation matrix of dependent and independent variables

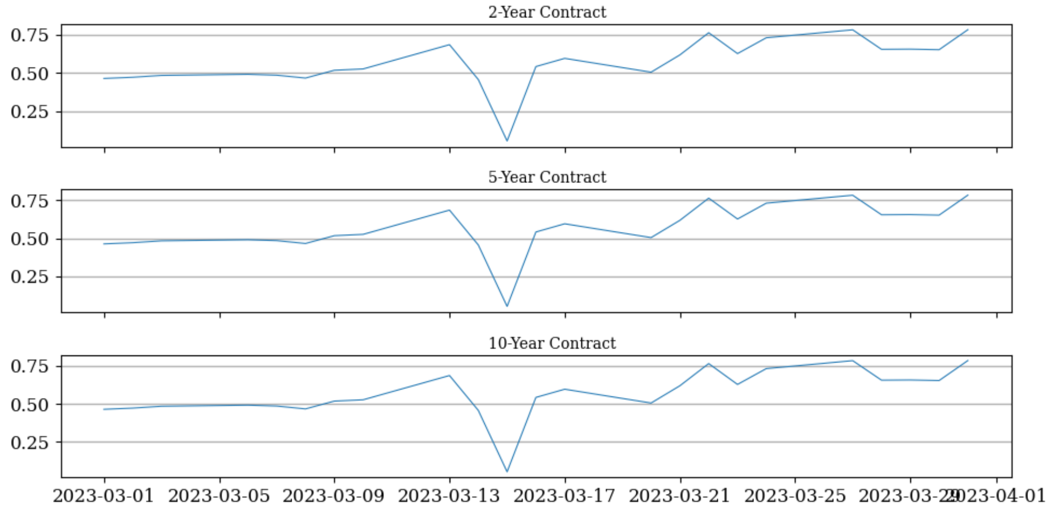

Figure A4.6: January 1, 2023 - March 31, 2023 Basis

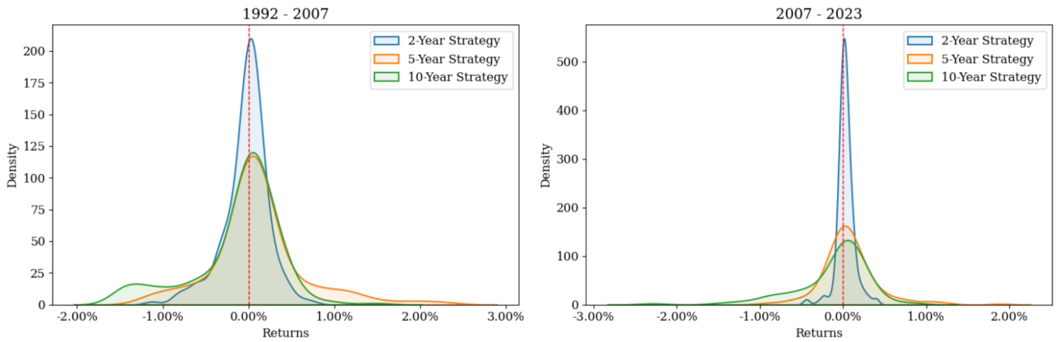

Figure A4.7: January 1, 1992 - August 31, 2007 and September 30, 2007 - March 31, 2023, Distribution of strategy returns

A5 Subsample summary statistics

Table A5.1: January 1, 1992 - August 31, 2007, summary statistics

	N	S	L	μ	σ	Min	Med.	Max	Skew	Kurt
2Y	375	356	19	-0.034	0.696	-1.122	0.018	0.727	-1.346	5.688
5Y	375	307	68	1.090	1.591	-1.211	0.043	2.318	1.120	4.556
10Y	375	359	16	-1.432	1.687	-2.349	0.009	1.489	-1.311	2.721

Where 2Y is the 2-year, 5Y is the 5-year, 10Y is the 10-year, N is the number of trades, S is the number of times short, L is the number of times long, μ is the annual mean, σ is the annual standard deviation, and Kurt is the excess kurtosis.

Table A5.2: September 30, 2007 - March 31, 2023, summary statistics

	N	S	L	μ	σ	Min	Med.	Max	Skew	Kurt
2Y	375	356	19	-0.034	0.696	-1.122	0.018	0.727	-1.346	5.688
5Y	375	307	68	1.090	1.591	-1.211	0.043	2.318	1.120	4.556
10Y	375	359	16	-1.432	1.687	-2.349	0.009	1.489	-1.311	2.721

Where 2Y is the 2-year, 5Y is the 5-year, 10Y is the 10-year, N is the number of trades, S is the number of times short, L is the number of times long, μ is the annual mean, σ is the annual standard deviation, and Kurt is the excess kurtosis.

A6 Variance Inflation Factors

Table A6.1: VIF: 2-year contract

	Sample 1		Sample 2	
$Constant$	1.2089	1.2011	1.0745	1.0744
R_{NOTE}	3.0757	1.0869	1.3184	1.1074
R_M	3.9071	3.4951	3.8653	2.9059
R_{SMB}	1.2578	1.2475	1.3114	1.2994
R_{HML}	2.3804	2.2569	1.9577	1.9501
R_{UMD}	1.1131	1.1128	1.4685	1.4036
$MOVE$	1.0222	1.0179	1.1672	1.1169
R_{SPB}	3.0519	3.0376	4.3478	4.1380
R_{BBB}	3.0193		1.8509	

Sample 1 is the time period from January 1, 1992 to August 31, 2007. Sample 2 is the time period from September 30, 2007 to March 31, 2023. The first column in each sample shows the variance inflation factors of each independent variable in the regression with the BBB corporate bond variable, and the second column in each sample shows the same but excluding it.

Table A6.2: VIF: 5-year contract

	Sample 1		Sample 2	
$Constant$	1.1744	1.1743	1.0715	1.0700
R_{NOTE}	5.9477	1.1120	1.6898	1.1421
R_M	3.9880	3.4591	3.9533	2.8399
R_{SMB}	1.3249	1.2608	1.3165	1.3124
R_{HML}	2.3668	2.2536	1.9802	1.9801
R_{UMD}	1.1612	1.1385	1.4774	1.3910
$MOVE$	1.0206	1.0183	1.1710	1.1185
R_{SPB}	3.0299	3.0240	4.3374	4.1143
R_{BBB}	5.7072		2.3003	

Sample 1 is the time period from January 1, 1992 to August 31, 2007. Sample 2 is the time period from September 30, 2007 to March 31, 2023. The first column in each sample shows the variance inflation factors of each independent variable in the regression with the BBB corporate bond variable, and the second column in each sample shows the same but excluding it.

Table A6.3: VIF: 10-year contract

	Sample 1		Sample 2	
$Constant$	1.1708	1.1706	1.0625	1.0614
R_{NOTE}	8.2337	1.1122	1.9906	1.1574
R_M	3.8560	3.4437	3.9449	2.8171
R_{SMB}	1.4090	1.2706	1.3199	1.3186
R_{HML}	2.3434	2.2565	1.9847	1.9842
R_{UMD}	1.1804	1.1397	1.4904	1.3892
$MOVE$	1.0195	1.0192	1.1753	1.1189
R_{SPB}	3.0229	3.0208	4.3135	4.1108
R_{BBB}	7.8993		2.6739	

Sample 1 is the time period from January 1, 1992 to August 31, 2007. Sample 2 is the time period from September 30, 2007 to March 31, 2023. The first column in each sample shows the variance inflation factors of each independent variable in the regression with the BBB corporate bond variable, and the second column in each sample shows the same but excluding it.