Limited Arbitrage Analysis of CDS-Basis Trading

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Abstract

By modeling time-varying funding costs and demand pressure as the limits to arbitrage, the paper shows that assets with identical cash-flows have not only different expected returns, but also different expected returns in excess of funding costs. I solve the model in closed-form to show that arbitrage on the CDS and corporate bond market is risky regardless of the degree of price discrepancy. The profitability and risk of this arbitrage, which is called CDS-basis trading, are increasing in market friction levels and assets' maturities. High levels of market frictions also destruct the positive predictability of credit spread term structure on credit spread changes. Empirical results support model predictions. CDS-basis trading is exposed to systematic risk factors, while TED spread squared times adjusted corporate bond trading volume predicts abnormal CDS-basis trading return in the latter half of 2008.

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1 Introduction

As summarized in Gromb and Vayanos (2010), costs or demand shocks faced by arbitrageurs can prevent them from eliminating mis-pricings on the markets and therefore generate market anomalies. My model illustrate how the interaction of time-varying funding cost and demand pressure faced by arbitrageurs results in two assets with identical payoffs having different expected excess return. This result imply taking opposite positions on these two assets is a risky arbitrage that is expected to earn profit in excess of funding costs. I then use CDS basis trading, which is the arbitrage using CDS and corporate bonds, as an example to derive implications of the model and find supportive empirical evidence.

I explain the riskiness of arbitraging on two defaultable bonds with identical cash-flows as the result of the interaction of funding illiquidity and market illiquidity. Under a continuous-time demand-based framework in which risk-averse arbitrageurs trade on two markets with identical defaultable bonds to meet demand pressure posed by local investors, the presence of demand pressure results in arbitrageurs requiring risk premium for the positions they take. Without other frictions, demand pressure alone doesn't generate pricing discrepancies between assets with identical cash-flows. Arbitrageurs also face time-varying funding costs on the two markets, which under certain conditions result in the two assets have different risk exposures and carry different levels of risk premium. The co-existence of time-varying funding cost and demand pressure makes taking opposite positions on the two markets a risky arbitrage. As shown in the model, without any one of these two sources of friction, the arbitrage doesn't generate expected excess profit.

I solve the model in closed-form under two cases. The first case assumes constant demand pressures from local investors while the second case assumes opposite stochastic demand pressures. In the latter case, even if the arbitrageurs can take the exact opposite positions on the two markets in equilibrium so that they are completely protected from the risk of defaults, they still have non-zero exposures to other risk factors. Applying the results to the CDS and corporate bond markets suggests CDS basis trading is in fact risky arbitrage and it is reasonable for the CDS basis to deviate from its theoretical frictionless value of zero under severe market frictions. The profitability of the risky arbitrage depends on market frictions rather than the level of the price discrepancy. The model also shows the arbitrageurs sometimes magnify rather than correct price distortion under market frictions and offers a number of results on term structure properties.

Empirical results support the model predictions. Using Markit CDX and iBoxx Indices data and corporate bond data from TRACE, I show that basis trading is exposed to systematic risk factors, while the interaction of funding cost and market liquidity have predictive power on abnormal basis trading returns. As predicted by the model, the predictability of credit spread term structure slope on future credit spread change disappears when market frictions are high. I also find the size and volatility of realized basis trading excess return is increasing in the degree of market frictions. Moreover, basis trading profit is increasing in underlying maturity and the size of CDS basis is increasing in corporate bond market trading volume.

In early theoretical literature, Tuckman and Vila (1990) show that exogenous price discrepancies between two assets with identical cash-flows do not necessarily create arbitrage opportunities if there's shorting-selling cost. As show in Gromb and Vayanos (2010), without other frictions, the discrepancies between the expected returns of the two assets should compensate exactly for the funding costs so that an arbitrageur is still expected to earn zero excess return. In contrary, my model suggests arbitrageur can earn a risky profit even after adjusting for the funding costs if the funding costs are time-varying and arbitrageur faces demand pressure.

The demand pressure faced by the arbitrageurs is another important source of market friction that contributes to the rise of market anomalies. Investors other than arbitrageurs can have endogenous demand shocks that arise via different channels,[1] but a number of papers have focused on the pricing implications given exogenous demand shocks as I do. These theoretical demand-based papers include Garleanu, et.al.(2009), Naranjo (2009) and Vayanos and Villa (2009). By assuming exogenous underlying asset prices, Garleanu, et.al.(2009) and Naranjo (2009) solve derivative prices endogenously to show that exogenous demand shocks and frictions in arbitrageurs' trading can drive derivative prices away from conventional prices implied by the no-arbitrage conditions. Naranjo (2009) considers extra funding cost faced by arbitrageurs as the friction limiting her ability to eliminate price discrepancies on the futures and underlying markets. However, he assumed the underlying asset's price as exogenously given, so the market frictions only have impact on the futures price but not on the underlying market, which is unrealistic as derivative markets' trading do have impact on underlying price.

My paper is the closest to Vayanos and Vila (2009) in that prices on all markets are endogenized so frictions on one market affect all markets. Vayanos and Villa (2009) study arbitrage across different Treasury bonds maturities, i.e. assets with different cash-flows, and there's no other frictions than the demand shocks from other preferred habitat investors. However, my paper introduces an additional friction, which is the time-varying funding costs, to show that two assets with identical cash-flows can earn different expected excess return, which implies profitability yet risk for a cross-market arbitrage trade. The two assets with identical cash-flows are two defaultable bonds, one represents corporate bond, while the other represents a synthetic corporate bond position created by writing a CDS protection and default-free lending.[2] Trading corporate bonds through repo and reverse-repo generates additional funding costs that are sensitive to default intensity of the bonds. Therefore I model

[1]See Gromb and Vayanos (2010) for details.

[2]The equivalence of synthetic corporate bond and writing CDS plus lending will be illustrated in the next section.

the funding costs as functions of default intensity. Although the assumption on funding costs are not fully endogenized, a clear motivation in **Appendix A** along with empirical findings by Gorton and Metrick (2010) justify this assumption, which is further supported by a recent paper by Mitchell and Pulvino (2011), which illustrates the consequence of funding liquidity failure on arbitrage activities from practitioners' perspectives.

I apply the model's implications on CDS basis trading, which turned out to be a risky arbitrage activity in the 2007/08 crisis. Credit default swap (CDS) is an OTC contract in which one party pays the other party a periodical fee (the CDS premium) for the protection against credit events of an underlying bond, in which case the protection seller pays the protection buyer for the loss from the underlying bond. The CDS market offers hedgers and speculators to trade credit risks in a relatively easy way. It is a fast growing market with vast market volume. The exact way to trade CDS has experienced some significant changes in the recent years following hot debates over the role it plays in the 2007/08 financial crisis. In the past, the two parties of a CDS trade agree on the CDS premium that makes the CDS contract having zero value at origination. Then as conditions change in the life of this contract, it has a marked-to-market value that is not zero. Following the implementation of the so-called CDS Big-Bang regulations on the North American markets in April 2009, the CDS premia are fixed at either 100bps or 500bps, and the two parties exchange an amount of cash at origination to reflect the true value of the contract. For instance, if the reasonable CDS premium should be 200bps, then the protection buyer pays the protection writer a certain amount of money at the beginning, and then pays CDS premium at 100bps each period. This is certainly a change in order to make the market more standardized and more liquid, however, the CDS market is still very opaque and illiquid.

Theoretical papers such as Duffie (1999) and Hull and White (2000) show the parity between CDS price and credit spread under the no-arbitrage condition, i.e. investors who hold a defaultable bond and short a CDS (buy protection) on this bond is effectively holding a default-free bond and thus should earn the risk free return. In other words, the CDS basis, which is CDS premium minus the credit spread, should be zero if basis trading earns only risk free return. Empirical works including Hull, et. al.(2004), Blanco, et. al.(2005) and Zhu (2006) using relatively early data support this zero basis hypothesis. However, practitioners observe positive or negative basis at times and many investors engage in basis trading. Buying a bond and CDS protection is known as negative basis trading, while shorting a bond and writing CDS protection is called positive basis trading. Meanwhile, recent work by Garleanu and Pedersen (2009) and Fontana (2010) document large negative basis persisted from the summer of 2007 to early 2009. **Figure 1** shows that during the 2007/08 crisis the CDS basis become very negative for a long period, which contradicts text-book arbitrage argument, yet negative basis trading still lost money even at quite negative CDS basis level. In this paper, I reveal the risky arbitrage nature of CDS basis trading in closed-form and show the profitability of basis trading depends on market frictions rather than the level of CDS basis.

To justify the deviation from the law of one price on the CDS and corporate bond markets, Garleanu and Pedersen (2009) attributes two otherwise identical assets' different exposures to risk factors to the different level of exogenous margin requirement on the two markets. Empirical work by Fontana (2010) found that funding costs variables are important in explaining CDS basis changes, while Bai and Collin-Dufresne (2010) explained cross-sectional variations in CDS basis with funding liquidity risk, counterparty risk and collateral quality. However, their results concerned only on the changes in CDS basis, which according to my model doesn't determine the profitability of basis trading in the presence of funding costs. My paper is also related to a number of empirical works in explaining credit spread and CDS price movements such as: Collin-Dufresne, et. al.(2001), Elton, et. al.(2001), Huang and Huang (2003), Blanco, et. al.(2005), Tang and Yan (2007), and Ellul, et. al.(2009) among others. A recent work of Giglio (2011) proposed a novel way of inferring implied joint distribution of financial institution's default risk from the CDS basis, which shows the role of counterparty risk in widening CDS basis.

The next section introduces model set-up while Section 3 solves the model under two cases and provides a number of results on the expected excess return of basis trading and the term structure properties of credit spread and basis trading profits. I then carry out empirical study in Section 4 to verify theoretical results. Finally, Section 5 concludes the paper.

2 The Model

2.1 The Markets

In a continuous time economy with a horizon from zero to infinity, there are two defaultable bond markets C and D, each with a continuum of zero-coupon[3] defaultable bonds with face value of one and time to maturity τ, $\tau \in (0, T]$. Denote the time t prices of these bonds by $P_t^c(\tau)$ and $P_t^d(\tau)$ respectively. Assume all bonds on the two markets are issued by the same entity, so that a bond on market C has identical cash-flow as the bond on market D with the same time to maturity. Therefore, the model is in line with other limited-arbitrage models in deriving price discrepancies between assets with identical cash-flows under market frictions. When applying equilibrium results to explain real world phenomenon, I refer to bond market C as the cash market, which corresponds to the corporate bond market, and bond market D as the derivative market, which corresponds to the CDS market plus default-free lending. The linkage between synthetic defaultable bond position and CDS plus default-free lending is given at the end of this sub-section.

Upon the exogenous default of the underlying entity, the bond holder loses L fraction of the bond's market value. To keep the model tractable, I assume L is constant. Now suppose N_t is the counting process for the underlying bond's default time T', which is a

[3]The coupon rate is assumed to be zero so as to derive closed form solutions.

doubly-stochastic stopping time[4]. $N_t = 0$ if no default happens before time t and $N_t = 1$ if default happens before time t. Here, I model N_t as a counting process with a intensity $\widetilde{\lambda} + \lambda_t$. In general:

$$N_t = \int_0^t (\widetilde{\lambda} + \lambda_s) ds + M_t \tag{1}$$

where M_t is a jump martingale that jumps to one at the time of default. The stochastic λ_t follows the Ornstein-Uhlenbeck process:

$$d\lambda_t = \kappa_\lambda(\bar{\lambda} - \lambda_t)dt + \sigma_\lambda dB_{\lambda,t} \tag{2}$$

I also assume that the money invested into money market account generates instantaneous return at an exogenous short rate r_t, which also follows an Ornstein-Uhlenbeck process:

$$dr_t = \kappa_r(\bar{r} - r_t)dt + \sigma_r dB_{r,t} \tag{3}$$

In early literature such as Duffie (1999), the equivalence of defaultable bond and CDS plus default-free lending is best illustrated in the case of floating rate notes (FRN), i.e. the cash flow of a defaultable FRN is the same as the cash flow from writing CDS protection plus the cash flow of a default-free FRN. Without using FRNs, the equivalence still hold in the following way: assume the zero-coupon defaultable bond holder gets the face value of 1 dollar at maturity in the absence of default, and gets the default-free present value of this 1 dollar and loses L fraction of the bond's pre-default market value in the case of default. As for the CDS, assume the CDS premium is paid up-front so that unless there's a default, there's no cash-flow between the two parties except at the origination of the contract. Then assume the CDS protection writer also invests in the money market account an amount with future value of 1 dollar. Therefore, if there's no default, the CDS writer's total payoff at maturity is the 1 dollar from the money market account. If there's default, the CDS writer pays fraction L of the defaultable bond's market value before default, and withdraws from the money market account to get the present value of the 1 dollar. So the CDS writer's total payoff is also default-free present value of 1 dollar minus L fraction of the bond's market value before default. Therefore, the cash-flow from CDS writing and default-free lending replicates that of a defaultable bond. Hence I regard one of the two defaultable bond markets in the model as the derivative market, which corresponds to the CDS market.

When applying model's predictions to real world phenomenon, I define negative basis trading as buying cash bond C and selling derivative bond D, which corresponds to buying corporate bond through borrowing and buying CDS protection. In the contrary, positive basis trading is defined as buying derivative bond D and selling cash bond C, which corresponds to shorting corporate bond and writing CDS protection.

2.2 The Agents and Demand Pressure

There are two type of agents, arbitrageurs and local investors. The continuum of risk-averse arbitraguers can trade any amount on the two bond markets, and therefore renders

[4] Refer to Duffie (2004) for full explanation

the prices arbitrage free. At any time t, the continuum of arbitrageurs are born in time t and die in $t + dt$, so arbitrageur's utility is to trade off instantaneous mean and variance. The arbitrageurs have zero wealth when they're born, so an arbitrageur's time t wealth $W_t = 0$. Denote the arbitrageur's amount invested on the cash market for maturity τ by $x_t^c(\tau)$ and the amount invested on the derivative market for maturity τ by $x_t^d(\tau)$.

Local investors are segmented into the two markets. Denote the cash market investors' amount invested by $z_t^c(\tau)$, and the derivative market investors' amount invested by $z_t^d(\tau)$. Assume both markets have zero supply. At equilibrium, the arbitrageurs and local investors clear both markets, i.e. $x_t^c(\tau) + z_t^c(\tau) = 0$ and $x_t^d(\tau) + z_t^d(\tau) = 0$.

A positive z_t^i, $i = c, d$ corresponds to local investors' excess demand while a negative z_t^i corresponds to local investors' excess supply. A negative z_t^i means the arbitrageurs have a pressure to buy and a positive z_t^i means they have a pressure to short. In general, assume the local investors' demand are:

$$\begin{aligned} z_t^i(\tau) &= \bar{\theta}^i(\tau) + \theta^i(\tau) z_t & (4) \\ dz_t &= \kappa_z(\bar{(}z) - z_t)dt + \sigma_z dB_{z,t} & (5) \end{aligned}$$

where $i = c, d$. $\bar{\theta}^i(\tau)$ and $\theta^i(\tau)$ are functions of τ. Assume the three Brownian Motions $B_{r,t}$, $B_{\lambda,t}$ and $B_{z,t}$ are independent.

In reality, large excess demand/supply from local investors exist on both the CDS market and the corporate bond market. The excess supply of bond could come from regulation restricted fire-sale of bonds by insurance companies or simply a flight to quality during crisis while the excess demand of bond can come from large inflows into bond market funds. On the other hand, excess demand or supply on the CDS markets can come from the hedging demand from banks who hold bonds/loans or those who gain exposure to default risk from other credit derivative market positions. Sometimes the local investors' demand on the two markets can be exactly the opposite. As documented by Mitchell and Pulvino (2011) and also in other practitioners' articles, some banks that hold corporate bonds and CDS protection on these underlying bonds unwound their positions after the Lehman Collapse in order to free up more cash. Their trades introduced negative z_t^c and positive z_t^d with the same absolute value. In this scenario, the arbitrageurs face exactly the opposite demand pressures from the two markets. A special case of my model investigates this scenario in detail in the following sections.

The presence of demand pressure has implications on asset pricing because the arbitraguers, who provide liquidity by clearing the markets , need to be compensated for the risk exposure they get by doing so. As summarized by Gromb and Vayanos (2010), several kinds of demand pressure effects on treasury bonds, futures and options markets have been studied.[5] Without other frictions, demand pressure alone doesn't generate pricing discrep-

[5]By Vayanos and Villa (2009), Naranjo (2008), and Garleanu, et.al. (2009) respectively

ancies between assets with identical cash-flows. My model of defaultable bonds differ from these models in the introduction of the time-varying funding costs, which work together with demand pressure in causing pricing discrepancies.

2.3 Funding costs

In the real world, buying bonds through borrowing (repo) and short-selling through reverse-repo incurs funding costs in excess of the short rate. I assume that the exogenous funding costs are linear functions of λ_t:

$$h_t^i(\tau) = \alpha^i(\tau)\lambda_t + \delta^i(\tau) \quad i = c, d \quad 0 < \alpha^i < L \tag{6}$$

In **Appendix A** I provide motivations for this assumption by solving for the optimal hair-cuts applied in repo and reverse-repo. Given exogenous interest rates, the cost of borrowing using the defaultable bond as collateral is shown to be increasing in the default intensity risk λ_t. This is because the amount that can be borrowed using the bond as collateral is decreasing in λ_t. Therefore, when λ_t is higher, the borrower has to borrow more at the un-collateralized rate, and therefore incur more borrowing costs. The short-selling cost is also shown to be increasing in λ_t. The short-seller will be asked to put more cash collateral to borrow the bond for sale when λ_t is higher because the bond is more risky which makes the short-seller more likely to default on the obligation to return the bond. As a result, the short-seller lends more at collateralized rate, less at uncollateralized rate, therefore earns less interest from the proceeds of the short-selling(incurs more short-selling costs). The above rationale is supported by empirical evidence found by Gorton and Metrick (2010) that the repo hair-cut is increasing in the riskiness of collaterals. Mitchell and Pulvino (2011) also justify the above assumption from a practitioner's perspective. This funding cost models both the borrowing cost and short-selling cost, so it reduces arbitrageur's wealth regardless of the direction of her trades.

If trading on the CDS market is frictionless, then $\alpha^d(\tau)$ and $\delta^d(\tau)$ are both zeros. However, although the CDS market used to have extremely low funding costs due to its low margin requirement, it is not frictionless. During the 2007/08 crisis, counterparty risk in CDS contract led to the raise in margin requirement on the CDS market. Counterparty risk refers to the possibility that protection writers may default on their obligation to pay the buyers upon the default of the underlying, or the possibility that protection buyers default on their obligation to pay the CDS premium. CDS protection writers were asked to put more collaterals than before, while protection buyers were asked to pay CDS premium up-front. These changes made CDS having comparable funding costs as trading corporate bonds. An alternative way for CDS protection writers to provide collateral that was widely used in practice is for them to buy a CDS on their own names for the protection buyer from a third party. In this way, if the CDS writer defaults, the buyer can still get paid by the third party. Therefore, the CDS protection writer incurs additional periodical cost that equals to the CDS premium on themselves. If the CDS writer's default can only be triggered by the underlying's default, then this additional cost should be increasing in the underlying's default intensity. So it's also reasonable to assume funding costs as an increasing function of λ_t when making the analogy between derivative market D and the CDS market.

2.4 The Arbitrageurs' Optimization Problem

The representative arbitrageur's problem is:

$$\max_{x_t^c, x_t^d} [E_t(dW_t) - \frac{\gamma}{2} Var_t(dW_t)] \tag{7}$$

$$\begin{aligned} dW_t &= [W_t - \int_0^T x_t^c(\tau)d\tau - \int_0^T x_t^d(\tau)d\tau]r_t dt \\ &+ \int_0^T x_t^c(\tau)[\frac{dP_t^c(\tau)}{P_t^c(\tau)} - LdN_t]d\tau + \int_0^T x_t^d(\tau)[\frac{dP_t^d(\tau)}{P_t^d(\tau)} - LdN_t]d\tau \\ &- \int_0^T |x_t^c(\tau)| h_t^c(\tau) d\tau dt - \int_0^T |x_t^d(\tau)| h_t^d(\tau) d\tau dt \end{aligned} \tag{8}$$

In the above dynamic budget constraint, W_t is the representative arbitrageur's wealth at time t and is assumed to be zero. γ is her risk aversion coefficient. Ignoring τ, x_t^c is the amount she invests into cash bond C and x_t^d is the amount she invests into derivative bond D. The first term on the right hand side of the dynamic budget constraint gives the amount earned by her money market account. The arbitrageur's wealth is also affected by changes in the cash and derivative bond prices, as well as jumps upon default. Additionally, since the arbitrageur is born with zero wealth, she can only buy through borrowing or sell through short-selling. Therefore, trading on the cash and derivative markets incurs funding cost at the rate of $h_t^c(\tau)$ and $h_t^d(\tau)$. These costs reduce arbitrageur's wealth regardless of the direction of her trades, so the costs are multiplied by the absolute value of arbitrageur's trade.

3 Main Theoretical Results

3.1 Understanding the First Order Conditions

I first derive the arbitrageur's F.O.C.s and provide intuition and definition that facilitate discussions in later subsections. Ignoring τ where it doesn't cause confusion, the F.O.C.s are derived as follows.

Lemma 1. *The Arbitrageur's F.O.C.s are:*

$$\mu_t^c - r_t - h_t^c \frac{\partial |x_t^c|}{\partial x_t^c} - L(\widetilde{\lambda} + \lambda_t) = L\Phi_{J,t} + \Sigma\sigma_j(\frac{\partial P_t^c}{\partial j}/P_t^c)\Phi_{j,t} \tag{9}$$

$$\mu_t^d - r_t - h_t^d \frac{\partial |x_t^d|}{\partial x_t^d} - L(\widetilde{\lambda} + \lambda_t) = L\Phi_{J,t} + \Sigma\sigma_j(\frac{\partial P_t^d}{\partial j}/P_t^d)\Phi_{j,t} \tag{10}$$

where μ_t^c and μ_t^d are the expected returns of bond C and D, conditional on no default, and

$$\Phi_{J,t} = \gamma L \int_0^T [x_t^c(\tau) + x_t^d(\tau)] d\tau (\widetilde{\lambda} + \lambda_t) \tag{11}$$

$$\Phi_{j,t} = \gamma \sigma_j \int_0^T [x_t^c(\tau)(\frac{\partial P_t^c}{\partial j}/P_t^c) + x_t^d(\tau)(\frac{\partial P_t^d}{\partial j}/P_t^d)] d\tau \tag{12}$$

$j = \lambda, r, z$ are the market prices of risks.

Proof. *see Appendix B.*

The left hand side of the F.O.C.s is the instantaneous expected excess return, hereafter EER, and the right hand side is the risk premium. The EER is the expected return of an asset in excess of the short rate and the funding cost. The EER is given by the risk premium which equals exposure to risk times the market price of risk. By construction, bond C and bond D have the same exposure to the jump risk of default, which carries market price of risk $\Phi_{J,t}$. Their exposures to other market prices of risks $\Phi_{j,t}$, $j = \lambda, r, z$ depend on equilibrium terms $\frac{\partial P_t^i}{\partial j}/P_t^i$, $i = c, d$.

Subtracting the first F.O.C. from the second one gives the total expected excess return of the so-called negative basis trade. In contrary, subtracting the second F.O.C. from the first one gives the expected excess return of positive basis trade. Formally, I make the following definition.

Definition 1: *Negative basis trading (nbt) is defined as buying bond C and selling bond D for the same time-to-maturity (which corresponds to buying corporate bond through borrowing and buying CDS protection); Positive basis trading (pbt) is defined as selling bond C and buying bond D for the same time-to-maturity (which corresponds to shorting corporate bond and writing CDS protection plus lending).*

$$EER^{nbt} = \Sigma \sigma_j (\frac{\partial P_t^c}{\partial j}/P_t^c - \frac{\partial P_t^d}{\partial j}/P_t^d) \Phi_{j,t} \tag{13}$$

$$EER^{pbt} = \Sigma \sigma_j (\frac{\partial P_t^d}{\partial j}/P_t^d - \frac{\partial P_t^c}{\partial j}/P_t^c) \Phi_{j,t} \tag{14}$$

The EER of basis trade measures the expected instantaneous profitability of taking opposite positions on two assets with identical cash-flows in excess of the funding costs. Without deducting the funding costs, the difference in the instantaneous expected returns of the two assets equals funding cost difference plus the expected excess return of basis trading. For instance,

$$\mu_t^c - \mu_t^d = (h_t^c - h_t^d) + EER_{nbt} \tag{15}$$

Based on the F.O.C.s, equilibrium results are solved using the market clearing condition that on each market, the optimally derived quantities of the arbitrageurs plus those from the local investors equals zero. To solve the model in closed-form, I make further assumptions on the local investors demand and derive equilibrium results in the following two cases.

3.2 Equilibrium under Constant Demand Pressure

3.2.1 Solutions

In the first case, I assume that the local investors' demand on the two markets are constants, i.e. $\theta^i(\tau) = 0$ and $z_t^i(\tau) = \bar{\theta}^i(\tau) = z^i(\tau)$, $i = c, d$. This assumption removes the demand shock factor z_t from the model, I therefore conjecture that the bond prices to take the following form:

$$P_t^c(\tau) = e^{-[A_\lambda^c(\tau)\lambda_t + A_r^c(\tau)r_t + C^c(\tau)]} \tag{16}$$

$$P_t^d(\tau) = e^{-[A_\lambda^d(\tau)\lambda_t + A_r^d(\tau)r_t + C^d(\tau)]} \tag{17}$$

where $A_j^i(\tau)$ and $C^i(\tau)$, $i = c, d$, $j = \lambda, r$ are functions of τ.

Lemma 2: *$A_j^i(\tau)$ are solved as:*

$$\begin{aligned}
A_\lambda^c(\tau) &= \{-\alpha^c(\tau)\frac{|z^c(\tau)|}{z^c(\tau)} + L - \gamma L^2 \int_0^T [z^c(\tau) + z^d(\tau)]d\tau\}\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda} \\
A_\lambda^d(\tau) &= \{-\alpha^d(\tau)\frac{|z^d(\tau)|}{z^d(\tau)} + L - \gamma L^2 \int_0^T [z^c(\tau) + z^d(\tau)]d\tau\}\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda} \\
A_r^c(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r} \\
A_r^d(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r}
\end{aligned} \tag{18}$$

Proof. *see Appendix B.*

Prices on the two markets have the same coefficients for the short rate. When local investors' demand on the two markets are in the same direction, then prices on the two markets have the different coefficients for the default intensity risk if funding costs on the two markets have different sensitivity to the default intensity risk, i.e. $\alpha^c(\tau) \neq \alpha^d(\tau)$; when local investors' demand on the two markets are in opposite directions, i.e. $sign[z^c(\tau)] = -sign[z^d(\tau)]$, the prices on the two markets have different coefficients for λ_t even if the funding costs have the same sensitivities to λ_t.

Proposition 1: *The expected excess returns of basis trading are:*

$$EER^{nbt} = \sigma_\lambda[\alpha^c(\tau)\frac{|z^c(\tau)|}{z^c(\tau)} - \alpha^d(\tau)\frac{|z^d(\tau)|}{z^d(\tau)}]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}\Phi_{\lambda,t} \tag{19}$$

$$EER^{pbt} = -EER^{nbt} \tag{20}$$

$$\Phi_{\lambda,t} = \gamma\sigma_\lambda \int_0^T [z^c(\tau)A_\lambda^c(\tau) + z^d(\tau)A_\lambda^d(\tau)]d\tau \tag{21}$$

Proof. *see Appendix B.*

Corollary 1: The expected excess return of basis trading

- *In scenarios other than the following three, basis trading earns non-zero expected excess return: 1)* $\alpha^c(\tau) = \alpha^d(\tau) = 0$*; 2)* $\alpha^c(\tau) = \alpha^d(\tau) \neq 0$ *and* $sign[z^c(\tau)] = sign[z^d(\tau)]$*; and 3)* $z^c(\tau) = z^d(\tau) = 0$*.*

- *When capital is flowing away from both markets, or only moderate amount of capital is flowing into both markets, basis trading is profitable by buying the asset whose funding cost has higher sensitivity to default intensity risk and selling the other.*

- *When huge amount of capital is flowing into both markets such that prices have positive sensitivities to default intensity, basis trading is profitable by buying the asset whose funding cost is less sensitive to default intensity and selling the other.*

- *When* $sign(z^c) = sign(z^d)$*, risk exposure of basis trading is increasing in* $|\alpha^c - \alpha^d|$*.*

- *When* $sign(z^c) = -sign(z^d)$*, risk exposure of basis trading is increasing in* $(\alpha^c + \alpha^d)$*.*

- *Size of basis trading EER is increasing in the volatility of default intensity.*

The first point suggests that basis trading is a risky arbitrage that earns non-zero EER only when both funding cost friction and market liquidity friction are present. Under scenario 1) and 2), either funding costs on the two markets have no sensitivities to λ_t or they have the same sensitivities while arbitrageur takes the same side of trade on the two markets, then the two assets carry the same exposures to the default intensity risk factor, which results in them carrying the same risk premium. Therefore, buying on one market and selling on the other results in zero aggregate exposure to risk factors and basis trading earns zero EER. In scenario 3), even if assets on the two markets may have different risk exposures to default intensity risk, the market prices of risks are all zeros because the arbitrageur doesn't have to provide liquidity in equilibrium and all EERs should be zero. Other than in the above mentioned three scenarios, basis trading is expected to earn non-zero return in excess of the funding costs, i.e. earning non-zero EER.

The second and third points concern the sign of basis trading EERs. When local investors on the two markets are all selling, bonds on both markets carry positive risk premia which compensates the arbitrageurs who are buying to provide liquidity. The arbitageur is exposed to more default intensity risk on the market with higher funding cost sensitivity to λ_t, therefore earns more default intensity risk premium on this market. So buying bond on this market and selling on the other generates positive expected excess return. For instance, if there's funding cost on corporate bond market but not on CDS market, i.e. $\alpha^c > 0$ and $\alpha^d = 0$, then if local investors are selling on both markets, the model predicts negative basis trading to be profitable even after deducting the funding costs. In contrary, when local investors on the two markets are all buying moderate amount, bonds on both markets carry negative risk premium. The market whose funding cost has higher sensitivity to λ_t has lower sensitivity to the default intensity risk, therefore earns less negative risk premium. So buying bond on this market and selling on the other is expected to be profitable.

However, if local investors are buying too much on both markets, bonds also carry negative default intensity risk premium but the market whose funding cost has lower sensitivity to λ_t now has lower sensitivity to the default intensity risk, therefore earns less negative risk premium. So buying bond on this market and selling on the other is expected to be profitable. The difference here with the moderately positive local investor demand case is that when local investors are buying too much, bond prices become increasing in default intensity. This is true because of the assumption that bond holders retain $(1-L)$ fraction of bond's market value upon default. The compensation to arbitrageur for providing liquidity in this case is for price to be increasing in default intensity so that she's expected to gain more upon default when default intensity is higher.

As mentioned above, the net exposure to default intensity risk depends on the funding costs' sensitivities to λ_t. When the local demands on the two markets are in the same direction, the net exposure is determined by the difference of α^c and α^d. But when the local investors' demand are in opposite directions, the net exposure depends on the sum of α^c and α^d. The size of EER of basis trading is also increasing in σ_λ, which is not surprising as σ_λ is positively priced in both the basis trading's absolute net exposure to default intensity risk and the market price of default intensity risk.

3.2.2 Implications on Credit Spread Term Structure and the Predictability of Credit Spread

Earlier empirical works such as Bedendo et.al.(2007) found that the slope of the credit spread term structure positively predicts future changes in credit spread. Such a result still hold under my model when friction is moderate, but may not hold when there's high level of market friction. To see this point in detail, I first make the following definitions.

Definition 2: *Credit spread is the difference between the yield to maturity of a defaultable bond and the yield to maturity of a default-free bond of the same maturity. Denote yields to maturity of the defaultable bond with time to maturity τ in by $Y_t^c(\tau)$, and the credit spread by $CS_t^c(\tau)$.*

$$Y_t^c(\tau) = -\frac{logP_t^c(\tau)}{\tau} \tag{22}$$

There's no default-free bond market in my model, but it is safe to conjecture that default-free bond prices are $DF_t(\tau) = e^{-[A_r(\tau)r_t + C^{df}(\tau)]}$,[6] so that yield to maturity of default-free bond can be denoted by $Y_t^{df}(\tau) = -\log DF_t(\tau)/\tau$. Because the defaultable bond and

[6]For example, this can be derived from Vayanos and Vila (2009) by assuming arbitrageurs in their model are risk-neutral.

default-free bond have the same coefficient to short rate r_t, therefore the credit spread term structure $CS_t(\tau)$ only has one time-varying risk factor λ_t.

$$CS_t(\tau) = Y_t(\tau) - Y_t^{df}(\tau) = \frac{A_\lambda^c(\tau)}{\tau}\lambda_t + \frac{C^c(\tau)}{\tau} - \frac{C^{df}(\tau)}{\tau} \tag{23}$$

Bedendo et.al.(2007) run the following regression for credit spread of a certain maturity τ and found coefficient ψ to be significantly positive, which suggests the slope of credit spread term structure positively predicts future credit spread changes.

$$CS_{t+\Delta\tau}(\tau - \Delta\tau) - CS_t(\tau) = \psi_0 + \psi[CS_t(\tau) - CS_t(\tau - \Delta\tau)] + \epsilon_{t+\Delta\tau} \tag{24}$$

Proposition 2: *Denote* $F(\tau) = -\alpha^c(\tau)\frac{|z^c(\tau)|}{z^c(\tau)} + L - \gamma L^2 \int_0^T [z^c(\tau) + z^d(\tau)]d\tau$*, when* $\Delta\tau \to 0$*, the regression coefficient* $\psi(\tau) = \frac{F(\tau)}{1-F(\tau)e^{-\kappa_\lambda \tau}}$

- *When there's no friction, i.e.* $\alpha^c(\tau) = 0$ *and* $z^c(\tau) = z^d(\tau) = 0$*, then* $\psi > 0$ *for sure.*
- *When local investors are selling large quantities and funding cost is very sensitive to* λ_t*, i.e.* $z^c(\tau) > 0$ $\alpha^c(\tau) > 0$ *and both large, it is possible to have* $\psi < 0$*.*
- $\psi < 0$ *is more likely to happen to bonds with short time-to-maturity.*

Proof. *see Appendix B.*

Under standard set-up without the funding cost and demand pressure frictions, the condition for $\psi > 0$ simplifies to $L < e^{\kappa_\lambda \tau}$, which is always satisfied as $L < 1$ by assumption. Therefore, the credit spread slope should always positively predict future credit spread changes, which has been documented by Bedendo et.al.(2007) among others. But new features in this model suggests market frictions can distort this predictability. The coefficient ψ can be either positive or negative depending on market conditions, so the positive predictability may disappear under market conditions described in the second point of Proposition 2. In the empirical section, this point is supported by data during the crisis in 2008.

3.3 Equilibrium under Opposite Stochastic Demand Pressure

3.3.1 Solutions

To add more dynamics to the model, I make an additional assumption that the demand from local investors on the cash and derivative markets are exactly the opposite, i.e. $-z_t^d(\tau) = z_t^c(\tau)$. This is equivalent to assuming:[7]

$$z_t^c(\tau) = \bar{\theta}(\tau) + \theta(\tau)z_t \tag{25}$$

$$z_t^d(\tau) = -\bar{\theta}(\tau) - \theta(\tau)z_t \tag{26}$$

[7] If I assume the two demand pressures to be exactly the opposite and price-elastic, the equilibrium prices can still be solved in closed-form, but takes very complicated forms that makes discussions on assets returns unclear, so results for that case are not presented.

For the two scenarios: 1) $\bar{\theta}(\tau)$ very positive and 2) $\bar{\theta}(\tau)$ very negative, the model has closed-form solution. I conjecture that prices are exponential affine in the risk factors:

$$
\begin{aligned}
P_t^c(\tau) &= e^{-[A_\lambda^c(\tau)\lambda_t + A_r^c(\tau)r_t + A_z^c(\tau)z_t + C^c(\tau)]} && (27)\\
P_t^d(\tau) &= e^{-[A_\lambda^d(\tau)\lambda_t + A_r^d(\tau)r_t + A_z^d(\tau)z_t + C^d(\tau)]} && (28)
\end{aligned}
$$

and solve for the coefficients for the two scenarios separately in **Lemma 3**.

Lemma 3a: *For very negative $\bar{\theta}(\tau)$ and negative $\theta(\tau)$:*

$$
\begin{aligned}
A_\lambda^c(\tau) &= [\alpha^c(\tau) + L]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}\\
A_\lambda^d(\tau) &= [-\alpha^d(\tau) + L]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}\\
A_r^c(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r}\\
A_r^d(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r}\\
A_z^c(\tau) &= -\gamma\sigma_\lambda^2 A_\lambda^c(\tau)\int_0^T \theta(\tau)[\alpha^c(\tau) + \alpha^d(\tau)]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}d\tau\frac{1 - e^{-\kappa_z^* \tau}}{\kappa_z^*}\\
A_z^d(\tau) &= -\gamma\sigma_\lambda^2 A_\lambda^d(\tau)\int_0^T \theta(\tau)[\alpha^c(\tau) + \alpha^d(\tau)]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}d\tau\frac{1 - e^{-\kappa_z^* \tau}}{\kappa_z^*}
\end{aligned}
$$

where κ_z^* is the unique solution to:

$$
\kappa_z^* = \kappa_z + \gamma\sigma_z^2\int_0^T \theta(\tau)[A_z^c(\tau) - A_z^d(\tau)]d\tau \qquad (29)
$$

Lemma 3b: *For very positive $\bar{\theta}(\tau)$, positive $\theta(\tau)$ and very positive κ_z:*

$$
\begin{aligned}
A_\lambda^c(\tau) &= [-\alpha^c(\tau) + L]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}\\
A_\lambda^d(\tau) &= [\alpha^d(\tau) + L]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}\\
A_r^c(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r}\\
A_r^d(\tau) &= \frac{1 - e^{-\kappa_r \tau}}{\kappa_r}\\
A_z^c(\tau) &= \gamma\sigma_\lambda^2 A_\lambda^c(\tau)\int_0^T \theta(\tau)[\alpha^c(\tau) + \alpha^d(\tau)]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}d\tau\frac{1 - e^{-\kappa_z^* \tau}}{\kappa_z^*}\\
A_z^d(\tau) &= \gamma\sigma_\lambda^2 A_\lambda^d(\tau)\int_0^T \theta(\tau)[\alpha^c(\tau) + \alpha^d(\tau)]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda}d\tau\frac{1 - e^{-\kappa_z^* \tau}}{\kappa_z^*}
\end{aligned}
$$

where κ_z^* is the unique solution to:

$$\kappa_z^* = \kappa_z + \gamma\sigma_z^2 \int_0^T \theta(\tau)[A_z^c(\tau) - A_z^d(\tau)]d\tau \tag{30}$$

Proof. *see Appendix B.*

Once again, prices on the two markets have the same coefficients for the short rate. But unlike in the previous case with constant demand pressure, since local investors' demand on the two markets are always in opposite directions, the prices on the two markets have different coefficients for λ_t and z_t even if the funding costs on the two markets have same sensitivities to λ_t. The calculation of expected excess return is now complicated by the inclusion of z_t as the EER of basis trading has exposure to two sources of risk premium.

Proposition 3: *The expected excess returns of basis trading are:*

$$\begin{aligned} EER^{nbt} &= -\gamma\sigma_\lambda^2 G^\lambda(\tau) \int_0^T G^\lambda(\tau) z_t^c(\tau)d\tau - \gamma\sigma_z^2 G^z(\tau) \int_0^T G^z(\tau) z_t^c(\tau)d\tau \\ EER^{pbt} &= -EER^{nbt} \qquad (31) \\ G^\lambda(\tau) &= [\alpha^c(\tau) + \alpha^d(\tau)]\frac{1 - e^{-\kappa_\lambda \tau}}{\kappa_\lambda} \\ G^z(\tau) &= -\gamma\sigma_\lambda^2 G^\lambda(\tau) \int_0^T G^\lambda(\tau)\theta(\tau)d\tau \frac{1 - e^{-\kappa_z^* \tau}}{\kappa_z^*} \qquad (32) \end{aligned}$$

- *EER of basis trading is non-zero unless $\alpha^c(\tau) = \alpha^d(\tau) = 0$.*
- *$sign(EER^{nbt}) = -sign(EER^{pbt}) = -sign(z_t^c)$ The market on which local investors are selling has higher EER, taking long position on this market and short position on the other market is expected to earn profit in excess of funding costs.*
- *The size of expected excess return of basis trading is increasing in α^i, σ_j and $|z_t^c(\tau)|$.*

Proof. *see Appendix B.*

Under the assumption about local investors' demand in this case, the arbitrageur is always taking opposite positions on the two markets. If the funding costs are constants that have no sensitivities to risk factors such as λ_t, the two assets carry exactly the same exposure to risk factors. Then the arbitrageur is left with zero aggregate exposure to any risk factors, therefore all market prices of risk will be zero. In that case, bonds on both markets and basis trading will all earn zero risk premia and hence zero EER. But as long as at least one funding cost has sensitivity to the default intensity risk factor λ_t, the two assets carry different exposures to default intensity risk and also different exposures to the demand shock risk. The arbitrageur captures non-zero aggregate exposures to these two risks, hence market prices of risks for these two factors are non-zero. Therefore, the two assets carry different level of risk premium and basis trading is expected to be profitable in excess of funding costs.

Moreover, the sign of basis trading EER is completely determined by the sign of local investors's demand on the cash market. Since the non-zero condition of basis trading EER is completely determined by the funding costs' sensitivities to default intensity risk, **Proposition 3** suggests that the profitability of basis trading is completely determined by the properties of the two sources of limits to arbitrage. In the real-world, practitioners tend to see positive CDS basis as signal to do positive CDS basis trading and vice versa, but results here suggests that the timing and directional signals of CDS basis trading are current market frictions. The CDS basis which characterizes price discrepancy between the two markets is an endogenous term itself. Empirical proxies of the interaction of funding cost friction and demand pressure friction should be more reliable in predicting CDS basis trading excess returns than the CDS basis.

Corollary 3: *The expected excess return of bond is positive no matter if local investors are buying or selling.*

- *When* $z_t^c < 0$*:* $EER^c > EER^d > 0$
- *When* $z_t^c > 0$*:* $EER^d > EER^c > 0$

The result that if $z_t^i > 0$ then $sign(EER^i) = sign(z_t^i)$ is against conventional wisdom. The usual conclusion on the pricing implication of demand shocks is that when there's excess demand, those who provide the liquidity will only agree to sell at a high price in equilibrium so as to earn something extra, which is the compensation for providing liquidity. Therefore, the instantaneous expected excess return should have the opposite sign of the local investors demand. However, with the presence of the other market, the arbitrageur in this model is willing to provide liquidity at a loss on the market she shorts because she can earn more on the other market. By doing so, the arbitrageur doesn't correct but instead magnifies the price deviation and creates a bubble.

3.3.2 Implications on Basis

Definition 3: *Basis is the difference between the yield to maturity of bond on market D minus the yield to maturity of bond on market C with the same time to maturity.*

$$\begin{aligned} Basis(\tau) &= [-\frac{logP_t^d(\tau)}{\tau}] - [-\frac{logP_t^c(\tau)}{\tau}] \\ &= [\frac{A_\lambda^d(\tau)}{\tau} - \frac{A_\lambda^c(\tau)}{\tau}]\lambda_t + [\frac{A_z^d(\tau)}{\tau} - \frac{A_z^c(\tau)}{\tau}]z_t + \frac{C^d(\tau)}{\tau} - \frac{C^c(\tau)}{\tau} \qquad (33) \end{aligned}$$

Under conventional wisdom, the negative Basis implies negative basis trading is profitable while positive Basis implies positive basis trading is profitable. But the value of Basis is not very meaningful in the presence of funding costs. As shown in the previous subsection, in the presence of market frictions in the model, the sign of basis trading EER is determined just by the sign of local investors' demand. The value of Basis depends on the values of λ_t, z_t and τ. The solution of $C^i(\tau)$ also makes the discussion very complicated. However, the sensitivities of Basis to the risk factors can be derived clearly:

Proposition 4: *The sensitivities of Basis to risk factors are:*

- *When* $z_t^c < 0$*:* $\frac{\partial Basis}{\partial \lambda_t} < 0$*, and* $\frac{\partial Basis}{\partial z_t} > 0$.
- *When* $z_t^c > 0$*:* $\frac{\partial Basis}{\partial \lambda_t} > 0$*, and* $\frac{\partial Basis}{\partial z_t} > 0$.

Proof. *see Appendix B.*

3.3.3 Implications on Term Structure

The coefficients of λ_t and z_t in bond prices are increasing in the bond's time to maturity τ. Assume the funding cost's sensitivity to λ_t is the same across τ, then basis trading on underlying of longer time to maturity has larger net exposure to the risk factors than basis trading on underlying of shorter time to maturity. Therefore, the size of basis trading EER is increasing in τ. Together with the property of the sign of basis trading EER, I derive the following **Proposition 5**:

Proposition 5: *Assume* $\alpha^c(\tau) = \alpha^c$ *and* $\alpha^d(\tau) = \alpha^c$ *for* $\tau \in [0, T]$*, then the term structures of expected excess returns are:*

- *When* $z_t^c < 0$*:* $\frac{\partial EER^{nbt}}{\partial \tau} > 0$*, and* $\frac{\partial EER^{pbt}}{\partial \tau} < 0$.
- *When* $z_t^c > 0$*:* $\frac{\partial EER^{nbt}}{\partial \tau} < 0$*, and* $\frac{\partial EER^{pbt}}{\partial \tau} > 0$.
- *The expected excess profit of basis trading* $|EER^{nbt}|$ *is increasing in the time to maturity of basis trading instruments.*

Proof. *see Appendix B.*

As in the previous case, $Y_t(\tau)$ denotes the time t yield to maturity of bond with time to maturity τ. The collection of $Y_t(\tau)$ gives the yield curve of corporate bonds. As shown in the following **Proposition 6**, the slope of corporate bond yield curve $\partial Y_t(\tau)/\partial\tau$ is decreasing in λ_t, but the degree of the decreasing relationship depends on local investors' demand.

Proposition 6: *The sensitivity of yield curve slope to default intensity risk is* $\partial^2 Y_t(\tau)/(\partial\tau\partial\lambda_t) = [\frac{A_\lambda^c(\tau)}{\tau}]' < 0$.

- *The slope of corporate bond yield curve is decreasing in* λ_t.
- *The decreasing effect is stronger when* $z_t^c < 0$ *than when* $z_t^c > 0$.

Proof. *see Appendix B.*

4 Empirical Study

The model suggests that the co-existence of frictions in funding cost and market liquidity turns basis trading into a risky arbitrage. To test this point, I run a set of regressions to test whether basis trading is exposed to systematic factors. I also test whether certain parts of the EER formula from the model have any predictive power on abnormal basis trading returns after controlling for systematic factors. Besides, I test the comparative statics results of the size/risk of basis trading profits, the term structure of basis trading profits and the CDS basis as predicted by the model. Moreover, I test the predictability of credit spread term structure on future credit spread changes to support the points made in **Proposition 2**. I focus on data from 2007 to 2009, a period which has not only persistently negative CDS basis, but also high funding costs and poor market liquidity. In general, the empirical results are consistent with the model's predictions.

4.1 Data and Key Variables

I collected various CDS and corporate bond indices data from Markit, individual CDS and corporate bond data from Bloomberg and TRACE, various kinds of interest rates data from the Federal Reserve web-site and Fama-French three factor data from Kenneth French's web-site. Daily observation starts as early as the beginning of 2007 and ends at the end of 2009.

I calculate the realized excess return (RER) of negative basis trading as:

$$RER^{nbt}_{t,t+k} = Return^{CBond}_{t,t+k} - Return^{CDS}_{t,t+k} - NetFundingCost_{t,t+k} \tag{34}$$

Since my main results are on the instantaneous expected excess return or expected returns, I mainly focus on k =1 day and 1 week. By definition, the realized excess return of doing positive basis trading is the opposite of that of negative basis trading. The realized excess return of doing negative basis trading between time t and $t + k$ is calculated as the return from holding corporate bond index minus the return from holding CDS index, and finally subtract net funding costs. The model implies that the return of positive basis trading is the opposite of negative basis trading, therefore the absolute value of negative basis trading RER is used as the profits of basis trading. For the corporate bond index, I first collect the 1-10yrs Markit iBoxx USD Domestic Corporates AAA, AA, A and BBB indices[8], and then create a value-weighted corporate bond index by taking the average return of these four indices weighted by their market values. Holding period return of the corporate bond index is calculated as change of the corporate bond index for each holding period divided by the index value at the beginning of the holding period. The CDS index return is calculated from the Markit CDX North America Investment Grade Excess Return Index, whose components have maturities of 5-year.

[8]average maturity around 5-year

The net funding cost is the funding cost of corporate minus the funding cost of CDS. I proxy the funding cost of corporate as:

$$BondFundingCost_{t,t+k} = \Sigma_{s=t}^{t+k-1}[(1 - haircut) * Tbill_s + haircut * LIBOR_s] \qquad (35)$$

This assumption implies investors can fund the one minus hair-cut fraction of their corporate bond purchase at the collateralized rate, and the hair-cut fraction at uncollateralized rate. The funding cost is increasing in the hair-cut, the difference between collateralized and uncollateralized rate. Ideally, the hair-cut input should be time-varying as well, however, daily data on hair-cut is very difficult to get. Therefore, I applied different values of hair-cut for different sub-periods in the sample based on the average hair-cut data described in Gorton and Metrick (2010). The empirical evidence is not very sensitive to different hair-cut assumptions. I calculate funding cost for each day and sum up to get funding cost over a period.

The funding cost of CDS is approximated by the average CDS premium on financial institutions. During the crisis, the main friction on CDS market is the counterparty risk, especially from the protection writers' side. A protection buyer would suffer from the joint default of the underlying entity and the protection writer. In order for the protection buyer to be willing to trade at the CDS premium without counterparty risk, the protection buyer requires the protection seller to buy a CDS on the seller herself for the buyer, so that in the event of joint default, the protection buyer can at least get paid from the CDS on the protection seller. Therefore, I calculated the average CDS premium on financial institutions, and divide this premium according to the holding periods to reflect the funding cost. The funding cost of CDS is close to zero before the crisis, but becomes very large during the crisis. After the Lehman collapse, the funding cost of CDS is even higher than the funding cost of corporate bond, which is consistent with both empirical evidence found by others and observation made by practitioners.

I also collect Markit iBoxx USD Domestic Corporate rating indices for 1-3 years, 3-5 years, 1-5 years, 5-7 years, 7-10 years and 5-10 years of maturity and use the asset swap spread of these indices to build the credit spread term structure. To test the term structure property of basis trading profits, I further calculated RER of negative basis trading on underlying with approximately 2 years, 5 years and 9 years using individual CDS and corporate bond data.

In the calculation of bond funding cost, the hair-cut is multiplied by LIBOR-Tbill. Comparing with the model assumption, if hair-cut is linear in default intensity risk λ_t, then α is a multiple of LIBOR-Tbill, which is the TED spread. Therefore, α in the model is empirically proxied by the TED spread. The sign of local investors' demand is difficult to measure, but the absolute value of local investors' demand on the cash market can be proxied by the corporate bond market trading volume, hereafter TV, which is collected from TRACE. I also use the contemporaneous volatility of asset swap spread (hereafter ASW) of Liquid

Corporate Bond Index from Markit to proxy for the volatility of λ_t since this asset swap rate less affected by movements in interest rate and market liquidity.

4.2 Rolling Window Time-series Tests on Negative Basis Trading Returns

Hypothesis 1: *Basis trading return in excess of arbitrage costs contains systematic risk premium and the exposures to these risk premium are time-varying.*

The model implies that the expected excess return of basis trading contains compensation for the exposure to risk factors. Therefore, the realized excess return (or return) of basis trading might be explained by systematic risk factors. However, the model suggests that negative basis trading's exposure to risk factors is time-varying. Depending on the sign of local investors demand and relative sensitivity of funding cost on λ_t, negative basis trading can have positive or negative loadings on the risk premia. In other words, the betas are time-varying depending on market conditions. Thus it is not appropriate to test the negative basis trading return on systematic factors over the entire sample period.

Instead, for each month commencing from March 2007, I run times-series regressions on daily observations for the next quarter. For each type of regressions specified later, I then obtain 30 sets of coefficient estimates and Newey-West t-stats. I report these estimates and t-stats in **Table 1-3** to see the time-varying patterns of realized negative basis trading excess return's exposure to systematic risk factors and other factors. I also plot the coefficient estimates for certain factors to highlight the time-varying patterns that are consistent with the model's predictions. If basis trading return in excess of funding costs represents compensation from taking systematic risk, then the regression results will have significant coefficient estimates for systematic risk factors. I run the following two regressions to test the above **Hypothesis 1**:

Regression A

$$\begin{aligned} RER^{nbt}_{t,t+k} &= \beta_0 + \beta_1(LIBOR - FFR)_{t,t+k} + \beta_2 FFR_{t,t+k} + \beta_3 TED_{t,t+k} + \beta_4 (TED * ASW)_{t,t+k} \\ &\quad + \beta_5 Basis_t + \epsilon_{A,t} \end{aligned} \quad (36)$$

Regression B

$$\begin{aligned} RER^{nbt}_{t,t+k} &= \beta_0 + \beta_1(LIBOR - FFR)_{t,t+k} + \beta_2 FFR_{t,t+k} + \beta_3 TED_{t,t+k} + \beta_4 (TED * ASW)_{t,t+k} \\ &\quad + \beta_5 Basis_t + \beta_6 MKTRF_{t,t+k} + \beta_7 DEF_{t,t+k} + \beta_8 TERM_{t,t+k} + \epsilon_{B,t} \end{aligned} \quad (37)$$

Because the funding costs in the calculation of basis trading profits may not be accurate enough, I include 4 terms to control for potential mis-measurement of funding costs in Regression A to see if funding costs can explain the realized return of negative basis trading, which is given by the absolute value of RER of negative basis trading. The four control terms are Libor-FFR, FFR, TED spread and TED*ASW, where FFR is the federal funds rate. The TED*ASW term accounts for the effect from the mis-measurement of the haircut. I also include Basis as an independent variable. Basis is calculated as the average CDS basis of a number of individual entities. Conventional thinking regards negative basis as signal for profit in doing negative basis trading. But the model doesn't suggest any relationship between the level of basis and basis trading returns. Therefore, I include this variable to test whether there's any significance relationship. In Regression B, I added three of the Fama-French five factors, the MKTRF factor is the excecss return of the market portfolio, the DEF factor is the liquid corporate bond index return minus the T-Note index return of similar maturity[9], and the TERM factor is the T-Note return minus the T-Bill return from Kenneth French's website. I use factor value that are contemporaneous with dependent variable.

As can be seen from **Table 1**, funding cost variables are significant during month 13-20, which correspond to the period from Bear Stearn's crisis to the end of 2008. This suggests there may be some mis-measurement in the funding costs when calculating realized returns, but also suggests funding costs have important roles in justifying the return of basis trading during the crisis. The Basis factor is not significant for 27 out of 30 rolling windows. This is consistent with the model. It highlights the importance of not relying on observed price discrepancy when doing risky arbitrage because the signal given by price discrepancy is affected by the existence of arbitrage cost such as funding costs.

However, funding costs variables along are not good enough to explain the return of negative basis trading. Regression A has significant intercept estimates in most windows. Adding Fama-French factors doesn't reduce the significance of intercepts by much, but the Fama-French factors are indeed significant and the betas are indeed time-varying as predicted by the model. As shown in **Table 2** and **Figure 2**, beta for DEF factor is significantly negative for the early periods but not very significant in later periods, while beta for TERM factor is not very significant for the early periods but is significantly positive in later periods. Kim et.al.(2010) has shown that corporate bond returns during the same period has negative exposure to DEF factor and positive exposure to TERM factor. According to the model, when corporate bond market investors are selling, corporate bond returns are more sensitive to risk factors than CDS, therefore negative basis trading return's exposures to risk factors should have the same signs as that of the corporate bond return. This point is well supported by the above findings.

Hypothesis 2: *Interaction of funding liquidity and market liquidity predicts abnormal basis trading return*

According to the model, the expected excess profit of basis trading is driven by the interaction of funding costs and local investors' demand. Therefore, I add two other terms to Regression B in order to better explain the abnormal returns of basis trading. The first term

[9]calculated based on Markit iBoxx 1-10yrs USD Domestic Treasury Index

SignedTV is the time t corporate bond market trading volume signed by price changes from $t-1$ to t. This term accounts for the momentum driven by market liquidity. The second term is TED spread squared times adjusted trading volume, where the adjusted trading volume is calculated as the corporate bond market trading volume minus its -45 days to +45 days median. This adjusted trading volume term is aimed to model the absolute value of demand shocks in local investors demand, i.e. $|z_t|$. This $TED_t^2 * AdjTV_t$ term is implied by the formula for negative basis trading return in the model.

Regression C

$$\begin{aligned} RER_{t,t+k}^{nbt} &= \beta_0 + \beta_1(LIBOR - FFR)_{t,t+k} + \beta_2 FFR_{t,t+k} + \beta_3 TED_{t,t+k} + \beta_4(TED * ASW)_{t,t+k} \\ &+ \beta_5 Basis_t + \beta_6 MKTRF_{t,t+k} + \beta_7 DEF_{t,t+k} + \beta_8 TERM_{t,t+k} \\ &+ \beta_9 SignedTV_t + \beta_{10} TED_t^2 * AdjTV_t + \epsilon_{B,t} \end{aligned} \tag{38}$$

As shown in **Table 3**, the SignedTV term is significantly positive for most windows. This is not surprising as negative basis trading consists of buying corporate bond, which is positively affected by the momentum in corporate bond returns. The $TED_t^2 * AdjTV_t$ term is significantly negative during the latter half of 2008. This is highly consistent with the model's prediction. **Proposition 3** suggests that negative basis trading return is increasing in α and $-z_t$, which during the later half of 2008 are well proxied by TED spread and adjusted corporate bond trading volume respectively. More importantly, Regression C results in insignificant intercepts for most windows, and the Basis factor is not significant for almost all windows.

4.3 Term Structure of Basis Trading Profit

Proposition 5 predicts that absolute value of basis trading return, which is also the profit of basis trading, is increasing in the time to maturity of the underlying bond. I compared the profits of basis trading on underlyings with 2 years, 5 years and 9 years time to maturity. I list the average 1-day, 1-week and 1-month holding period profits for these maturities in **Table 4**, which clearly shows that basis trading on longer maturities earn higher profits.

This result is also shown by the plot of cumulative 1-week profits of basis trading on these maturities in **Figure 3**. Basis trading on longer maturities have higher cumulative profits, and the gaps between the lines are also increasing over time, which is consistent with the prediction that basis trading profit is increasing in the time to maturity of the underlying bond.

4.4 Comparative Statics on Basis Trading and the CDS Basis

The model yields several testable comparative statics results. The purpose here is to show that more severe market frictions make basis trading more risky, hence earning higher expected return. To be specific, I tested the following predictions:

Hypothesis 3:

- *The size of basis trading return is increasing in α^c and σ_λ.*
- *Basis trading is risky, the size of basis trading return is increasing in the volatility of basis trading return.*
- *The volatility of basis trading return is increasing in α^c, which is proxied by TED spread.*

The volatility of basis trading return is the next 90-day volatility of the negative basis trading RER. To test the comparative statics results, I sort the time-series of the absolute value and volatility of basis trading returns of different holding periods based on their corresponding TED and default intensity volatility values. For instance, I assign each date in the sample period into 5 groups according to the TED spread value at each date, the first group contains dates with the lowest TED spread values, the 5th group contains dates with the highest TED spread values. Then I calculate the median value of the absolute value of negative basis trading return for each group, and report in a table to see if the group with higher TED spread also has larger basis trading return size. I also sort the sizes of basis trading return into negative basis trading volatility groups. Results are summarized in **Table 5**, in which each panel provides result of each comparative statics. In general, the results support **Hypothesis 3** very well.

Using the similar approach, I test the prediction from **Proposition 4** that CDS basis is increasing in the demand shock on corporate bond market. The results in **Proposition 4** are given conditional on the sign of local investors' demand on cash market. Together with the result on the sign of basis trading returns and the assumption that basis is more likely to be negative when negative basis trading is profitable and vice versa, I conjecture that the absolute value of CDS basis is increasing in the absolute value of local investors' demand on corporate bond market, which is proxied by the corporate bond market trading volume. **Table 6** shows that those dates with larger corporate bond market trading volume has larger absolute basis. Therefore, the following hypothesis is also supported by the data.

Hypothesis 4: *The absolute value of CDS basis is increasing in corporate bond market trading volume.*

4.5 The Predictability of Credit Spread Term Structure Slope on Future Credit Spread Changes

Hypothesis 5:

- *Credit spread term structure slope positively predicts future credit spread changes when frictions are small.*

- *Credit spread term structure slope does not positively predict future credit spread changes when investors are selling corporate bonds and funding cost has high sensitivity to default intensity. This poor predictability is more likely for shorter maturities.*

I carry out the following regressions to test this hypothesis:

$$CS_{t+k} - CS_t = \psi_0 + \psi Slope_t + \epsilon_t \tag{39}$$

I used 4 sets of dependent variables and independent variables. For instance, for Set 1, I use the 1-5 years grade A corporate bond index asset swap spread as the CS variable. For this dependent variable, I use the 3-5 years grade A corporate bond index asset swap spread minus the 1-3 years grade A corporate bond index asset swap spread as the Slope variable. For this set, the dependent variable proxies the future change in credit spread of a 3-year corporate bond, while the independent variable proxies the difference in credit spreads of a 4 year corporate bond and a 2 year corporate bond issued by the same entity as the 3-year bond. The independent variable thus proxies the term structure of credit spread at 3 year. A full list of variables for other sets are listed in **Table 7**, which also reports regression results. I test for k =5 days and 15 days respectively and run the regressions on three sub-periods: sub-periods 1 (07/2007 to 02/2008), sub-period 2 (03/2008-03/2009) and sub-periods 3 (04/2009-09/2009) to characterize different levels of market frictions.

The results are in favor of **Hypothesis 5**. For sub-periods 1 (07/2007 to 02/2008) and sub-periods 3 (04/2009-09/2009) which corresponds to periods with less market frictions, the positive predictability of the independent variable on dependent variable is found in most cases. These results are consistent with Bedendo et.al.(2007). But in sub-period 2 (03/2008-03/2009) when market frictions are high after the Bear Stern and Lehman Collapse, the predictability is lost for Set 1 and Set 3, which correspond to credit spread term structure at approximately 3 year, while the predictability is still significant for Set 2 and Set 4, which correspond to longer time to maturity at approximately 7.5 year. Such findings support the predictions from Proposition 2, which states the regression coefficient ψ is positive when friction is low but can take negative values when friction is high. Therefore, it's not surprising to find that the predictability is lost during sub-period 2, in which severe frictions can drive the coefficient negative at times. Using shorter sub-period windows, I even find negative coefficient ψ for the 3 year term structure as shown in **Figure 4**.

4.6 Robustness Checks

The main results are not affected when using alternative funding cost proxies. To test if the results are sensitive to the construction of the Markit indices, I also construct alternative negative basis trading returns using individual CDS and corporate bond data. Regression results using these returns as dependent variables are consistent with results in the previous section. But individual CDS and corporate bond data are less reliable than the Markit indices, so I still report results using the Markit indices as the main results.

5 Conclusion

The theoretical part of this paper proposes a continuous-time limited arbitarge model to show how time-varying funding costs and demand pressure jointly create risky arbitrage opportunities on markets with identical assets. The interaction of funding illiquidity and market illiquidity results in one assets being more sensitive to risk factors that have non-zero market prices of risk than another asset with identical cash-flow does. Taking opposite positions on the two markets therefore has non-zero risk exposure and hence non-zero expected excess return. The model is applied to analyze CDS basis trading in closed-form and generate a number of testable predictions. Empirically, I find evidence for the time-varying exposure of basis trading to systematic risks as the Fama-French MKT, DEF and TERM factors are significant in explaining realized basis trading returns. Factors in the form of TED spread squared times adjusted corporate bond market trading volume has short-term predictive power on abnormal basis trading returns. The size and volatility of realized basis trading return is increasing in the severity of market frictions, while basis trading profits are increasing in the time to maturity of the underlying bond. As predicted by the model, under high levels of market frictions, the positive predictability of credit spread term structure slope on future changes in credit spread no longer exists.

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6 Appendix A: Motivation for the Funding Costs Function

6.1 Borrowing Costs

Assume there's a continuum of competitive cash lenders lends y_t cash for 1-dollar worth of bond.

$$\max_{y_t}[E_t(dw_t) - \frac{\bar{\gamma}}{2}Var_t(dw_t)] \tag{40}$$

$$dw_t = (w_t - y_t)r_t dt + y_t(r_t + s)dt + [(1 - L) - y_t]d\bar{N}_t \tag{41}$$

where $\bar{N}_t$ is counting process for the borrower's default, the intensity of $\bar{N}_t$ is $f(\lambda_t)$ which is increasing in λ_t. $s > 0$ is the exogenous rate above short-rate asked by the lender for lending using the risky bond as collateral.

$$y_t^* = s/[\bar{\gamma} f(\lambda_t)] - 1/\bar{\gamma} + (1 - L) \tag{42}$$

Therefore y_t^* is decreasing in $f(\lambda_t)$, thus decreasing in λ_t. The borrower borrows y_t^* fraction of her bond purchase at $r_t + s$ and $1 - y_t^*$ fraction at $r_t + u$, where $u > 0$ reflects the difference between un-collateralized rate and risk-free short rate. So the borrow cost in excess of r_t is:

$$h_t = y_t^*(r_t + s) + (1 - y_t^*)(r_t + u) - r_t = u - (u - s)y_t^* \tag{43}$$

which is a decreasing function of y_t^*. Since y_t^* is decreasing in λ_t, the borrow cost h_t is increasing in λ_t. With careful choice of the exogenous $f(\lambda_t)$, the borrow cost has the linear functional form of $\alpha\lambda_t + \delta$ as in the model.

6.2 Short-selling Costs

Assume there's a continuum of competitive bond lenders requires y_t cash for 1-dollar worth of bond.

$$\max_{y_t}[E_t(dw_t) - \frac{\widetilde{\gamma}}{2}Var_t(dw_t)] \tag{44}$$

$$dw_t = (w_t + y_t)r_t dt + y_t(r_t - s)dt + (y_t - 1)d\widetilde{N}_t \tag{45}$$

where $\widetilde{N}_t$ is counting process for the short-seller's default, the intensity of $\widetilde{N}_t$ is $g(\lambda_t)$ which is decreasing in λ_t. $s > 0$ is the exogenous special repo rate offered by the bond lender on the cash collateral.

$$y_t^* = s/[\widetilde{\gamma} g(\lambda_t)] + 1/\widetilde{\gamma} + 1 \tag{46}$$

Therefore y_t^* is decreasing in $g(\lambda_t)$, thus increasing in λ_t. The short-seller lends y_t^* fraction of her bond sales at $r_t - s$ and $1 - y_t^*$ fraction at r_t. So her short selling cost is:

$$h_t = r_t - [y_t^*(r_t - s) + (1 - y_t^*)r_t] = s y_t^* \tag{47}$$

which is a increasing function of y_t^*. Since y_t^* is also increasing in λ_t, the short-selling cost h_t is increasing in λ_t. With careful choice of the exogenous $g(\lambda_t)$, the short-selling cost has the linear functional form of $\alpha\lambda_t + \delta$ as in the model.

7 Appendix B: Proofs of Lemma and Proposition

7.1 Proof of Lemma 1

In the most general set-up, there're 4 sources of uncertainties, one is the jump at default, characterized by N_t, and three others as the Brownian Motions in the default intensity λ_t, short rate r_t and local investors' demand shock z_t, i.e. $B_{\lambda,t}$, $B_{r,t}$ and $B_{z,t}$. The dynamic of N_t only enters into play through λ_t, so I can rewrite $P_t^d(\tau)$ as $P_t^d(\tau, \lambda, r, z)$ and $P_t^c(\tau)$ as $P_t^c(\tau, \lambda, r, z)$. Assuming all three Brownian Motions $B_{\lambda,t}$, $B_{r,t}$ and $B_{z,t}$ are independent, I apply Ito's lemma to write $dP_t^c(\tau, \lambda, z)$ and $dP_t^d(\tau, \lambda, z)$ as:

$$dP_t^c(\tau,\lambda,r,z) = \mu_t^c(\tau)P_t^c dt + \sigma_\lambda \frac{\partial P}{\partial \lambda} dB_{\lambda,t} + \sigma_r \frac{\partial P}{\partial r} dB_{r,t} + \sigma_z \frac{\partial P}{\partial z} dB_{z,t} \quad (48)$$

$$dP_t^d(\tau,\lambda,r,z) = \mu_t^d(\tau)P_t^d dt + \sigma_\lambda \frac{\partial V}{\partial \lambda} dB_{\lambda,t} + \sigma_r \frac{\partial V}{\partial r} dB_{r,t} + \sigma_z \frac{\partial V}{\partial z} dB_{z,t} \quad (49)$$

where μ_t^c and μ_t^d are the expected returns of the bond C and bond D, conditional on no default. Entering the above dynamic into the arbitrageur's optimization problem and dropping τ, I derive the F.O.C. as in Lemma 1.

7.2 Proof of Lemma 2

Applying Ito's lemma, the dP_t^d/P_t^d and dP_t^c/P_t^c terms can be re-written as:

$$\frac{dP_t^c(\tau)}{P_t^c(\tau)} = \mu_t^c(\tau)dt - A_\lambda^c \sigma_\lambda dB_{\lambda,t} - A_r^c \sigma_r dB_{r,t} \quad (50)$$

$$\frac{dP_t^d(\tau)}{P_t^d(\tau)} = \mu_t^d(\tau)dt - A_\lambda^d \sigma_\lambda dB_{\lambda,t} - A_r^d \sigma_r dB_{r,t} \quad (51)$$

where, omitting τ, the instantaneous expected returns conditional on no default are:

$$\mu_t^c = -A_\lambda^c \kappa_\lambda(\bar{\lambda} - \lambda_t) - A_z^c \kappa_r(\bar{r} - r_t) + A_\lambda^{c\prime}\lambda_t + A_r^{c\prime} r_t + C^{c\prime} + \frac{1}{2}A_\lambda^{c\,2}\sigma_\lambda^2 + \frac{1}{2}A_r^{c2}\sigma_r^2 \quad (52)$$

$$\mu_t^d = -A_\lambda^d \kappa_\lambda(\bar{\lambda} - \lambda_t) - A_r^d \kappa_r(\bar{r} - r_t) + A_\lambda^{d\prime}\lambda_t + A_r^{d\prime} r_t + C^{d\prime} + \frac{1}{2}A_\lambda^{d2}\sigma_\lambda^2 + \frac{1}{2}A_r^{d2}\sigma_r^2 \quad (53)$$

Substitute the above into the dynamic budget constraint, the arbitrageur's F.O.C.s are:

$$\mu_t^c(\tau) - r_t - h_t^c(\tau)\frac{|x_t^c(\tau)|}{x_t^c(\tau)} - L\lambda_t = L\Phi_{J,t} - \sigma_\lambda A_\lambda^c(\tau)\Phi_{\lambda,t} - \sigma_r A_r^c(\tau)\Phi_{r,t} \quad (54)$$

$$\mu_t^d(\tau) - r_t - h_t^d(\tau)\frac{|x_t^d(\tau)|}{x_t^d(\tau)} - L\lambda_t = L\Phi_{J,t} - \sigma_\lambda A_\lambda^d(\tau)\Phi_{\lambda,t} - \sigma_r A_r^d(\tau)\Phi_{r,t} \quad (55)$$

where

$$\Phi_{J,t} = \gamma L \int_0^T [x_t^d(\tau) + x_t^c(\tau)]d\tau\lambda_t \quad (56)$$

$$\Phi_{\lambda,t} = \gamma\sigma_\lambda \int_0^T [-x_t^d(\tau)A_\lambda^d(\tau) - x_t^c(\tau)A_\lambda^c(\tau)]d\tau \quad (57)$$

$$\Phi_{r,t} = \gamma\sigma_r \int_0^T [-x_t^d(\tau)A_r^d(\tau) - x_t^c(\tau)A_r^c(\tau)]d\tau \quad (58)$$

are the market prices of risks to the default jump, default intensity and short rate factors.

In equilibrium, markets clear. So $x_t^i + z^i = 0$, $i = c, d$. Replace $x_t^i(\tau)$ by $-z^i(\tau)$, and replace h_t^i by the functions defined in previous sections, then the F.O.C.s are affine equations in the risk factors λ_t and r_t. Setting the linear terms in λ_t and r_t to zero implies that $A_j^i(\tau)$ are the solutions to the a system of ODEs with initial conditions $A_j^i(0) = 0$, $i = v, p$ and $j = \lambda, r$:

$$A_\lambda^{c\prime}(\tau) + \kappa_\lambda A_\lambda^c(\tau) - [-\alpha^c(\tau)\frac{|z^c(\tau)|}{z^c(\tau)} + L] = -\gamma L^2 \int_0^T [z^d(\tau) + z^c(\tau)]d\tau \quad (59)$$

$$A_\lambda^{d\prime}(\tau) + \kappa_\lambda A_\lambda^d(\tau) - [-\alpha^d(\tau)\frac{|z^d(\tau)|}{z^d(\tau)} + L] = -\gamma L^2 \int_0^T [z^d(\tau) + z^c(\tau)]d\tau \quad (60)$$

$$A_r^{c\prime}(\tau) + \kappa_r A_r^c(\tau) - 1 = 0 \quad (61)$$

$$A_r^{d\prime}(\tau) + \kappa_r A_r^d(\tau) - 1 = 0 \quad (62)$$

7.3 Proof of Proposition 1

Replace $\frac{\partial P_t^c}{\partial \lambda}/P_t^c$ with $-A_\lambda^c(\tau)$ and replace $\frac{\partial P_t^d}{\partial \lambda}/P_t^d$ with $-A_\lambda^d(\tau)$ in Definition 1, $\frac{\partial P_t^c}{\partial r}/P_t^c$ and $\frac{\partial P_t^c}{\partial r}/P_t^c$ are the same.

7.4 Proof of Proposition 2

The time-varying component in the dependent variable is: $\frac{A_\lambda^c(\tau-\Delta\tau)}{\tau-\Delta\tau}\lambda_{t+\Delta\tau} - \frac{A_\lambda^c(\tau)}{\tau}\lambda_t$, the time-varying componet in the independent variable is: $\frac{A_\lambda^c(\tau)}{\tau}\lambda_t - \frac{A_\lambda^c(\tau-\Delta\tau)}{\tau-\Delta\tau}\lambda_t$. So the regression coefficient is:

$$\psi = \frac{cov[\frac{A_\lambda^c(\tau-\Delta\tau)}{\tau-\Delta\tau}\lambda_{t+\Delta\tau} - \frac{A_\lambda^c(\tau)}{\tau}\lambda_t, \frac{A_\lambda^c(\tau)}{\tau}\lambda_t - \frac{A_\lambda^c(\tau-\Delta\tau)}{\tau-\Delta\tau}\lambda_t]}{var[\frac{A_\lambda^c(\tau)}{\tau}\lambda_t - \frac{A_\lambda^c(\tau-\Delta\tau)}{\tau-\Delta\tau}\lambda_t]} \quad (63)$$

$$= \frac{\tau A_\lambda^c(\tau-\Delta\tau)e^{-\kappa_\lambda\Delta\tau} - (\tau-\Delta\tau)A_\lambda^c(\tau)}{(\tau-\Delta\tau)A_\lambda^c(\tau) - \tau A_\lambda^c(\tau-\Delta\tau)} \quad (64)$$

when $\Delta\tau \to 0$,

$$\psi = -\frac{\tau[A_\lambda^c(\tau)' + \kappa_\lambda A_\lambda^c(\tau)]}{\tau[A_\lambda^c(\tau)' - 1]} \quad (65)$$

$$= \frac{F(\tau)}{1 - F(\tau)e^{-\kappa_\lambda\tau}} \quad (66)$$

where $F(\tau) = -\alpha^c(\tau)\frac{|z^c(\tau)|}{z^c(\tau)} + L - \gamma L^2 \int_0^T [z^c(\tau) + z^d(\tau)]d\tau$.

$\psi > 0$ if $F(\tau) < e^{\kappa_\lambda \tau}$, and $\psi < 0$ if $F(\tau) > e^{\kappa_\lambda \tau}$.

7.5 Proof of Lemma 3

Lemma 3a: For very negative $\bar{\theta}(\tau)$ and negative $\theta(\tau)$, the Arbitrageur's F.O.C.s are:

$$\mu_t^c(\tau) - r_t - h_t^c(\tau) - L\lambda_t = L\Phi_{J,t} - \sigma_\lambda A_\lambda^c(\tau)\Phi_{\lambda,t} - \sigma_r A_r^c(\tau)\Phi_{r,t} - \sigma_z A_z^c(\tau)\Phi_{z,t} \quad (67)$$

$$\mu_t^d(\tau) - r_t + h_t^d(\tau) - L\lambda_t = L\Phi_{J,t} - \sigma_\lambda A_\lambda^d(\tau)\Phi_{\lambda,t} - \sigma_r A_r^d(\tau)\Phi_{r,t} - \sigma_z A_z^d(\tau)\Phi_{z,t} \quad (68)$$

where

$$\Phi_{J,t} = \gamma L \int_0^T [x_t^d(\tau) + x_t^c(\tau)]d\tau \lambda_t \quad (69)$$

$$\Phi_{\lambda,t} = \gamma\sigma_\lambda \int_0^T [-x_t^d(\tau)A_\lambda^d(\tau) - x_t^c(\tau)A_\lambda^c(\tau)]d\tau \quad (70)$$

$$\Phi_{r,t} = \gamma\sigma_r \int_0^T [-x_t^d(\tau)A_r^d(\tau) - x_t^c(\tau)A_r^c(\tau)]d\tau \quad (71)$$

$$\Phi_{z,t} = \gamma\sigma_z \int_0^T [-x_t^d(\tau)A_z^d(\tau) - x_t^c(\tau)A_z^c(\tau)]d\tau \quad (72)$$

are the market prices of risks to the default jump, default intensity, short rate and demand shock factors.

In equilibrium, markets clear. So $x_t^i + z_t^i = 0$. Then the F.O.C.s are affine equations in the risk factors λ_t, r_t and z_t.[10] Setting the linear terms in λ_t, r_t and z_t to zero implies that $A_j^i(\tau)$ are the solutions to the a system of ODEs with initial conditions $A_j^i(0) = 0$, $i = v, p$ and $j = \lambda, r, z$:

$$A_\lambda^{c\prime}(\tau) + \kappa_\lambda A_\lambda^c(\tau) - [\alpha^c(\tau) + L] = 0 \quad (73)$$

$$A_\lambda^{d\prime}(\tau) + \kappa_\lambda A_\lambda^d(\tau) - [-\alpha^d(\tau) + L] = 0 \quad (74)$$

$$A_r^{c\prime}(\tau) + \kappa_r A_r^c(\tau) - 1 = 0 \quad (75)$$

$$A_r^{d\prime}(\tau) + \kappa_r A_r^d(\tau) - 1 = 0 \quad (76)$$

$$A_z^{c\prime}(\tau) + \kappa_z A_z^c(\tau) = -\gamma\sigma_\lambda^2 A_\lambda^c(\tau) \int_0^T \theta(\tau)[A_\lambda^c(\tau) - A_\lambda^d(\tau)]d\tau - \gamma\sigma_z^2 A_z^c(\tau) \int_0^T \theta(\tau)[A_z^c(\tau) - A_z^d(\tau)]d\tau \quad (77)$$

$$A_z^{d\prime}(\tau) + \kappa_z A_z^d(\tau) = -\gamma\sigma_\lambda^2 A_\lambda^d(\tau) \int_0^T \theta(\tau)[A_\lambda^c(\tau) - A_\lambda^d(\tau)]d\tau - \gamma\sigma_z^2 A_z^d(\tau) \int_0^T \theta(\tau)[A_z^c(\tau) - A_z^d(\tau)]d\tau \quad (78)$$

Lemma 3b: similar to Lemma 3a, but the unique positive solution of κ_z^* is guaranteed only when κ_z is large enough.

[10] By assuming that the two markets have exact opposite demand pressure, the market price of risk for the default jump factor becomes zero as the arbitrageur's aggregate positions are free of default jump risk.

7.6 Proof of Proposition 3

Replace $\frac{\partial P_t^c}{\partial \lambda}/P_t^c$ with $-A_\lambda^c(\tau)$, replace $\frac{\partial P_t^d}{\partial \lambda}/P_t^d$ with $-A_\lambda^d(\tau)$, replace $\frac{\partial P_t^c}{\partial z}/P_t^c$ with $-A_z^c(\tau)$, replace $\frac{\partial P_t^d}{\partial z}/P_t^d$ with $-A_z^d(\tau)$ in Definition 1, $\frac{\partial P_t^c}{\partial r}/P_t^c$ and $\frac{\partial P_t^c}{\partial r}/P_t^c$ are the same.

7.7 Proof of Proposition 4

$$\frac{\partial Basis}{\partial \lambda_t} = \frac{A_\lambda^d(\tau)}{\tau} - \frac{A_\lambda^c(\tau)}{\tau} \tag{79}$$

$$\frac{\partial Basis}{\partial z_t} = \frac{A_z^d(\tau)}{\tau} - \frac{A_z^c(\tau)}{\tau} \tag{80}$$

so $sign(\frac{\partial Basis}{\partial \lambda_t}) = sign(A_\lambda^d - A_\lambda^c)$ and $sign(\frac{\partial Basis}{\partial z_t}) = sign(A_z^d - A_z^c)$.

7.8 Proof of Proposition 5

Easily proved by taking the derivatives of $G^\lambda(\tau)$ and $G^z(\tau)$ on τ, then summarize results for different signs of $z_t^c(\tau)$.

7.9 Proof of Proposition 6

$\partial^2 Y_t(\tau)/\partial\tau = [\frac{A_\lambda^c(\tau)}{\tau}]'\lambda_t + constants$, where $\frac{A_\lambda^c(\tau)}{\tau} = [\alpha^c + L]\frac{1-e^{-\kappa_\lambda \tau}}{\kappa_\lambda \tau}$ when $z_t^c < 0$ and $\frac{A_\lambda^c(\tau)}{\tau} = [-\alpha^c + L]\frac{1-e^{-\kappa_\lambda \tau}}{\kappa_\lambda \tau}$ when $z_t^c > 0$. $\frac{1-e^{-\kappa_\lambda \tau}}{\kappa_\lambda \tau}$ is a decreasing function of τ, therefore $\partial^2 Y_t(\tau)/(\partial\tau\partial\lambda_t) = [\frac{A_\lambda^c(\tau)}{\tau}]' < 0$. When $z_t^c < 0$, $[\frac{A_\lambda^c(\tau)}{\tau}]' = [\alpha^c + L](\frac{1-e^{-\kappa_\lambda \tau}}{\kappa_\lambda \tau})'$ is more negative than $[\frac{A_\lambda^c(\tau)}{\tau}]' = [-\alpha^c + L](\frac{1-e^{-\kappa_\lambda \tau}}{\kappa_\lambda \tau})'$ when $z_t^c > 0$.

Appendix C: Figures and Tables

Figure 1: CDS Basis and 1-week Negative Basis Trading Returns

Dashed line plots CDS basis from April 2007 to December 2009.
Values in the left vertical axis are in basis points.
Solid line plots 1-week realized excess return of negative basis trading.

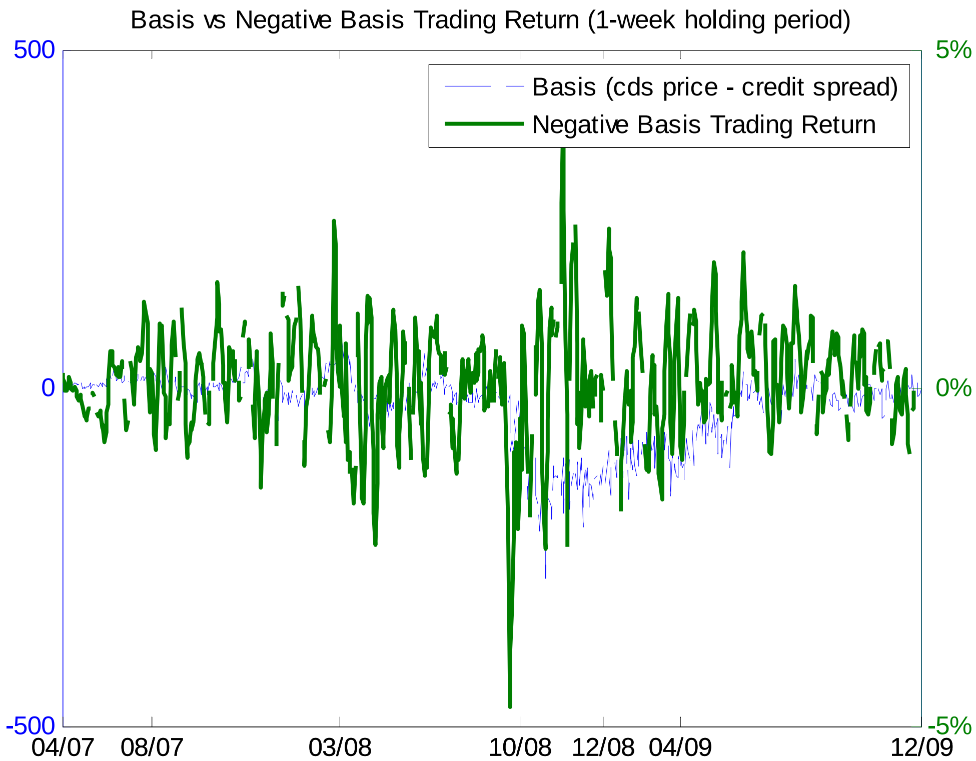

Figure 2: Negative Basis Trading Return's Time-varying Exposure to Systematic Factors

The solid line plots rolling window beta of the DEF factor in Regression B.
The dashed line plots rolling window beta of the TERM factor in Regression B.
Dependent variable: 1-day realized excess return of negative basis trading.
As predicted by the model, betas are highly time-varying.

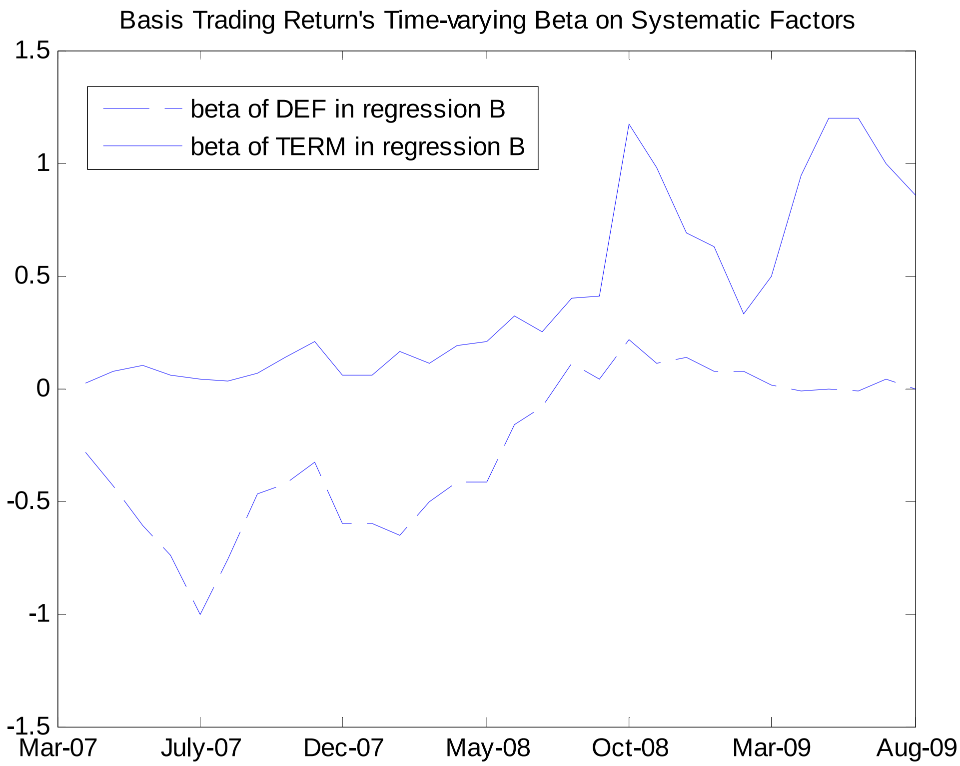

Figure 3: Cumulative Profit of Basis Trading on Underlying of Different Maturities

The three lines plot the cumulative sum of the absolute value of negative CDS basis trading returns on underlying bonds of three different maturities.
Size of basis trading return is larger for underlying bond with longer time to maturity.

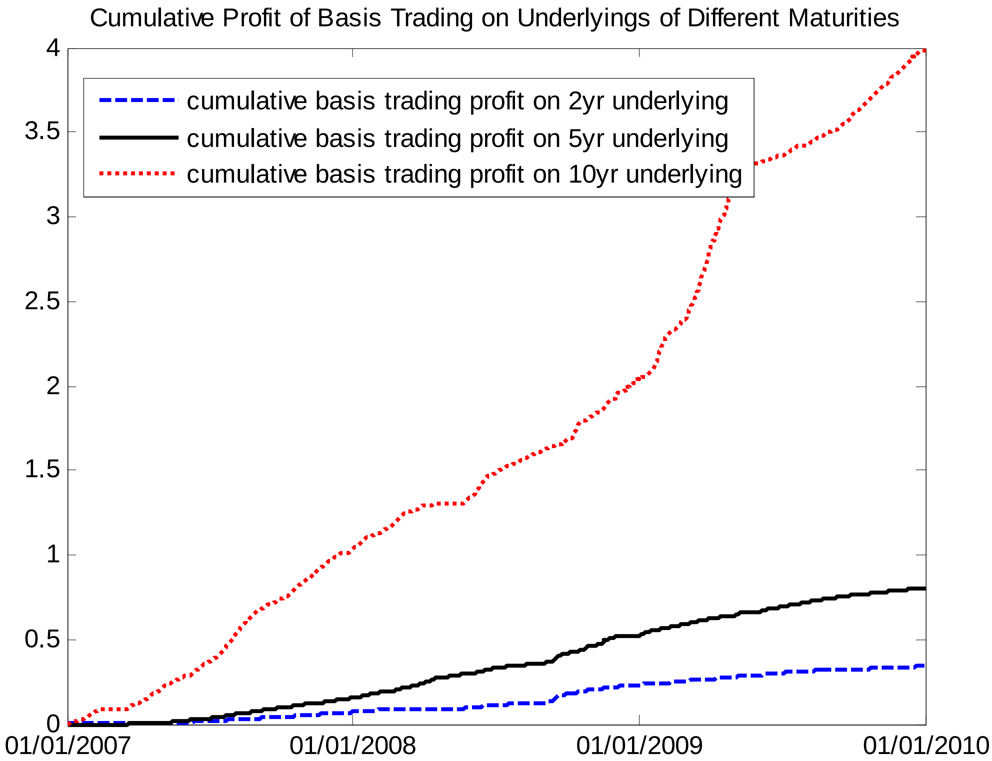

Figure 4: Time-varying Coefficient Estimate of psi for 3yr Grade A Corporate Bond Index

The solid line plots rolling window coefficient estimate of the 3yr Grade A credit spread term structure in regression for Hypothesis 5.
The dashed line plots the corresponding Newey-West T-stats.
Dependent variable: future 15-day change in 3yr Grade A credit spread.
Independent variable: slope of Grade A credit spread term structure at 3yr.
As predicted by the model, the coefficient estimate psi was significantly positive before and after the crisis but became significantly negative during crisis.

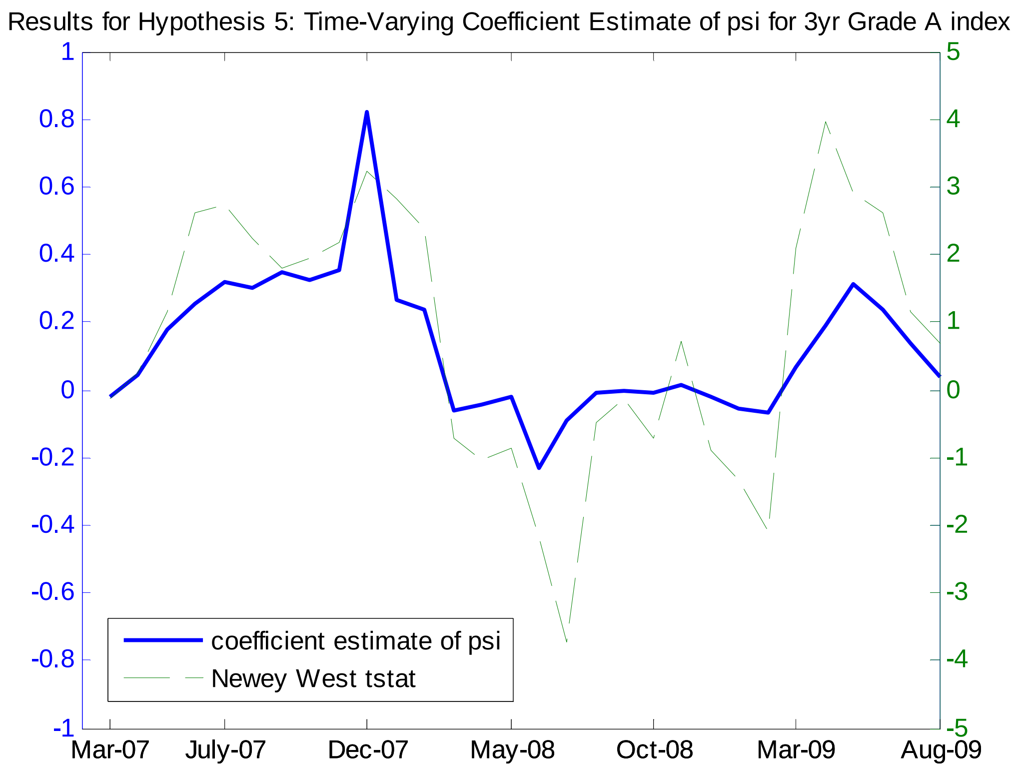

Table 1: Beta and NW-Tstats of Rolling-Window Regression A

Dependent varible: 1-day realized excess return of negative basis trading

Panel A: Beta

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis
Mar-07	May-07	0.001	0.544	-0.064	-0.739	0.605	0.506
Apr-07	Jun-07	0.040	-2.401	-2.752	-1.596	3.298	0.703
May-07	Jul-07	-0.049	3.389	3.314	0.110	-0.872	0.713
Jun-07	Aug-07	-0.025	2.370	1.792	0.180	-1.170	0.159
Jul-07	Sep-07	0.006	0.480	-0.315	0.295	-0.796	0.099
Aug-07	Oct-07	0.005	-0.008	-0.321	0.049	-0.222	0.380
Sep-07	Nov-07	0.001	-0.057	-0.110	0.884	-0.698	0.290
Oct-07	Dec-07	0.007	-0.773	-0.527	0.503	-0.180	0.044
Nov-07	Jan-08	0.001	-0.064	0.036	0.367	-0.420	0.075
Dec-07	Feb-08	-0.002	0.572	0.275	0.474	-0.378	0.118
Jan-08	Mar-08	-0.007	2.252	0.917	-0.212	-0.214	0.217
Feb-08	Apr-08	-0.008	2.777	1.339	-1.726	0.349	0.261
Mar-08	May-08	0.011	1.640	-2.049	-2.549	1.182	-0.314
Apr-08	Jun-08	-0.018	5.203	3.304	-8.051	3.159	-0.141
May-08	Jul-08	-0.019	4.961	3.399	-4.758	1.362	-0.470
Jun-08	Aug-08	0.018	0.099	-2.994	1.141	-0.910	-0.275
Jul-08	Sep-08	0.010	0.744	-0.929	-2.635	0.596	0.422
Aug-08	Oct-08	0.008	0.275	-1.250	-1.188	0.331	0.456
Sep-08	Nov-08	0.002	-0.204	-1.322	0.085	0.178	0.334
Oct-08	Dec-08	0.001	-0.680	-1.958	1.878	-0.200	0.303
Nov-08	Jan-09	-0.002	0.906	0.692	0.623	-0.280	-0.102
Dec-08	Feb-09	0.007	1.539	-13.012	4.885	-1.609	-0.069
Jan-09	Mar-09	0.004	1.677	-7.665	3.424	-1.181	-0.030
Feb-09	Apr-09	0.004	0.679	-9.861	0.800	-0.180	0.149
Mar-09	May-09	0.005	1.720	-9.133	0.439	-0.275	0.259
Apr-09	Jun-09	-0.002	-0.302	4.188	0.513	0.023	0.155
May-09	Jul-09	-0.005	3.115	6.883	5.158	-2.234	0.220
Jun-09	Aug-09	-0.008	5.581	18.200	0.867	-1.487	0.099
Jul-09	Sep-09	0.001	3.351	-4.239	3.337	-2.016	0.315
Aug-09	Oct-09	0.002	5.987	-3.484	5.294	-4.361	0.027

Table 1 Continued: Beta and NW-Tstats of Rolling-Window Regression A

Dependent varible: 1-day realized excess return of negative basis trading

Panel B: Newey West Tstat

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis
Mar-07	May-07	0.022	0.153	-0.018	-1.338	1.210	1.503
Apr-07	Jun-07	0.504	-0.501	-0.505	-1.581	1.750	1.965
May-07	Jul-07	-1.755	2.169	1.765	0.111	-0.684	1.224
Jun-07	Aug-07	-2.641	3.988	2.655	0.192	-1.332	0.385
Jul-07	Sep-07	0.550	0.779	-0.429	0.302	-0.773	0.248
Aug-07	Oct-07	0.879	-0.012	-0.650	0.050	-0.247	1.647
Sep-07	Nov-07	0.126	-0.084	-0.132	1.846	-1.640	1.367
Oct-07	Dec-07	1.616	-1.891	-1.407	0.985	-0.561	0.251
Nov-07	Jan-08	0.334	-0.127	0.128	0.308	-0.501	0.274
Dec-07	Feb-08	-0.590	0.941	0.763	0.398	-0.612	0.392
Jan-08	Mar-08	-0.993	1.849	0.974	-0.082	-0.167	0.698
Feb-08	Apr-08	-0.838	1.833	0.799	-0.715	0.359	0.597
Mar-08	May-08	0.373	0.454	-0.388	-0.878	1.870	-1.066
Apr-08	Jun-08	-1.985	3.651	2.078	-2.765	2.139	-0.515
May-08	Jul-08	-2.055	3.395	1.991	-2.464	1.538	-2.239
Jun-08	Aug-08	1.370	0.089	-1.186	0.758	-1.798	-1.524
Jul-08	Sep-08	2.900	1.581	-1.585	-2.629	2.225	1.802
Aug-08	Oct-08	2.884	0.430	-2.405	-0.868	1.004	2.506
Sep-08	Nov-08	1.298	-0.254	-2.975	0.059	0.590	1.835
Oct-08	Dec-08	0.845	-0.671	-1.512	1.021	-0.507	1.704
Nov-08	Jan-09	-1.115	0.883	0.337	0.297	-0.514	-0.575
Dec-08	Feb-09	3.081	1.067	-3.909	2.042	-2.520	-0.456
Jan-09	Mar-09	1.153	1.635	-1.315	1.345	-1.682	-0.218
Feb-09	Apr-09	1.258	0.519	-1.319	0.855	-1.218	0.892
Mar-09	May-09	2.264	1.288	-1.807	0.462	-1.004	1.675
Apr-09	Jun-09	-0.695	-0.084	0.620	0.232	0.085	0.763
May-09	Jul-09	-1.641	1.009	0.914	1.370	-1.897	0.725
Jun-09	Aug-09	-1.957	1.735	1.855	0.310	-1.699	0.420
Jul-09	Sep-09	0.601	1.069	-0.722	0.514	-0.532	1.200
Aug-09	Oct-09	0.976	1.535	-0.676	0.973	-1.239	0.126

Table 2: Beta and NW-Tstats of Rolling-Window Regression B

Dependent varible: 1-day realized excess return of negative basis trading

Panel A: Beta

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis	MKTRF	DEF	TERM
Mar-07	May-07	0.068	-3.273	-4.633	-0.484	0.709	0.270	0.016	-0.282	0.020
Apr-07	Jun-07	0.021	-2.775	-1.433	-3.512	8.881	0.696	-0.030	-0.436	0.079
May-07	Jul-07	-0.057	3.635	3.935	0.505	-1.418	0.798	-0.029	-0.607	0.104
Jun-07	Aug-07	-0.013	1.515	1.024	-0.960	0.273	0.237	-0.051	-0.745	0.056
Jul-07	Sep-07	0.018	0.051	-1.145	-2.355	2.169	0.376	-0.067	-1.007	0.040
Aug-07	Oct-07	0.002	0.360	-0.063	-0.565	0.367	0.272	-0.032	-0.757	0.030
Sep-07	Nov-07	-0.006	0.110	0.494	0.401	-0.276	0.369	-0.019	-0.466	0.062
Oct-07	Dec-07	0.001	-0.543	-0.055	0.599	-0.167	0.027	-0.041	-0.424	0.132
Nov-07	Jan-08	0.000	-0.258	0.040	0.448	0.009	-0.208	-0.059	-0.330	0.209
Dec-07	Feb-08	0.000	0.646	0.048	0.587	-0.413	-0.213	-0.048	-0.603	0.056
Jan-08	Mar-08	-0.011	2.635	1.402	-1.024	0.253	-0.034	-0.057	-0.605	0.060
Feb-08	Apr-08	-0.013	4.292	2.066	-3.766	1.316	0.328	-0.103	-0.650	0.166
Mar-08	May-08	0.010	1.730	-1.818	-3.473	1.722	-0.248	-0.142	-0.502	0.106
Apr-08	Jun-08	-0.019	5.671	3.676	-9.383	3.915	0.111	-0.036	-0.413	0.187
May-08	Jul-08	-0.023	5.239	4.147	-5.518	1.835	-0.218	-0.046	-0.413	0.209
Jun-08	Aug-08	0.006	1.868	-0.575	1.885	-1.786	-0.679	-0.065	-0.161	0.319
Jul-08	Sep-08	0.008	1.558	-0.061	-3.650	0.676	0.341	-0.041	-0.088	0.251
Aug-08	Oct-08	0.006	0.479	-0.642	-1.354	0.338	0.403	-0.033	0.110	0.395
Sep-08	Nov-08	0.002	0.141	-0.666	-0.647	0.317	0.368	-0.039	0.041	0.410
Oct-08	Dec-08	0.001	-0.168	-1.424	0.875	-0.048	0.214	-0.042	0.213	1.172
Nov-08	Jan-09	0.000	1.597	-0.474	1.450	-0.518	0.003	-0.035	0.106	0.980
Dec-08	Feb-09	0.006	0.531	-11.117	5.893	-1.694	-0.009	0.002	0.140	0.691
Jan-09	Mar-09	0.002	1.948	-4.978	4.822	-1.629	-0.050	-0.010	0.072	0.628
Feb-09	Apr-09	0.004	0.151	-9.468	0.844	-0.139	0.124	0.000	0.079	0.328
Mar-09	May-09	0.004	1.066	-7.447	0.398	-0.141	0.245	-0.032	0.009	0.492
Apr-09	Jun-09	-0.001	-4.554	1.482	2.018	0.222	0.229	-0.020	-0.015	0.941
May-09	Jul-09	-0.003	-2.891	1.308	7.599	-2.122	0.175	-0.046	-0.003	1.195
Jun-09	Aug-09	-0.006	2.394	11.082	2.999	-1.610	-0.078	-0.029	-0.011	1.199
Jul-09	Sep-09	0.001	2.117	-4.418	11.093	-5.735	-0.020	0.011	0.042	0.996
Aug-09	Oct-09	0.002	8.331	-4.068	10.783	-8.135	-0.186	0.005	-0.003	0.858

Table 2 Continued: Beta and NW-Tstats of Rolling-Window Regression B

Dependent varible: 1-day realized excess return of negative basis trading

Panel B: Newey West Tstat

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis	MKTRF	DEF	TERM
Mar-07	May-07	1.040	-0.878	-1.038	-0.867	1.006	0.939	0.640	-4.756	1.105
Apr-07	Jun-07	0.276	-0.554	-0.276	-3.322	4.422	3.065	-1.079	-6.020	1.787
May-07	Jul-07	-2.823	3.272	2.884	0.511	-1.250	1.658	-1.323	-3.341	1.856
Jun-07	Aug-07	-0.790	1.982	0.918	-0.945	0.274	0.692	-2.478	-4.520	0.925
Jul-07	Sep-07	1.831	0.105	-1.637	-2.130	2.075	1.046	-3.405	-5.428	1.080
Aug-07	Oct-07	0.394	0.894	-0.143	-0.678	0.490	1.019	-1.571	-7.699	0.686
Sep-07	Nov-07	-0.466	0.143	0.520	0.510	-0.586	1.378	-0.980	-3.154	0.805
Oct-07	Dec-07	0.365	-1.281	-0.151	0.575	-0.258	0.126	-2.083	-3.228	1.277
Nov-07	Jan-08	-0.080	-0.548	0.154	0.279	0.008	-0.849	-2.813	-4.444	2.364
Dec-07	Feb-08	-0.029	1.009	0.174	0.471	-0.677	-0.884	-1.798	-5.866	0.509
Jan-08	Mar-08	-1.420	1.870	1.446	-0.423	0.220	-0.127	-1.457	-5.918	0.610
Feb-08	Apr-08	-1.545	2.860	1.471	-1.833	1.600	0.883	-2.289	-5.915	1.490
Mar-08	May-08	0.456	0.602	-0.467	-1.419	2.244	-0.827	-2.325	-5.526	1.342
Apr-08	Jun-08	-1.835	3.613	1.940	-3.137	2.736	0.547	-1.647	-6.488	1.875
May-08	Jul-08	-2.048	3.145	2.058	-2.823	2.264	-1.131	-3.010	-4.561	1.986
Jun-08	Aug-08	0.587	1.928	-0.322	1.661	-4.954	-3.058	-4.014	-1.619	3.000
Jul-08	Sep-08	2.688	2.015	-0.095	-2.680	2.000	1.220	-1.717	-0.906	1.595
Aug-08	Oct-08	2.557	0.674	-1.304	-0.933	1.035	2.076	-1.658	0.925	1.948
Sep-08	Nov-08	1.541	0.181	-1.316	-0.489	1.167	2.164	-1.969	0.294	1.657
Oct-08	Dec-08	0.945	-0.192	-1.444	0.553	-0.142	1.399	-2.082	1.915	3.010
Nov-08	Jan-09	-0.519	1.748	-0.331	0.748	-1.031	0.016	-1.575	1.076	3.834
Dec-08	Feb-09	3.582	0.325	-4.750	3.427	-2.968	-0.063	0.158	1.622	4.773
Jan-09	Mar-09	0.814	1.660	-0.868	2.556	-3.002	-0.318	-0.620	0.802	4.131
Feb-09	Apr-09	1.328	0.094	-1.369	0.844	-0.864	0.736	-0.002	0.979	1.576
Mar-09	May-09	1.575	0.749	-1.374	0.424	-0.505	1.801	-1.401	0.201	1.909
Apr-09	Jun-09	-0.350	-1.476	0.304	1.140	0.954	1.699	-0.717	-0.390	3.744
May-09	Jul-09	-0.783	-0.908	0.203	2.546	-2.413	1.120	-2.092	-0.128	8.719
Jun-09	Aug-09	-2.505	0.964	1.977	1.467	-2.317	-0.527	-1.384	-0.289	8.388
Jul-09	Sep-09	0.590	0.727	-1.016	1.676	-1.478	-0.133	0.426	0.518	5.990
Aug-09	Oct-09	1.235	2.794	-0.980	2.005	-2.431	-1.166	0.267	-0.031	4.087

Table 3: Beta and NW-Tstats of Rolling-Window Regression C

Dependent varible: 1-day realized excess return of negative basis trading

Panel A: Beta

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis	MKTRF	DEF	TERM	SignedTV	TED2*TV
Mar-07	May-07	-0.007	1.140	0.446	-1.035	1.043	0.216	0.002	-0.420	-0.009	0.033	0.412
Apr-07	Jun-07	-0.011	-0.243	0.790	-1.874	5.106	0.460	-0.014	-0.503	0.065	0.046	-0.110
May-07	Jul-07	-0.067	4.641	4.663	0.115	-2.412	0.631	-0.016	-0.704	0.025	0.057	0.275
Jun-07	Aug-07	-0.020	1.906	1.511	-1.508	0.659	0.178	-0.024	-0.900	0.035	0.066	0.016
Jul-07	Sep-07	0.011	0.423	-0.580	-2.578	2.301	0.254	-0.041	-1.131	0.050	0.064	-0.010
Aug-07	Oct-07	-0.001	0.777	0.202	-1.127	0.778	0.276	-0.018	-1.026	0.016	0.090	-0.018
Sep-07	Nov-07	0.007	-0.503	-0.464	0.095	-0.185	-0.059	0.002	-0.666	0.015	0.100	0.070
Oct-07	Dec-07	0.001	-0.382	-0.050	-0.039	-0.002	-0.003	-0.029	-0.663	0.028	0.088	0.059
Nov-07	Jan-08	0.000	-0.257	-0.037	-0.483	0.485	-0.195	-0.042	-0.528	0.139	0.075	0.075
Dec-07	Feb-08	-0.001	1.386	0.112	1.501	-0.863	-0.224	-0.015	-0.744	-0.003	0.090	-0.126
Jan-08	Mar-08	-0.010	2.310	1.278	-0.559	0.099	-0.111	-0.035	-0.781	0.011	0.113	-0.103
Feb-08	Apr-08	-0.012	3.895	1.667	-2.581	0.933	0.322	-0.072	-0.784	0.081	0.108	-0.120
Mar-08	May-08	0.008	1.496	-1.569	-2.732	1.444	-0.129	-0.117	-0.623	0.092	0.068	-0.030
Apr-08	Jun-08	-0.012	4.305	2.255	-6.985	3.087	0.256	-0.020	-0.533	0.210	0.059	-0.116
May-08	Jul-08	-0.020	4.501	3.625	-5.248	2.066	-0.050	-0.026	-0.571	0.255	0.064	-0.125
Jun-08	Aug-08	0.001	2.238	0.303	1.509	-1.660	-0.663	-0.043	-0.131	0.320	0.016	-0.033
Jul-08	Sep-08	0.005	1.422	0.139	-3.258	0.674	0.368	-0.011	-0.089	0.234	0.094	-0.023
Aug-08	Oct-08	0.004	0.535	-0.241	-1.031	0.321	0.343	0.007	0.072	0.337	0.156	-0.051
Sep-08	Nov-08	0.001	0.230	-0.530	-0.706	0.298	0.333	-0.025	-0.082	0.263	0.099	0.002
Oct-08	Dec-08	0.001	0.002	-1.290	1.019	-0.153	0.217	-0.034	0.126	0.938	0.067	0.032
Nov-08	Jan-09	0.000	1.937	-0.720	1.098	-0.633	-0.089	-0.030	-0.058	0.611	0.086	0.083
Dec-08	Feb-09	0.004	0.596	-8.394	5.413	-1.574	0.008	0.003	0.061	0.648	0.049	0.023
Jan-09	Mar-09	0.002	1.355	-4.665	5.818	-1.725	-0.060	-0.006	-0.008	0.525	0.055	-0.273
Feb-09	Apr-09	0.005	-0.431	-11.309	1.872	-0.245	0.133	-0.001	-0.009	0.207	0.033	-0.177
Mar-09	May-09	0.005	0.379	-9.181	1.407	-0.243	0.219	-0.029	0.009	0.394	0.003	-0.143
Apr-09	Jun-09	-0.001	-4.500	2.013	1.850	0.225	0.234	-0.022	-0.002	0.990	-0.014	0.031
May-09	Jul-09	-0.003	-2.506	1.751	7.430	-2.176	0.181	-0.051	0.004	1.220	-0.012	0.048
Jun-09	Aug-09	-0.006	2.327	10.628	2.993	-1.576	-0.046	-0.022	-0.037	1.159	0.020	0.011
Jul-09	Sep-09	0.001	1.944	-4.402	10.927	-5.568	-0.040	0.011	0.038	0.994	0.001	-0.094
Aug-09	Oct-09	0.002	8.687	-4.225	11.403	-8.536	-0.210	0.008	-0.044	0.826	0.009	-0.122

Table 3 Continued: Beta and NW-Tstats of Rolling-Window Regression C

Dependent varible: 1-day realized excess return of negative basis trading

Panel B: Newey West Tstat

Start	End	constant	Libor-FFR	FFR	TED	TED*ASW	Basis	MKTRF	DEF	TERM	SignedTV	TED2*TV
Mar-07	May-07	-0.102	0.289	0.100	-1.681	1.631	0.857	0.079	-5.302	-0.483	3.762	1.693
Apr-07	Jun-07	-0.216	-0.073	0.216	-1.741	2.487	2.045	-0.639	-6.056	1.864	3.362	-0.518
May-07	Jul-07	-2.720	2.971	2.743	0.142	-2.003	1.510	-0.726	-4.053	0.442	2.510	1.268
Jun-07	Aug-07	-1.612	3.229	1.757	-1.431	0.722	0.587	-1.110	-5.878	0.640	2.461	0.305
Jul-07	Sep-07	0.851	0.862	-0.674	-2.028	2.088	0.798	-1.654	-6.825	1.565	2.301	-0.216
Aug-07	Oct-07	-0.346	2.235	0.636	-1.445	1.260	1.403	-1.214	-11.036	0.397	6.066	-0.517
Sep-07	Nov-07	0.711	-0.757	-0.650	0.143	-0.429	-0.191	0.118	-4.593	0.223	4.106	1.646
Oct-07	Dec-07	0.312	-0.944	-0.184	-0.040	-0.004	-0.010	-1.485	-3.904	0.268	3.143	1.572
Nov-07	Jan-08	0.136	-0.623	-0.176	-0.339	0.485	-0.919	-1.850	-5.728	1.714	2.949	2.247
Dec-07	Feb-08	-0.531	1.780	0.394	1.450	-1.640	-0.943	-0.430	-6.909	-0.031	2.552	-1.608
Jan-08	Mar-08	-1.537	1.705	1.588	-0.297	0.115	-0.432	-0.839	-7.537	0.132	3.733	-0.895
Feb-08	Apr-08	-1.639	2.907	1.357	-1.406	1.329	0.926	-1.326	-7.163	0.784	3.103	-0.998
Mar-08	May-08	0.394	0.566	-0.432	-1.246	2.260	-0.432	-1.571	-5.666	1.143	2.003	-0.246
Apr-08	Jun-08	-1.134	2.644	1.159	-2.350	2.263	1.406	-0.740	-5.942	2.294	1.535	-1.873
May-08	Jul-08	-1.932	2.712	1.952	-3.131	3.193	-0.239	-1.646	-4.980	2.457	1.908	-2.405
Jun-08	Aug-08	0.092	2.194	0.164	1.446	-5.559	-3.368	-2.540	-1.073	3.158	0.425	-2.218
Jul-08	Sep-08	2.078	2.118	0.239	-2.950	2.120	1.296	-0.612	-0.822	1.589	1.901	-1.233
Aug-08	Oct-08	1.989	0.964	-0.615	-0.963	1.096	1.635	0.408	0.683	1.724	3.411	-2.614
Sep-08	Nov-08	1.034	0.290	-1.391	-0.545	1.182	1.927	-1.062	-0.647	0.872	1.670	0.075
Oct-08	Dec-08	0.943	0.002	-1.459	0.668	-0.464	1.379	-1.471	1.096	2.168	1.864	0.725
Nov-08	Jan-09	0.101	2.771	-0.587	0.708	-1.573	-0.463	-1.519	-0.506	3.498	2.488	3.802
Dec-08	Feb-09	2.708	0.368	-3.036	3.129	-2.665	0.054	0.196	0.670	4.773	1.803	0.835
Jan-09	Mar-09	0.821	1.268	-0.815	2.899	-2.912	-0.383	-0.383	-0.089	3.560	2.724	-2.442
Feb-09	Apr-09	1.508	-0.278	-1.587	1.557	-1.200	0.816	-0.055	-0.079	1.047	1.177	-1.512
Mar-09	May-09	1.903	0.234	-1.793	1.131	-0.877	1.623	-1.322	0.172	1.380	0.121	-1.295
Apr-09	Jun-09	-0.321	-1.248	0.365	0.808	0.921	1.720	-0.770	-0.055	4.691	-0.833	0.285
May-09	Jul-09	-0.780	-0.695	0.271	2.571	-2.293	1.285	-2.135	0.167	9.519	-0.785	0.357
Jun-09	Aug-09	-2.505	0.943	1.906	1.371	-1.932	-0.333	-0.985	-0.745	6.681	1.191	0.040
Jul-09	Sep-09	0.592	0.633	-1.025	1.649	-1.414	-0.263	0.419	0.371	5.147	0.066	-0.212
Aug-09	Oct-09	1.331	2.888	-1.051	2.096	-2.530	-1.438	0.379	-0.308	3.559	0.574	-0.267

Table 4 Term Structure of Basis Trading Profits

Average Profit of Basis Trading on Underlyings of Different Maturity				
		2year	5year	9year
	1day	0.08%	0.19%	2.90%
|RER_nbt|	1week	0.22%	0.46%	3.12%
	1month	0.79%	1.24%	4.21%

Table 5 Comparative Statics Results on Basis Trading

5A

Relationship between Size of Basis Trading Return and TED						
				TED		
		low		medium		high
	1day	0.172	0.110	0.173	0.204	0.281
|RER_nbt|	1week	0.362	0.271	0.450	0.463	0.707
	1month	1.181	0.693	1.221	1.326	1.487
	2month	1.951	1.657	1.860	2.813	2.317

5B

Relationship between Size of Basis Trading Return and Vol of Default Intensity						
				Vol of Lambda		
		low		medium		high
	1day	0.192	0.186	0.158	0.224	0.259
|RER_nbt|	1week	0.537	0.384	0.397	0.472	0.707
	1month	0.764	0.929	1.275	1.061	1.979
	2month	1.413	1.673	1.623	3.247	3.813

5C

Relationship between Size and Volatility of Basis Trading Return						
				Vol_nbt		
		low		medium		high
|RER_nbt|	1day	0.117	0.167	0.181	0.262	0.255
	1week	0.191	0.464	0.433	0.524	0.608

5D

Relationship between Volatility of Basis Trading Return and TED						
				TED		
		low		medium		high
Vol_nbt	1day	0.072	0.138	0.177	0.243	0.263
	1week	0.179	0.271	0.338	0.495	0.539

Table 6 Size of CDS Basis and Corporate Bond Trading Volume

Relationship between Size of Basis and Corporate Bond Trading Volume						
				TV		
		low		medium		high
|Basis|	10/07-08/09	0.072	0.138	0.177	0.243	0.263
	03/08-03/09	0.179	0.271	0.338	0.495	0.539

Table 7 Predictability of Credit Spread Term Structure Slope on Future Credit Spread Changes

Set 1 Y variable: changes in 1-5yr Grade A ASW spread
Set 1 X variable: 3-5yr Grade A ASW spread minus 1-5yr Grade A ASW spread
Set 2 Y variable: changes in 1-5yr Grade AA ASW spread
Set 2 X variable: 3-5yr Grade AA ASW spread minus 1-5yr Grade AA ASW spread
Set 3 Y variable: changes in 5-10yr Grade A ASW spread
Set 3 X variable: 7-10yr Grade A ASW spread minus 5-7yr Grade A ASW spread
Set 4 Y variable: changes in 5-10yr Grade AA ASW spread
Set 4 X variable: 7-10yr Grade AA ASW spread minus 5-7yr Grade AA ASW spread

7A

Regression Results of 15-day Credit Spread Change on Slope of Credit Spread Term Structure								
	Set 1		Set 2		Set 3		Set 4	
Period 1: 07/2007-02/2008								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.09	(2.27)	0.39	(3.82)	-0.14	(-1.83)	-0.04	(-0.62)
slope	0.00	(1.75)	-0.01	(-1.05)	0.00	(0.05)	0.02	(2.86)
adj.R^2	0.03		0.01		-0.01		0.09	
Period 2: 03/2008-03/2009								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.13	(1.42)	0.01	(0.17)	-0.92	(-7.91)	-1.01	(-11.92)
slope	0.00	(-0.04)	0.01	(2.30)	0.00	(0.99)	0.02	(6.98)
adj.R^2	0.00		0.09		0.02		0.39	
Period 3: 04/2009-09/2009								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.02	(0.76)	0.05	(1.24)	-0.98	(-14.16)	-1.25	(-5.53)
slope	0.00	(7.07)	0.02	(10.81)	0.03	(6.55)	0.03	(4.29)
adj.R^2	0.60		0.60		0.38		0.46	

7B

Regression Results of 5-day Credit Spread Change on Slope of Credit Spread Term Structure								
	Set 1		Set 2		Set 3		Set 4	
Period 1: 07/2007-02/2008								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.00	(0.29)	0.17	(2.13)	-0.22	(-3.20)	-0.01	(-0.11)
slope	0.00	(2.87)	0.00	(0.37)	0.00	(0.37)	0.00	(0.39)
adj.R^2	0.14		0.00		0.00		0.00	
Period 2: 03/2008-03/2009								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.03	(0.84)	-0.05	(-1.03)	-0.91	(-8.63)	-0.94	(-17.79)
slope	0.00	(-0.55)	0.01	(3.40)	0.00	(0.44)	0.01	(7.89)
adj.R^2	0.00		0.24		0.00		0.32	
Period 3: 04/2009-09/2009								
	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat	estimate	Nwtstat
constant	0.00	(-0.24)	0.20	(9.91)	-0.88	(-16.29)	-1.05	(-7.20)
slope	0.00	(3.16)	0.01	(14.11)	0.02	(5.61)	0.02	(5.89)
adj.R^2	0.22		0.72		0.29		0.54	