Essays On Credit Risk

Jeong Seog Song

Submitted in partial fulfillment of the requirements for
the degree of Doctor of Philosophy
under the Executive Committee of the Graduate School of
Arts and Sciences

COLUMBIA UNIVERSITY

2008
ABSTRACT

Essays On Credit Risk

Jeong Seog Song

In the first chapter, I test whether credit risk for Emerging Market Sovereigns is priced equally in the credit default swap (CDS) and bond markets. The parity relationship between CDS premiums and bond yield spreads, that was tested and largely confirmed in the literature, is mostly rejected. Prices below par can result in positive basis, i.e. CDS premiums that are greater than bond yield spreads and vice versa. To adjust for the non-par price, we construct the bond yield spreads implied by the term structure of CDS premiums for various maturities. I am able to restore the parity relation and confirm the equivalence of credit risk pricing in the CDS and bond markets for many countries that have bonds with non-par prices and time varying credit quality. I detect non-parity even after the adjustment mainly with countries in Latin America where the bases are beyond the bid ask spreads of the market. I also find that repo rate of bonds decreases around the credit quality deterioration, which helps the basis remain positive.

In the second chapter, I develop various frameworks for the separation of loss given default and default probability from various credit instruments. They include spot and forward credit default swaps, digital default swaps and defaultable bonds. Cross-sectional no-arbitrage restriction between different securities allows the pure measure of default probability and loss given default not contaminated by the other. Using spot and forward CDS premium data of 10 emerging market sovereigns, I find that 75% level of loss given default prevails in the sovereign CDS markets across countries over time. Positive correlation between loss given default and default probability is only found in Brazil and Venezuela during the period of political turmoil in each country. This result is puzzling considering diverse fundamentals across countries and time variation of the marginal rate of substitution. Loss given default below (above) the 75% generates negative (positive) pricing errors in forward
CDS and the magnitude of them is economically significant.
Contents

1 The Behavior of Emerging Market Sovereigns' Credit Default Swap Premiums and Bond Yield Spreads 1
  1.1 Introduction ................................................. 1
  1.2 Pricing Model .................................................. 5
    1.2.1 Case I: Base Model ...................................... 6
    1.2.2 Case II: Payment of Accrued CDS Premiums at Default ...... 8
    1.2.3 Case III: Coupon Payments from Riskless Bonds at Default .... 9
    1.2.4 Case IV: Non Par Floating Rate Risky Bond .................. 11
    1.2.5 Smiles or Not? ........................................... 14
    1.2.6 Case V: Risky Bonds with Fixed Rate Coupons ................ 15
  1.3 Dynamic Relations between Bonds and CDS .......................... 17
    1.3.1 Data ...................................................... 17
    1.3.2 Term Structure of CDS premiums ............................ 18
    1.3.3 Bond Yield Spreads and Implied Bond Yield Spreads .......... 20
    1.3.4 Dynamic Relations between CDS and Bonds .................... 21
    1.3.5 Liquidity and the Limit of Arbitrage ........................ 25
  1.4 Conclusion .................................................. 27

2 Loss Given Default Implied by Cross-sectional No Arbitrage 47
  2.1 Introduction .................................................. 47
  2.2 Default Probability and Loss Given Default ........................ 51
    2.2.1 Illustration ............................................... 52
List of Figures

1.1 Basis for $\lambda \in [0.0, 0.5]$ and $P_B \in [0.8, 1.2]$ .......................... 29
1.2 $\frac{\partial}{\partial \lambda} (\text{basis})$ for $\lambda \in [0.001, 2]$ and $C \in [0.05, 0.14]$ ......................... 30
1.3 Term Structure of CDS Premiums 1 ................................................. 31
1.4 Term Structure of CDS Premiums 2 ................................................. 32
1.5 Argentina ................................................................. 33
1.6 Brazil ................................................................. 34
1.7 Venezuela ................................................................. 35
1.8 5 Year CDS Premiums for Latin Countries ................................. 36
1.9 Basis and Repo Rate ................................................................. 37

2.1 CDS Premiums and Bond Prices ......................................................... 78
2.2 Identification of $L^Q$ ......................................................... 79
2.3 Spot CDS Premiums ................................................................. 80
2.4 Spot CDS Premiums ................................................................. 81
2.5 Spot CDS Premiums ................................................................. 82
2.6 Spot and Forward CDS Premiums ......................................................... 83
2.7 Forward CDS Pricing Error: Mexico ......................................................... 84
2.8 Optimal Loss Given Default ......................................................... 85
List of Tables

1.1 Maximum Likelihood Estimation Result ......................... 38
1.2 Basic Statistics ............................................... 39
1.3 OLS estimation ............................................... 40
1.4 Unit Root Test ............................................... 41
1.5 Cointegration Test ........................................... 42
1.6 Correlation and Covariance ................................ 43
1.7 Basis and Bid Ask Spreads ................................. 44
1.8 White Noise Test ............................................ 45
1.9 OLS estimation ............................................... 46

2.1 Basic Statistics: Spot CDS Premiums .......................... 86
2.2 Basic Statistics: Forward CDS Premiums .................... 87
2.3 Basic Statistics: Bid Ask Spreads in Spot CDS .......... 88
2.4 RMS of Pricing Error ......................................... 89
2.5 Optimal Loss Given Default ................................ 90
Acknowledgements

The first chapter of this thesis is based on the working paper, "The Behavior of Emerging Market Sovereigns’ Credit Default Swap Premiums and Bond Yield Spreads", coauthored with Michael Adler. I am deeply indebted to my sponsor, Michael Adler, for his invaluable guidance, kindness, and support. I would like to thank the rest of my dissertation committee, Jialin Yu, Graciela Chichilnisky, Frank Zhang, and especially Suresh Sundaresan (chair) for their collective insight and encouragement.

I would like to address special thanks to John Donaldson for this general guidance and leadership in doctoral program in Columbia Business School. I really appreciate his kindness and support during my studies. My thanks also go to Andrew Ang, director of doctoral program in finance. His encouragement was invaluable. I also would like to thank my colleagues, Chang Yong Ha, Dongyup Lee and Ken Kim, for many useful discussions.

Finally, I would like to dedicate this thesis to my family and especially wife, Mi Hyun Park for their love and support.
To My Family
Chapter 1

The Behavior of Emerging Market Sovereigns’ Credit Default Swap Premiums and Bond Yield Spreads

1.1 Introduction

Credit default swaps (CDS) have become increasingly popular in recent years for providing a way to trade credit risk.\(^1\) Studies of the pricing of CDS ((Duffie 1999), (Hull and White 2000)) show that CDS premiums should be almost equal to the bond yield spreads of a given reference entity. This theoretical parity condition is largely confirmed by empirical studies that find that CDS premiums and bond yield spreads for high grade US corporates are generally cointegrated.\(^2\)

\(^{1}\) Important theoretical work on credit risk and derivatives includes (Jarrow and Turnbull 1995), (Longstaff and Schwartz 1995), (Das and Tufano 1996), (Duffie 1998), (Lando 1998), (Duffie and Singleton 1999), (Hull and White 2000), (Das and Sundaram 2000), (Jarrow and Yildirim 2002), (Acharya, Das, and Sundaram 2002), (Das, Sundaram, and Sundaresan 2003), and many others.

\(^{2}\) (Blanko, Brennan, and Marsh 2005) test the equivalence of CDS premiums and bond yield spreads, finding support for the parity as an equilibrium condition. (Houweling and Vorst 2005) compare the credit
In contrast, our study finds that for Emerging Market (EM) Sovereigns, there are fairly long periods during which the basis turns strongly positive with the result that the cointegration and parity relationships between CDS premiums and bond yield spreads are mostly rejected. The reason is that the parity relationship holds only when the reference bond is a floating rate note (FRN) and its price is at par. When the perceived credit quality of a reference entity changes, the price of a reference bond moves away from par.

Furthermore, the fact that most traded bonds are not FRNs but fixed rate, coupon paying bonds is another reason the cointegration relationship between CDS premiums and bond yield spreads fails. The bond yield spread of a fixed coupon bond is the same as the spread of a FRN when both are at par. However, as mentioned earlier, variations of perceived credit quality cause prices to deviate from par. Changes in the riskless rate may also cause the prices of fixed coupon bonds to vary, which is not the case for FRNs. When prices are not at par, the fixed coupon bond yield spread is a poor approximation of the FRN spread.

In recent years, the perceived credit quality of EM Sovereigns has been improving with narrowing credit spreads compared with the 1990's. This improvement in credit quality has resulted in prices above par and negative basis for countries such as South Korea, Poland and Malaysia. On the other hand, such countries as Argentina, Brazil, Venezuela, Colombia, Russia and Turkey experienced default or major deteriorations in their credit quality during the early 2000s. The difference between maximum and minimum bond yield spreads for these countries exceeded 10% in our sample period. In particular, Argentina defaulted in December 2001 and Brazil's bond yield spreads rose above 30% during the election crisis of 2002 and 2003. For these countries our data show that bases turned deeply positive before and during the credit event periods and came back to near zero level only after the crises had passed.

---

risk pricing between the bond market and the CDS market and find the price discrepancies between CDS premia and bond yield spreads are quite small (about 10 basis points). Zhu (2004) shows that CDS spreads and bonds yield spreads of U.S. corporate are cointegrated in the long run. In the short run, He finds negative basis when they use the swap rate or tax-adjusted treasury rate.
The prevalence of non-zero bases and the rejection of cointegration between CDS premiums and bond yield spreads do not, in and of themselves, indicate a different price for credit risk. Pricing model shows that deeply discounted bond prices account for positive bases. The basis does remain, however, during periods of deteriorating credit quality. This could arise naturally as providers of credit insurance not only raise their prices but also, as happens elsewhere in the insurance markets, become increasingly reluctant to write new contracts. We attempt to explain the remaining basis in this paper.

Our technique is basically to remove the bias in the basis caused by below-par prices. The availability of CDS premiums for various maturities makes it possible to estimate default probabilities for various terms. With an estimated term structure of the default probability, we can adjust for the effect on the basis of deeply discounted bond prices and extract what we call “implied bond yield spreads”. To do so, we calculate the implied price of fixed coupon paying bonds. Then we construct the implied yield spreads using the calculated bond prices. Finally we use the implied bond yield spreads instead of CDS premiums to test whether the CDS market and bond market price credit risk equally.

We find that this procedure restores the parity relationship between the implied bond yield spreads (IBYS) and the actual bond yield spreads (BYS) in some cases. The parity relation is no longer rejected for countries such as Mexico, Malaysia, Russia, and Turkey. This result shows that in these cases the CDS and bond markets were fairly well integrated with respect to pricing credit risk.

However, Argentina, which provides the actual default event and Brazil, which reached a very high credit event likelihood - more than 30% BYS in our sample period - do reject the revised parity relations. For Argentina, sub-period analysis confirms that the break down of the parity relation occurred near the default. After the default, CDS did not trade at all while the bonds continued to trade sporadically, albeit at long intervals and low volumes. For Brazil, the difference between the IBYS and the BYS was negative in the early period

---

3Unlike CDS for corporates, CDS contracts for sovereigns trade actively for various maturities: see (Packer and Suthiphongchai 2003).
of parity break-down. It changed to positive later.

We also find evidence of contagion when we document regional co-movements of the CDS premiums and BYS. When the CDS premiums and the BYS in Brazil increased during 2002 and 2003, all the Latin American countries in our sample showed increases in both their CDS premiums and BYS. In all the countries in our sample including Brazil, the increase of CDS premiums were larger than the increase of the implied BYS. This results in the rejection of the parity relations for countries in Latin America. However, the arbitrage opportunity is limited. We find that decreasing repo rate prevents CDS protection selling and bond short selling for the countries.

Overall, we believe the contributions of this paper are as follows. We derive pricing equations for the basis and explain how, and by how much, factors such as accrued payments and price discounts can affect the basis. We also offer a new explanation of the recently empirically observed 'basis smile'. This paper augments previous empirical studies in other respects as well. Ours is the first paper to use the term structure of the CDS premiums to correct the bias in the basis that is introduced by non-par prices. Unlike previous studies that dealt only with investment grade US corporates, we investigate EM Sovereigns with various credit qualities. We are even able to include a case of actual default in our sample. Our study provides evidence regarding the equivalence of credit risk pricing in the CDS and bond markets for EM sovereigns and, using the new measure 'implied bond yield spreads'. Furthermore we document that (reverse) repo rate decreased during the crisis for the bonds, which limits the arbitrage from the positive basis.

The remainder of this paper is organized as follows.

Section 2 presents pricing models for CDS premiums and the basis. We add to the basic model extensions for the payment of accrued CDS premiums, riskless interest rate movements, non-par FRN bond prices and fixed-coupon bonds. Section 3 presents the empirical tests and results. Section 4 summarizes the results and offers concluding remarks.
1.2 Pricing Model

(Duffie 1999) provides the basic CDS pricing equation. Our interest focuses on the basis and we develop the necessary extensions below. Based on (Duffie 1999), we derive the relation between CDS premiums and bond yield spreads. Because simple replication arguments do not hold exactly, we independently solve for the CDS premiums and the bond spreads and compare them. Basis is defined as the difference between the CDS premiums and the bond spreads.

We, first, set-up the common notations to be used in this paper. A probability space \((\Omega, \mathcal{F}, \mathbb{Q})\) is well defined, where the filtration \(\mathcal{F} = \{\mathcal{F}_t|0 \leq t \leq T\}\) satisfies \(\mathcal{F}_T = \mathcal{F}\) and it is complete, increasing and right continuous where \(\mathbb{Q}\) is the equivalent martingale measure. Suppose also a locally risk-free short rate process \(r\). Let \(\chi(T) = 1_{T \geq \tau}\) be a default indicator function of a reference entity, where \(\tau\) is the stopping time that characterizes the time of default by the reference entity. A risk neutral default intensity process \(\lambda(\tau)\) for a stopping time \(\xi\) is characterized by the property that the following is the martingale,

\[
\chi(\tau) - \int_0^\tau (1 - \chi(\mu)) \lambda(\mu) d\mu
\]

\(L\) denote the risk-neutral fractional loss of face value on a reference obligation in the event of a default.

---

(Duffie 1999) shows that the spread on a par risky floating rate note over a par default risk free floating rate note equals the CDS premiums. He extends his basic model and shows the relation between bond yield spreads and CDS premiums when the bond price is not at par. (Hull and White 2000) show that, with a flat risk free curve and constant interest rates, the bond yield spread is exactly equal to the CDS premium when the payout from a CDS on default is the sum of the principal amount plus accrued interest on a risky par yield bond times one minus the recovery rate. (Hourweling and Vorst 2005) show that the spread on a par risky fixed coupon bond over a par default risk free fixed coupon bond exactly equals the CDS premium if the payment dates on the CDS and bond coincide, and recovery on default is a constant fraction of face value.
1.2.1 Case I: Base Model

In this section, we derive a pricing model for CDSs and replicating portfolio. Suppose that two parties make a spot CDS contract at time $t$ with maturity of $\tau_c$. A buyer of protection periodically pays premiums, $s_{t,\tau_c}$, to a seller. The payment is made $M_c$ times per year until any one of the following events happens: the underlying reference entity defaults on its reference obligation or the maturity of the CDS contract comes. The payment begins at $t + \frac{1}{M_c}$.

The seller of protection receives the premium payment and its present value at $t$ is

$$\frac{s_{t,\tau_c}}{M_c} \sum_{j=1}^{M_c-(\tau_c-t)} E^Q \left[ \frac{B(t)}{B(t + \frac{j}{M_c})} \left( 1 - \chi \left( t + \frac{j}{M_c} \right) \right) \right]_{\mathcal{F}_t}$$

where $B(t) = e^{-\int_t^\tau r(s)ds}$. Then the value of the 'premium leg' is

$$\frac{s_{t,\tau_c}}{M_c} \sum_{j=1}^{M_c-(\tau_c-t)} E^Q \left[ e^{-\int_{t+\frac{j}{M_c}}^{\tau_c+t} \left( r(s) + \lambda(s) \right) ds} \right]_{\mathcal{F}_t}$$

The buyer of protection will receive a unit face value of the reference obligation in exchange of the physical delivery of the obligation when a credit event happens. The payoff process, $D(t)$, follows

$$dD(t) = (1 - \chi(t))\lambda(t)dt + dM_D(t)$$

where $M_D(t)$ is a martingale with respect to $Q$. Then the present value of the protection payment is

$$E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_0^\mu r(s)ds}d\mu \right]_{\mathcal{F}_t}$$

Since the net present value of a spot CDS at its initiation be zero, the spot CDS premium can be obtained by equating the value of the two legs

$$\frac{s_{t,\tau_c}}{M_c} \sum_{j=1}^{M_c-(\tau_c-t)} E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_0^\mu r(s)ds}d\mu \right]_{\mathcal{F}_t} = \frac{E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_0^\mu r(s)ds}d\mu \right]_{\mathcal{F}_t}}{\sum_{j=1}^{M_c-(\tau_c-t)} E^Q \left[ e^{-\int_{t+\frac{j}{M_c}}^{\tau_c+t} \left( r(s) + \lambda(s) \right) ds} \right]_{\mathcal{F}_t}} \quad (1.2.1)$$
Suppose a portfolio, constructed at time $t$, with a long position in a par floating riskless note and a short position in a par floating risky note. An investor will hold this position through the maturity of the risky FRN or until any credit event triggering the payment of the CDS protection payment, whichever is earlier. In the meantime, she pays the coupons on the risky FRN and receives the coupons from the riskless FRN. The net payoff is the cash outflow of the (constant) spread $SPR$. If a credit event does not occur before maturity, then both notes mature at par value, and there is no net cash flow associated with the principal. If a credit event occurs before maturity, then she unwinds her position at the first coupon date, immediately after the event. She will sell the riskless FRN at par.\(^5\) At the termination of the short position in risky FRN, she needs to pay $1 - L$. The net payoff will be $L$. Note that the payoff from this portfolio replicates the payoff from buying the CDS protection. The value of this portfolio is zero at time $t$.

\[
\frac{-SPR}{M_c} \sum_{j=1}^{M_c(t_c-t)} E^Q \left[ e^{-\int_t^{t_c} \mu_c r(s) + \lambda(s) ds} \right] + E^Q \left[ \int_t^{t_c} L \lambda(\mu)e^{-\int_t^\mu r(s) + \lambda(s) ds} d\mu \right] = 0
\]

Then

\[
SPR = \frac{E^Q \left[ \int_t^{t_c} L \lambda(\mu)e^{-\int_t^\mu r(s) + \lambda(s) ds} d\mu \right]}{\sum_{j=1}^{M_c(t_c-t)} E^Q \left[ e^{-\int_t^{t_c} \mu_c r(s) + \lambda(s) ds} \right]}
\]

From equation (1.2.1) and (1.2.2),

\[
\text{basis} = s - SPR = 0
\]

Equation (1.2.3) shows that the basis between CDS premiums and spread of the par risky FRN is zero. The result confirms the conclusion reached in (Duffie 1999), based on his replication arguments.

\(^5\)For now, we ignore the accrued coupon payment from the default free FRN. That coupon payment will be included in the calculation in subsection 1.2.3.
1.2.2 Case II: Payment of Accrued CDS Premiums at Default

In this section, we extend (Duffie 1999) and show that the accrued CDS premiums at default cause the basis to become negative. In practice, a CDS protection buyer pays the accrued CDS premiums to the protection seller when a credit event occurs. As a result, the protection buyer's payoff is reduced by the accrued CDS premiums. The value of premium leg is the same as the base case.

\[
M_c - \left( T_c - t \right) S^C_y \text{E} Q \sum_{j=1}^{3=1} e^{-f_t^t \lambda(s)ds} \left| F_t \right|
\]

(1.2.4)

The value of protection leg is, however, reduced by the payment of accrued premiums. The value of the protection leg is:

\[
E^Q \left[ \int_t^{T_c} \left( L - \frac{s_t \cdot M_c}{M_c} \cdot h(\mu) \right) \lambda(\mu)e^{-f_t^t \lambda(s)ds} d\mu \left| F_t \right] \right.
\]

where \( h(\mu) \) is the deterministic function of time \( \mu \) that accounts for the accrued CDS premiums.

\[
h(\mu) = \frac{\mu - t_{k-1}}{t_k - t_{k-1}} \text{ where } t_{k-1} \leq \mu < t_k, \ t_k = t + \frac{k}{M_c}
\]

(1.2.5)

Since the CDS is a zero cost contract at its initiation,

\[
\frac{s_t \cdot M_c}{M_c} \sum_{j=1}^{M_c - (r_c - t)} E^Q \left[ e^{-f_t^t \lambda(s)ds} \left| F_t \right] \right.
\]

= \[
E^Q \left[ \int_t^{T_c} \left( L - \frac{s_t \cdot M_c}{M_c} \cdot h(\mu) \right) \lambda(\mu)e^{-f_t^t \lambda(s)ds} d\mu \left| F_t \right] \right.
\]

(1.2.6)

Then

\[
\frac{s_t \cdot M_c}{M_c} = \frac{E^Q \left[ \int_t^{T_c} L\lambda(\mu)e^{-f_t^t \lambda(s)ds} d\mu \left| F_t \right] \right.}{\sum_{j=1}^{M_c - (r_c - t)} E^Q \left[ e^{-f_t^t \lambda(s)ds} \left| F_t \right] \right.} + E^Q \left[ \int_t^{T_c} h(\mu)\lambda(\mu)e^{-f_t^t \lambda(s)ds} d\mu \left| F_t \right] \right.}
\]

(1.2.7)

\(^6\)CDS premiums are paid quarterly before a credit event happens. When a credit event occurs, the CDS contract is physically settled within 30 days from the event's occurrence.
Note that in equation (1.2.7), $E^Q \left[ \int_t^{\tau_c} h(\mu)\lambda(\mu)e^{-\int_t^{s} r(s)+\lambda(s)ds} d\mu \mid F_t \right] > 0$ and this will cause the basis to be negative due to the payment of accrued CDS premiums at default.

Suppose a portfolio, constructed at time $t$, with a long position in a par floating riskless note and a short position in a par floating risky note. The value of this synthetic position is zero at time $t$.

$$\frac{-SPR}{M_c} \sum_{j=1}^{M_c(\tau_c-t)} E^Q \left[ e^{-\int_t^{t^j} r(s)+\lambda(s)ds} \mid F_t \right] + E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^{s} r(s)+\lambda(s)ds} d\mu \mid F_t \right] = 0$$

Then

$$\frac{SPR}{M_c} = \frac{E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^{s} r(s)+\lambda(s)ds} d\mu \mid F_t \right]}{\sum_{j=1}^{M_c(\tau_c-t)} E^Q \left[ e^{-\int_t^{t^j} r(s)+\lambda(s)ds} \mid F_t \right]}$$

From equations (1.2.7) and (1.2.8),

$$\frac{basis}{M_c} = \frac{s - \frac{-SPR}{M_c}}{M_c} = \frac{E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^{s} r(s)+\lambda(s)ds} d\mu \mid F_t \right]}{\sum_{j=1}^{M_c(\tau_c-t)} E^Q \left[ e^{-\int_t^{t^j} r(s)+\lambda(s)ds} \mid F_t \right] + E^Q \left[ \int_t^{\tau_c} h(\mu)\lambda(\mu)e^{-\int_t^{s} r(s)+\lambda(s)ds} d\mu \mid F_t \right]}$$

$$< 0$$

The result shows that the basis is negative when accrued CDS premiums are paid upon default: this extends the explanations of negative basis in the current literature.

### 1.2.3 Case III: Coupon Payments from Riskless Bonds at Default

In this section, we add the coupon payment from the riskless FRN at default and show that it causes the basis to become more negative. With a portfolio that replicates the payoffs
from a CDS, there will be a coupon payment from the riskless FRN when the position is closed due to the default of the risky FRN.

Since it does not directly affect either the cashflow of the CDS premium leg or that of CDS protection leg, CDS premiums do not change. For CDS premiums,

\[
\frac{s_{t,\tau C}}{M_C} = \frac{E^Q \left[ \int_t^{\tau C} L\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right]}{\sum_{j=1}^{M_C(\tau_C-t)} E^Q \left[ e^{-\int_t^{t+\frac{\tau t}{M_C} r(s)+\lambda(s)ds}} \mid \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau C} h(\mu)\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right]}
\]

(1.2.10)

However, the coupon spreads for the risky FRN do change. Suppose a synthetic CDS, constructed at time \( t \) by a long position in a par floating riskless note and a short position in a par floating risky note. The value of this synthetic position is zero at time \( t \). The value of the accrued interest from the riskless FRN is

\[
E^Q \left[ \int_t^{\tau C} g(\mu)\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right]
\]

where

\[
g(\mu) = R(t_{k-1}, t_k) \cdot \frac{\mu-t_{k-1}}{t_k-t_{k-1}} \text{ where } t_{k-1} \leq \mu < t_k, \ t_k = t + \frac{\mu}{M_C}
\]

(1.2.11)

\( R(t_{k-1}, t_k) \) is a risk free interest rate from \( t_{k-1} \) to \( t_k \) at time \( t_{k-1} \). Then

\[
\frac{-SPR}{M_C} \cdot \sum_{j=1}^{M_C(\tau_C-t)} E^Q \left[ e^{-\int_t^{t+\frac{\tau t}{M_C} r(s)+\lambda(s)ds}} \mid \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau C} L\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau C} g(\mu)\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right] = 0
\]

Then

\[
\frac{SPR}{M_C} = \frac{E^Q \left[ \int_t^{\tau C} L\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau C} g(\mu)\lambda(\mu)e^{-\int_t^\mu r(s)+\lambda(s)ds} d\mu \mid \mathcal{F}_t \right]}{\sum_{j=1}^{M_C(\tau_C-t)} E^Q \left[ e^{-\int_t^{t+\frac{\tau t}{M_C} r(s)+\lambda(s)ds}} \mid \mathcal{F}_t \right]}
\]

(1.2.12)
From equations (1.2.10) and (1.2.12),

\[
\frac{\text{basis}}{M_c} = \frac{s - SPR}{M_c}
\]

\[
= \frac{E^Q \left[ \int_t^{\tau_c} L \lambda(\mu) e^{-\int_t^\tau r(s) + \lambda(s) ds} d\mu \bigg| \mathcal{F}_t \right]}{\sum_{j=1}^{M_c(\tau_c-t)} E^Q \left[ e^{-\int_t^{\tau_c} \lambda(\mu) e^{-\int_t^\tau r(s) + \lambda(s) ds} d\mu} \bigg| \mathcal{F}_t \right]}
\]

\[
< 0
\]  

Equation (1.2.13) shows that the basis gets more negative when accrued interest from the riskless bond is to be paid.

**1.2.4 Case IV: Non Par Floating Rate Risky Bond**

In this section, we incorporate the possibility that risky FRN prices deviate from par and show that a discounted bond price may lead to a positive basis. In addition to that, we consider the time series and cross-section movements of the basis as credit quality changes. When we consider a single bond, the basis increases as the credit quality of the reference entity deteriorates. However, in cross-section, this is not always the case. We need to consider the price and credit quality jointly. Our analysis enables us to provide a new explanation of the 'basis smile' based on the cross-sectional properties of the basis.

Risky EM FRNs mostly trade away from par, occasionally above but more frequently below. Suppose that the price of a risky FRN, \( P_B \neq 1 \). Since the loss at default is a fraction of the face value, a non par price for the reference bond does not affect the CDS premiums.
Therefore, the CDS premiums are as before:

\[
\frac{q_{t, \tau_c}}{M_c} = \frac{E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right]}{\sum_{j=1}^{M_{c}(\tau_c-t)} E^Q \left[ e^{-\int_t^{t+\hat{\tau}_c} r(s) + \lambda(s)ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} h(\mu)\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right]}
\]

(1.2.14)

Suppose a portfolio constructed at time \( t \) with a long position in a par floating riskless note and a short position in a non-par floating rate risky note. The value of this synthetic position is \( (1 - P_B) \) at time \( t \). Then

\[
\frac{-SPR}{M_c} \cdot \sum_{j=1}^{M_{c}(\tau_c-t)} E^Q \left[ e^{-\int_t^{t+\hat{\tau}_c} r(s) + \lambda(s)ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} g(\mu)\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right] = 1 - P_B
\]

Then

\[
\frac{SPR}{M_c} = \frac{E^Q \left[ \int_t^{\tau_c} L\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} g(\mu)\lambda(\mu)e^{-\int_t^s r(s) + \lambda(s)ds} d\mu \bigg| \mathcal{F}_t \right]}{\sum_{j=1}^{M_{c}(\tau_c-t)} E^Q \left[ e^{-\int_t^{t+\hat{\tau}_c} r(s) + \lambda(s)ds} \bigg| \mathcal{F}_t \right] - \frac{1 - P_B}{\sum_{j=1}^{M_{c}(\tau_c-t)} E^Q \left[ e^{-\int_t^{t+\hat{\tau}_c} r(s) + \lambda(s)ds} \bigg| \mathcal{F}_t \right]}}
\]

(1.2.15)
From equations (1.2.14) and (1.2.15)

\[
\frac{\text{basis}}{M_c} = \frac{s - SPR}{M_c} = \frac{\mathbb{E}^Q \left[ \int_{t}^{\tau_c} L \lambda(t) e^{-\int_{t}^{\tau_c} r(s) + \lambda(s) ds} d\mu \mid \mathcal{F}_t \right]}{\sum_{j=1}^{M_c(\tau_c - t)} \mathbb{E}^Q \left[ e^{-\int_{t}^{\tau_c} \lambda(t) e^{-\int_{t}^{\tau_c} r(s) + \lambda(s) ds} d\mu} \mid \mathcal{F}_t \right]}\]

\[
= \sum_{j=1}^{M_c(\tau_c - t)} \mathbb{E}^Q \left[ e^{-\int_{t}^{\tau_c} \lambda(t) e^{-\int_{t}^{\tau_c} r(s) + \lambda(s) ds} d\mu} \mid \mathcal{F}_t \right] + \frac{\sigma_{\text{basis}}}{M_c}
\]

Note that a bond price that is discounted below par increases the basis. As the discount gets deep, the relative significance of the 'discount effect' can dominate the 'accrued payment effect' and result in the basis becoming positive. A deterioration of the credit quality of a reference entity causes not only \( P_B \) but also \( \sum_{j=1}^{M_c(\tau_c - t)} \mathbb{E}^Q \left[ e^{-\int_{t}^{\tau_c} \lambda(t) e^{-\int_{t}^{\tau_c} r(s) + \lambda(s) ds} d\mu} \mid \mathcal{F}_t \right] \) to decline, which reinforces the 'discount effect.'

Equations (1.2.16) has another interesting implication for the cross-sectional variation of the basis. Is the basis of low credit quality bonds always positive? The answer is, 'not necessarily.' The sign of the basis depends not only on \( \lambda \) but also on the price level. A low credit quality does not necessarily cause the basis to be positive; and, similarly, a high credit quality does not necessarily cause the basis to be negative. For example, regardless of credit quality, if a bond is at par, the basis is negative as shown in the equation (1.2.13).

Note that when the credit quality changes, the price also changes, the basis becomes as

\[7\] (Norden and Weber 2004) analyses the empirical relationship between CDS, bonds and stocks for U.S. and European corporates during the period 2000-2002. They find that changes in CDS premiums Granger cause changes in bond yield spreads for a higher number of firms than vice versa. They also find that the CDS market is significantly more sensitive to the stock market than the bond market and the magnitude of this sensitivity increases as credit quality deteriorates.
shown in the equation (1.2.16). The sign of the basis is jointly determined by \( \lambda \) and the price.

Suppose a bond is issued at par. When its credit quality does not change, the basis is negative regardless of the credit quality at the time of issuance.\(^8\) When its credit quality deteriorates, the basis will increase. It may become positive when the magnitude of the deterioration is big enough to make the ‘discount effect’ sufficiently significant. When its credit quality improves, the basis will decrease. The sign of the basis is dependent on the relative credit quality compared to the credit quality when the bond was issued.

[Insert figure (1.1) here]

To illustrate, we provide as an example a plot of the basis in Figure(1.1), fixing \( \Delta t = 0.25, r = 0.05, L = 0.5 \) and \( T = 5 \). We vary \( \lambda \) and \( P_B \). \( \lambda \in [0.0, 0.5] \) and \( P_B \in [0.8, 1.2] \) in Figure(1.1).

1.2.5 Smiles or Not?

Non-monotonicity in the average basis across credit ratings can be explained by transitions of credit ratings in each rating class.\(^9\) A rating class, which contains down-graded bonds rather than up-graded bonds will tend to have a less negative or positive basis. This is

\(^8\)In practice, coupon rates are picked in most cases to match the issue price of a bond as closely to par as possible.

\(^9\)A ‘basis smile’ was recently documented in (De Wit 2006). He explained the ‘basis smile’ citing (Hjort, McLeish, Dulake, and Engineer 2002). They argued that the zero-floor for CDS premiums mainly drives the basis upwards for very high grade credits, while other factors, such as the cheapest-to-deliver option, mainly affect credits with low ratings. De Wit himself found that the basis for the portfolio of entities with ‘AA’ credit ratings was larger than that for ‘A’ rated entities. But the basis for ‘BBB’ rating entities was bigger than that for ‘A’ rating entities. The basis smile was also found by (Blanko, Brennan, and Marsh 2005) and (Longstaff, Mithal, and Neis 2005). The average basis was -41.4 bp, -44.8 bp and -30.8 bp for ‘AAA - AA’, ‘A’ and ‘BBB’ credit rated entities in (Blanko, Brennan, and Marsh 2005). It was -53.1 bp, -70.4 bp, -72.9 bp and -70.1 bp for ‘AAA-AA’, ‘A’, ‘BBB’ and ‘BB’ credit rated entities in (Longstaff, Mithal, and Neis 2005).
because the prices of down-graded bonds move below par. Bonds with a current rating of 'AAA-AA' will previously have had an 'AAA-AA' rating or below. Up-graded bonds in this rating class will acquire a negative basis, as their prices move above par. On average, the basis in the 'AAA-AA' rating class will, therefore, be negative. Bonds with current ratings of 'A' can previously have been down-graded from 'AAA-AA'; maintained an 'A' rating; or have been up-graded from 'BBB' ratings or below. If there are more up-graded bonds than down-graded bonds in the 'A' class, it will have a negative basis.

The average basis of the 'A' ratings class can be smaller, i.e. more negative than the average basis of 'AAA-AA' if it contains more bonds that have been up-graded than down-graded. The average basis in the 'BBB' class can simultaneously be larger than that of the 'A' category if it contains a preponderance of down-graded bonds whose prices have moved to a discount and whose bases have become positive. Whether the average basis of 'A' is smaller than either that of 'AAA-AA' or 'BBB-B' depends on the relative proportion of up-graded bonds to down-graded bonds in each rating class. The same argument holds for other rating classes as well. The composition is determined by the transitions across credit ratings, and it can differ from period to period. By this token, 'smiles' in other periods could be flat or reversed ('frowns').

1.2.6 Case V: Risky Bonds with Fixed Rate Coupons

Most of the traded bonds are fixed rate coupon paying bonds and coupons are paid semi-annually. (Duffie and Liu 2001) examine the term structure of yield spreads between par floating-rate and par fixed-rate notes of the same credit quality and maturity. They show that spreads over default-free rates on par-fixed-rate and par-floating-rate notes are approximately equal. When prices deviate from par, bond yield spreads become poor approximations of the par-floating-rate. We examine how the use of bond yield spreads affects the basis.
Previous result for the CDS premiums still holds as below,

\[
\frac{s_{t,\tau_c}}{M_c} = \frac{E^Q \left[ \int_t^{\tau_c} L(\mu) e^{\int_s^{\tau_c} r(\mu) ds} \mu d\mu \bigg| \mathcal{F}_t \right]}{\sum_{j=1}^{M_B(\tau_c-\tau)} E^Q \left[ e^{-\int_t^{\tau_c} \frac{1}{M_B} (r(\mu) + \mu) ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} h(\mu) \lambda(\mu) e^{\int_s^{\tau_c} r(\mu) ds} \mu d\mu \bigg| \mathcal{F}_t \right]}
\]

Here 's' is the quoted CDS premiums for the year period and \( \frac{E^Q}{M_B} \) is CDS premiums per one premium payment period.

Suppose a reference bond with per period coupon \( \frac{C_D}{M_B} \) and maturity of \( \tau_B \) is traded at \( P_B \). The basis in the previous empirical studies is defined as:

\[
basis = s - BYS
\]

\( s.t. \)

\[
P_B = \frac{C_B}{M_B} \sum_{j=1}^{M_B(\tau_B-\tau)} E^Q \left[ e^{-\int_t^{\tau_c} \frac{1}{M_B} (r(\mu) + BYS) ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ e^{-\int_t^{\tau_B} r(\mu) ds} \bigg| \mathcal{F}_t \right]
\]

\[
= \frac{C_B}{M_B} \sum_{j=1}^{M_B(\tau_B-\tau)} E^Q \left[ e^{-\int_t^{\tau} \frac{1}{M_B} r(\mu) + \lambda(\mu) ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ e^{-\int_t^{\tau_B} r(\mu) ds} \bigg| \mathcal{F}_t \right] + E^Q \left[ \int_t^{\tau_c} (1 - L(\mu)) e^{-\int_s^{\tau_c} r(\mu) ds} \mu d\mu \bigg| \mathcal{F}_t \right]
\] (1.2.17)

There is no closed form solution for the basis in this case, as there was when all bonds were FRNs. Nonetheless, we can still explore how the basis changes when the credit quality of the reference entity changes for fixed coupon paying bonds and how it differs from that for FRNs. For simplicity, we assume flat term structures of default free zero-coupon rates and default intensities. The basis increases in \( \lambda \) for fixed coupon bonds as well, but that the magnitude of the change is smaller than in the case of FRNs.

[Insert figure (1.2) here]
1.3 Dynamic Relations between Bonds and CDS

1.3.1 Data

In the previous section, we showed that the basis increases in $\lambda$, i.e. the basis increases as the credit quality deteriorates both for FRNs and fixed coupon paying bonds. Unless the credit quality remains at the same level, the basis fluctuates as prices vary. With a (quasi) permanent credit quality shift, the level of the basis also shifts. The credit quality of Emerging Market Sovereigns has not been stable in our sample and we need to develop new empirical methods to deal with that. We describe our data and explain how we construct our new measure, 'implied bond yield spreads' to test whether credit risk is priced equivalently in the CDS market and bond market for EM sovereigns.

For riskless rates, we collect data for the constant maturity rate for six-month, one-year, two-year, three-year, five-year, seven-year, and ten-year rates from the Federal Reserve and construct zero rates. We then use a standard cubic spline algorithm to interpolate these zero rates at semiannual intervals. We use a linear interpolation of the corresponding adjacent rates to obtain the discount rate for other maturities.

Daily data for CDS premiums were supplied by J.P. Morgan Securities, one of the leading players in the CDS market. These CDS contracts are standard ISDA contracts for physical settlement for Emerging Market (EM) Sovereigns. The notional value of contract (lot size) is between five to ten million USD for a large market like Brazil, while it is typically between two to five million for small markets. The prices hold at 'close of business.'

Daily data for EM Sovereign bonds were also supplied by J.P. Morgan. Our sample ends in early January, 2006. We excluded all Brady bonds and bonds with embedded options, step-up coupons, sinking funds, or any other special feature which may affect the price of bonds. We excluded FRNs since we had only four FRNs and they had short samples, of about one and a half years from June, 2004. Furthermore, we excluded bonds with maturities of less than one year.
1.3.2 Term Structure of CDS premiums

Noticeable pattern in CDS premiums is that CDS premiums increase in maturity as shown in figure(1.3). However, CDS premiums with short maturities are often higher than ones with long maturities, especially when the credit quality has been severely deteriorating. It results in the inverted CDS premiums curve during the high credit risk period.

We first adapt the standard reduced-from model such as (Duffle and Singleton 1999), (Jarrow and Turnbull 1995), (Lando 1998), (Madan and Unal 1998), and (Duffee 1999). Following (Pearson and Sun 1994), (Duffee 1999), and (Zhang 2003), we specify the default intensity process $\lambda_t$ follows a CIR type squared-root process:

$$d\lambda_t = \kappa(\theta - \lambda_t)dt + \sigma\sqrt{\lambda_t}dB_t^P$$

where $B_t^P$ is a standard Brownian motion.

Market price of risk is assumed as $\xi/\sqrt{\lambda_t}$. Then the default intensity $\lambda_t$ under the equivalent risk neutral measure, follow

$$d\lambda_t = [\kappa\theta - (\kappa + \xi)\lambda_t]dt + \sigma\sqrt{\lambda_t}dB_t^Q$$

where $B_t^Q$ is a standard Brownian motions under the equivalent martingale measure $Q$.\textsuperscript{10}

We estimate the parameters with a standard quasi-maximum likelihood (QML) method widely used in the empirical term structure of interest rate literature (for similar treatment, see (Chen and Scott 1993), (Pearson and Sun 1994), (Duffie and Singleton 1997), (Duffee 2002), (Zhang 2003) and (Pan and Singleton 2006)). Since the default intensity $\lambda_t$ is unobservable, we assume that the 5-year CDS premiums are measured without error. Given the parameter set, implied default intensity vector $\lambda_t$ can be inverted numerically. In addition, We assume that the nonzero measurement errors $\{\epsilon_t\}$ of 1-, 3-, and 10-year default

\textsuperscript{10} In the literature on corporate CDS spreads, default intensity was modeled as a square-root process in (Zhang 2003) and (Longstaff, Mithal, and Neis 2005).
swap contracts are serially uncorrelated, but normally distributed with zero mean and variance-covariance matrix $\Omega_t$.

Under these above assumptions, the conditional maximum likelihood is,

$$L = \sum_{t=2}^{T} \ln f_\lambda(\lambda_t|\lambda_{t-1}) - \sum_{t=2}^{T} \ln |J^S_t| - \frac{3(T-1)}{2} \ln(2\pi) - \frac{T-1}{2} \ln |\Omega_t| - \frac{1}{2} \sum_{t=2}^{T} \epsilon_t'\Omega_t^{-1}\epsilon_t$$

where $f_\lambda(\lambda_t|\lambda_{t-1})$ is the probability density of state vector $\lambda_t$ conditional on $\lambda_{t-1}$ and $J^S_t$ is the Jacobian of the transformation at time $t$. $\Omega_t$ is decomposed into lower and upper triangular matrix. We denote the $(i,j)$th element of lower triangular matrix as $\{c_{i,j}\}$. The conditional densities, $f_\lambda(\lambda_t|\lambda_{t-1})$, are non-central chi-square, as shown in (Cox and Ross 1985). For $t = 2, \cdots, T$, the exact non-central chi-square density of $\lambda_t$ conditional on $\lambda_{t-1}$ is

$$f_\lambda(\lambda_t|\lambda_{t-1}) = d e^{-(u+v)} \left(\frac{u}{v}\right)^{\frac{q}{2}} I_q \left(2\sqrt{u \cdot v}\right)$$

$$d = \frac{2\kappa}{\sigma^2 [1 - e^{-\kappa\Delta t}]}$$

$$u = d\lambda_{t-1} e^{-\kappa\Delta t}$$

$$v = d\lambda_t$$

$$q = \frac{2\kappa\theta}{\sigma^2} - 1$$

$\Delta t$ is the time interval between $t$ and $t-1$, and $I_q(\cdot)$ is the modified Bessel function of the first kind of order $q$. The modified Bessel function is approximated by the normal (see (Zhang 2003) for details.) For the estimation using CDS data, we first assume the independence between the short rate process and default intensity in equation (1.2.14).11

Upon estimating the parameters, we can construct a bond price following equation (1.2.17). We provide the estimation result Table (1.1).

[Insert Table (1.1) here]

In contrast to time series approaches, we also use a cross-sectional approach as used in (Singh 2003), (Chan-Lau 2003), (Andritzky and Singh 2006), (Das and Hanouna 2006)

11 See (Longstaff, Mithal, and Neis 2005) and (Pan and Singleton 2006) for similar approach.
and (Nashikkar, Subrahmanyam, and Mahanti 2007). The development of the CDS market makes it possible to extract the default probability without relying on a particular model of credit risk and a specific parameterizations. Using the term structure of CDS premiums on a given day, we can calibrate the default probability without statistical parameter estimation. CDS premiums are function of short rate process, default probability and loss given default. With pre-specified level of loss given default and zero rate from the market, we can effectively extract default probability. Only information on a given trading day is used, which is the common way traders would calibrate any derivatives pricing model in actual practice.\footnote{See (Das and Hanouna 2006) and (Nashikkar, Subrahmanyam, and Mahanti 2007) for more details.} This approach is especially applicable for the purpose of this study, since default probability and discount rate prevailing each day is sufficient for the pricing of CDS premiums and bond as in equation (1.2.14) and (1.2.17).

As in equation (1.3.1) and (1.3.2), time series approaches imposes restrictions on the evolvement of the default probability, which is redundant for the purpose of this study. It is well known that time series approach cannot match the all cross section of prices. Its performance gets poor especially when the stationarity of the parameters and models become weak and it coincide with the period of crisis. We use the result from the cross-sectional approach for the remainder of the paper.

1.3.3 Bond Yield Spreads and Implied Bond Yield Spreads

Bond yield spreads are defined as follows:

\[
P_B = \frac{C_B}{M_B} \sum_{j=1}^{M_B/(r_B-t)} E^Q \left[ e^{-\int_t^{t+\delta_j} (r(s)+BYS)ds} \bigg| F_t \right] + E^Q \left[ e^{-\int_t^{T_B} (r(s)+BYS)ds} \bigg| F_t \right]
\]

As shown before, bond yield spreads are not equal to CDS premiums. They can be negatively or positively biased depending on accrued payments and bond prices. The disparity between CDS premiums and bond yields spreads (BYS) gets bigger as the credit quality of a reference entity deteriorates.
To adjust the disparity between CDS premiums and bond yield spreads, we construct ‘implied bond yield spreads’ (IBYS). Following estimation, we calculate the ‘implied price’ of a bond, $\tilde{P}_B$, via the following equation:

$$
\tilde{P}_B = \frac{C_B}{M_B} \sum_{j=1}^{M_B \cdot (\tau_B - t)} E^Q \left[ e^{-\int_t^{\tau_B} r(s) + \lambda(s) ds} \left| \mathcal{F}_t \right] \right] + E^Q \left[ e^{-\int_t^{\tau_B} r(s) \lambda(s) ds} \left| \mathcal{F}_t \right] \right]
$$

+ $E^Q \left[ \int_t^{\tau_c} (1 - L) \lambda(\mu) e^{-\int_t^\mu r(s) + \lambda(s) ds} d\mu \left| \mathcal{F}_t \right] \right]

The implied bond yield spreads (IBYS), are then calculated from the following equation.

$$
\tilde{P}_B = \frac{C_B}{M_B} \sum_{j=1}^{M_B \cdot (\tau_B - t)} E^Q \left[ e^{-\int_t^{\tau_B} \frac{1}{M_B} (r(s) + \text{IBYS}) ds} \left| \mathcal{F}_t \right] \right] + E^Q \left[ e^{-\int_t^{\tau_B} (r(s) + \text{IBYS}) ds} \left| \mathcal{F}_t \right] \right]
$$

Implied bond yield spreads should be close to actual bond yield spreads. Our results presented below demonstrate that the IBYS and BYS are indeed close to being equal during normal periods. Equality is violated during severe crisis periods.

We provide the basis statistics of bond yield spread (BYs), implied bond yield spreads (IBYS) and CDS in Table (1.2).

[Insert Table (1.2) here]

### 1.3.4 Dynamic Relations between CDS and Bonds

We first run two regressions: between CDS premiums and bond yield spreads and between implied bond yield spreads and bond yields spreads.

$$
CDS_t = \alpha + \beta \cdot BYS_t + \epsilon_t
$$

$$
\text{IBYS}_t = \alpha + \beta \cdot BYS_t + \epsilon_t
$$

As the significance of other factors such as liquidity, repo special and the value of CTD options becomes larger as credit quality deteriorates, the pricing equation for CDS premiums and bond yield spreads may become less precise. These factors could induce the two measures not to be exactly equal.

There are multiple bonds outstanding for each EM sovereign. For the analysis at the country level, we average the implied bond yield spread of each bond in our sample. This averaging reduces the bond-specific bias.
Result is provided in Table (1.3).

Bond yield spreads are highly auto-correlated and close to being unit root processes. Assuming a single mean, implied yield spreads and CDS premiums for Mexico are rejected at the 1% significance level. Assuming a trend, yield spreads, implied yield spreads and CDS premiums are rejected for Mexico at the 1% significance level. Turkey is rejected at the 5% significance level.

When two series are characterized by unit roots, we first perform a cointegration rank test as proposed by (Johansen 1991). Test results are provided in the second column in Table 1.5. The null hypothesis is that pairs of two processes are not cointegrated and it is rejected in most cases, implying that they are cointegrated.  

When the series pass the cointegration test, we impose the restriction that the cointegration vector is [1 -1 d]. If implied bond yield spreads and actual bond yield spreads are not cointegrated with [1 -1 d], then it implies that the CDS and bond markets price credit risk differently in excess of a constant amount or that there are time-varying non-transient factors differently affecting prices in the CDS and bond markets. Test results are provided in the third column of Table (1.5). The restriction on the CDS premiums and bond yield

---

15 (Chan-Lau and Kim 2004) study the relation between CDS, bonds and equities for seven EM sovereigns. Cointegration between CDS premiums and bond spreads is rejected for Mexico, Philippine and Turkey. The countries in their study are Brazil, Venezuela, Mexico, Colombia, Russia, Philippine and Turkey and the sample period is from March, 2001 to May, 2003. In their study, they use the JP Morgan Chase Emerging Market Bond Index Plus (EMBI+) and do not match maturities. The inclusion of Brady bonds in EMBI+ and/or the maturity mismatch may cause the rejection of cointegration.

16 (Blanko, Brennan, and Marsh 2005) mention that time varying CTD option values and repo costs may be such time-varying non-transient factors.
spreads is rejected for Argentina, Brazil, Chile, Colombia, Peru, Russia and Venezuela at the 1% significance level. Mexico, Malaysia, Panama and Turkey are rejected at the 5% significance level. The rejection of 11 cases out of 16 is in sharp contrast with previous empirical studies of investment grade corporates.\textsuperscript{17} Note that the countries for which the restriction is rejected are those which experience a big credit quality change, in other words, a large price change.\textsuperscript{18}

These results confirm that the parity relationship between CDS premiums and bond yield spreads is not valid, especially when prices are not near par. As in Figures (1.5) to (1.7), which display plots of CDS premiums and bond yield spreads for three countries with large differences of max-min bond yield spreads during the sample period, the CDS premiums are bigger than the bond yield spreads when the bond yield spreads are around their peaks, as our pricing model suggests.\textsuperscript{19}

\textsuperscript{17} In previous studies of high grade corporates, this restriction on cointegration between CDS premiums and bond yield spreads is rarely rejected. In Blanko et al.(2005), out of 16 U.S. companies studied, only three reject the restriction at the 5% level and none reject it at the 1% level. For the 10 European entities satisfying the cointegration restriction, the restriction is rejected in only two cases at the 5% level and none at the 1% level.

\textsuperscript{18} When sorted in terms of the differences between maximum bond yield spreads and minimum bond yield spreads during the sample period, the results are following. The number in each parenthesis is the difference. AR (33.35): rejected at 1%, BR (25.23): rejected at 1%, VE (15.44): rejected at 1%, RU (12.02): rejected at 5%, TR (10.22): rejected at 1%, CO (10.05): rejected at 1%, PE\textsubscript{1} (7.09): rejected at 1%, MX (5.87): not rejected, PA (5.39): rejected at 5%, PH (5.12): not rejected, ZA (3.15): not rejected, CL (2.21): rejected at 1%, ID (2.16): NA, PE\textsubscript{2} (1.59): not rejected, KR (1.54): not rejected, PL (1.34): rejected at 5%, MY (1.16): rejected at 5%, CN (0.73): not rejected.

\textsuperscript{19} Russia is the exception in that it displays negative basis during 2001.
The result shows that it is difficult to test directly whether the CDS and bond markets for EM Sovereigns price credit risk equally by simply comparing CDS premiums and bond yield spreads. By comparing the IBYS with the bond yield spreads (BYS), we can test more precisely whether the bond and CDS markets price credit risk equally. As in Figures (1.5) to (1.7), the differences between IBYS and BYS are smaller than the differences between CDS premiums and BYS.

As a formal test, we impose the restriction that the cointegration vector on the IBYS and the BYS is [1 -1 d]. 5 cases out of 16 reject the restriction at the 1% significance level. Test results are provided in the third column of Table 1.5. The parity relation is restored in the cases of Mexico, Malaysia, Russia and Turkey, which were formerly rejected at the 1% and/or 5% significance level. Parity relationship is improved for most of counties except Argentina.

However, Argentina, Brazil, Chile, Columbia, Panama, Peru and Venezuela still reject the restriction in our sample. Interestingly, they are countries in Latin America, a region that suffered from real default of Argentina and credit crisis for Brazil and Venezuela. Disparity occurs mainly during the crisis with positive basis and the parity is restored when we exclude the crisis periods. As shown in the figure (1.8), CDS premiums for these countries moves together. Contagion in the CDS market may be a partial explanation for the break down of parity relationship in the region.

When we check the correlation of the IBYS among each countries, it shows very high correlation. It implies that CDS premiums are moving together. In additions, we also find that the correlation of the BYS is also very high. (Longstaff, Pan, Pedersen, and Singleton 2007) also find that Sovereign credit spreads are surprisingly highly correlated and there is little or no country-specific credit risk premium in their CDS data. Our result complement the finding that the bond yield spreads are highly correlated as well. The difference in the movement of the IBYS and BYS comes from the volatility, not the direction of the movement. As shown in the table (1.6), the ratio of the covariance between

[Insert figure (1.8) here]
the IBYS and BYS are generally greater than one. It implies that the size of the movement is greater in the BYS, considering similar magnitude of the correlation. The difference in the liquidity or institutional features of each market may affect the price movement in each market.

[Insert Table (1.6) here]

1.3.5 Liquidity and the Limit of Arbitrage

When we impose the more severe restriction that the cointegration vector is \([1 \ -1 \ 0]\), the restriction is all rejected. These test results are provided on the final column in the Table 1.5. This is a sharp contrast of the test result with cointegration vector of \([1 \ -1 \ d]\).

We first find that the basis between the implied bond yield spread and bond yield spread is quite persistent with high auto correlation with high order as in Table (1.8).

[Insert Table (1.8) here]

We also run two regressions: between the change of CDS premiums and change of bond yield spreads and between change of implied bond yield spreads and change of bond yields spreads.

\[
\begin{align*}
\Delta CDS_t &= \alpha + \beta \cdot \Delta BYS_t + \epsilon_t \\
\Delta IBYS_t &= \alpha + \beta \cdot \Delta BYS_t + \epsilon_t
\end{align*}
\]  

(1.3.4)

Result is provided in Table(1.9). It is notable that \(R^2\) is low and the coefficient is not around one.

[Insert Table (1.9) here]

(Blanko, Brennan, and Marsh 2005), mention that non-zero ‘d’ may come from differences in the choice of the reference riskless rate. However if this is the main reason for it, the magnitude and sign of ‘d’ should be similar for each entity for similar periods, which
is not the case in our study. The sign and magnitude of the average basis are different as shown in Table (1.7).

Other than the choice of reference riskless rate, different liquidity and institutional features could also cause a non-zero 'd.' For investment grade U.S. corporates, the liquidity difference between the CDS and bond markets has been thought to be the main reason for the basis. Let us check whether liquidity in each market can explain the sign and the magnitude of the difference. In Table 1.7, we list the differences between the IBYS and the BYS, the bid-ask spreads of bonds and those of CDS premiums. Bid-ask spreads for bonds are the spreads between the yields to maturity from bid and ask bond prices, respectively.

[Insert Table (1.7) here]

In Brazil, Chile, Columbia, Panama and Peru, countries where cointegration were rejected, the magnitude of the IBYS - BYS difference is bigger in many cases than the transaction cost measured by the sum of the bid-ask spread in both markets when those are at the maximum. Similar pattern is observed for Mexico, Malaysia, Philippine, Turkey and South Africa. Arbitrageurs might have been able to make profits by shorting bonds and CDS protection, exploiting the positive basis, had they been able to trade.

Traders typically use a reverse repo contract to short bonds. Traders borrows a bond to short. When they borrow the bond, they put a cash collateral. An interest is paid

---

20 (Hull, Predescu, and White 2004) test if the difference between the 5-year bond par yield and the 5-year CDS quote equals the 5-year risk free rate. They find that the implied risk-free rate rises as the credit quality of the reference entity declines in cross section. They interpret this finding as the existence of counter party default risk in a CDS. They conclude that the results may be influenced by other factors such as differences in the liquidities of the bonds issued by reference entities in different rating categories. (Longstaff, Mithal, and Neis 2005) find that the ‘basis’ is time varying and strongly related to measures of bond-specific illiquidity as well as to macroeconomic measures of bond-market liquidity.

21 When it comes to the mean, Brazil, Columbia, Peru, Turkey show the similar pattern.

22 (Nashikkar and Pedersen 2007) find that Cash collateral in excess of 100% of the market value of the security to minimize counterparty credit risk. They find that cash collateral is often larger than the value of the borrowed security (usually 102%).
on the cash and it may be lower than the general interest rates. This makes the shorting costly. If there is accompanying cost for the bond short sales, it may prevent the arbitrage. We find that repo rates decrease as credit quality deteriorating. The repo cost effectively eliminates the arbitrage opportunity in Chile and Panama. Brazil, Venezuela and Peru, however, show the persistent positive basis above the bid ask spread and repo cost during the crisis period.

There are other factors that might affect the basis. The cheapest-to-deliver (CTD) option, new issues of bonds and counter party risks are among them. CTD options move deeper into the money and become more valuable whenever the credit quality of a reference entity deteriorates. New issues of bonds may bring higher hedging demand, resulting in a corresponding increase in demand for CDS protection and an increase in premiums. New issues may also improve liquidity in the bond market and reduce ‘liquidity’ premiums in the bonds’ yield spreads. While the factors mentioned above tend to increase the basis, counterparty risk may reduce it. The possibility that the CDS protection seller might default may cause protection buyers to require some compensation for that risk too and reduce the CDS premiums that they would be willing to pay. These issues remain for future research.

1.4 Conclusion

We show that most of the time the CDS and bond markets price credit risk for the Emerging Market Sovereigns equally. The basis, defined as the difference between the CDS premiums and bond yield spreads, is biased away from zero when the price is not at par. To correct the bias in bond yield spreads, we constructed ‘implied bond yield spreads’ using the CDS premiums for various maturities. Although adjusted prices in the CDS and bond markets

---

23(Singh and Andritzky 2005) studied the extent of disparity by using the CTD bond.
were fairly equal over a wide range of changes in credit quality in each entity, we found disparities in Argentina and Brazil when the likelihood of a credit event was very high. During the high yield period in Brazil from 2002 to 2003, CDS premiums and bond yield spreads moved together and affected all other regional Latin American countries. This co-movement resulted in a disparity in other countries in the region. We find that repo cost allow the positive basis to remain by making short sales of bond costly.

Assessing the empirical impact of cheapest-to-deliver (CTD) options, of new issuance of bonds, of other transaction costs and counter party risks, also remain for further research.
Figure 1.1: Basis for $\lambda \in [0.0, 0.5]$ and $P_B \in [0.8, 1.2]$
Figure 1.2: $\frac{\partial}{\partial \lambda}(basis)$ for $\lambda \in [0.001, 2]$ and $C \in [0.05, 0.14]$
Figure 1.4: Term Structure of CDS Premiums 2

(a) Panama
(b) Peru
(c) Philippines
(d) Poland
(e) Russia
(f) Turkey
(g) Venezuela
(h) South Africa
Figure 1.5: Argentina

(a) CDS d. BYS

(b) IBYS d. BYS
Figure 1.7: Venezuela

(a) CDS cf. BYS

(b) IBYS cf. BYS
Figure 1.8: 5 Year CDS Premiums for Latin Countries
Figure 1.9: Basis and Repo Rate

(a) Argentina
(b) Chile
Table 1.1: Maximum Likelihood Estimation Result

This table provides the estimation result for the CIR specification parameters. Standard variation of the estimator are in the parenthesis.

<table>
<thead>
<tr>
<th></th>
<th>$\kappa$</th>
<th>$\theta$</th>
<th>$\eta$</th>
<th>$\sigma$</th>
<th>$c_{11}$</th>
<th>$c_{22}$</th>
<th>$c_{33}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>0.030</td>
<td>0.694</td>
<td>-2.144</td>
<td>1.295</td>
<td>0.106</td>
<td>0.031</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.004)</td>
<td>(0.017)</td>
<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>BR</td>
<td>0.187</td>
<td>0.150</td>
<td>-0.966</td>
<td>0.946</td>
<td>0.199</td>
<td>0.037</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.005)</td>
<td>(0.141)</td>
<td>(0.047)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>CL</td>
<td>0.020</td>
<td>0.020</td>
<td>-0.012</td>
<td>0.078</td>
<td>0.468</td>
<td>0.468</td>
<td>0.468</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.048)</td>
<td>(0.004)</td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>CN</td>
<td>0.134</td>
<td>0.012</td>
<td>-0.010</td>
<td>0.204</td>
<td>0.082</td>
<td>0.083</td>
<td>0.101</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
<td>(0.005)</td>
<td>(0.007)</td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>CO</td>
<td>0.124</td>
<td>0.116</td>
<td>-0.001</td>
<td>0.360</td>
<td>0.111</td>
<td>0.010</td>
<td>0.297</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.011)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>KR</td>
<td>0.089</td>
<td>0.016</td>
<td>0.011</td>
<td>0.098</td>
<td>0.079</td>
<td>0.080</td>
<td>0.187</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.000)</td>
<td>(0.017)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>MY</td>
<td>0.032</td>
<td>0.032</td>
<td>-0.008</td>
<td>0.070</td>
<td>0.061</td>
<td>0.061</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.017)</td>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>PA</td>
<td>0.035</td>
<td>0.074</td>
<td>-0.144</td>
<td>0.100</td>
<td>0.021</td>
<td>0.011</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>PE</td>
<td>0.011</td>
<td>0.124</td>
<td>-0.472</td>
<td>0.188</td>
<td>0.013</td>
<td>-0.018</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.006)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>PH</td>
<td>0.133</td>
<td>0.153</td>
<td>-0.022</td>
<td>0.259</td>
<td>0.034</td>
<td>-0.044</td>
<td>0.217</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>PL</td>
<td>0.020</td>
<td>0.001</td>
<td>0.111</td>
<td>0.124</td>
<td>0.099</td>
<td>0.099</td>
<td>0.150</td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.010)</td>
<td>(0.090)</td>
<td>(0.013)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>RU</td>
<td>0.008</td>
<td>0.101</td>
<td>-0.578</td>
<td>0.198</td>
<td>0.010</td>
<td>0.025</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.007)</td>
<td>(0.010)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.001)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>TR</td>
<td>0.070</td>
<td>0.129</td>
<td>-0.261</td>
<td>0.275</td>
<td>0.013</td>
<td>0.005</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>VE</td>
<td>0.207</td>
<td>0.156</td>
<td>-0.017</td>
<td>0.878</td>
<td>0.195</td>
<td>0.024</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>(0.062)</td>
<td>(0.007)</td>
<td>(0.117)</td>
<td>(0.000)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>ZA</td>
<td>0.130</td>
<td>0.007</td>
<td>-0.009</td>
<td>0.345</td>
<td>0.089</td>
<td>0.090</td>
<td>0.135</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.008)</td>
<td>(0.156)</td>
<td>(0.024)</td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.011)</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.2: Basic Statistics

This table provides the basic statistics of yield spreads of sovereign bonds, implied yield spreads and CDS premiums. Yield spreads are averages of bid and ask spreads over riskless US Treasury zero coupon rates. CDS premiums are averages of bid and ask premiums. To calculate the implied yield spread, the prices of bonds are estimated first. Using these prices, implied bond yield spreads are then calculated.

<table>
<thead>
<tr>
<th>country</th>
<th>Date Begin</th>
<th>Date End</th>
<th>N</th>
<th>BYS (%)</th>
<th>IBYS (%)</th>
<th>CDS Premiums (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>11/16/1998</td>
<td>1/13/2006</td>
<td>1788</td>
<td>7.73 1.34 25.57</td>
<td>7.95 1.46 28.22</td>
<td>8.20 1.43 37.48</td>
</tr>
<tr>
<td>CL</td>
<td>5/1/2002</td>
<td>1/13/2006</td>
<td>927</td>
<td>1.01 0.41 2.60</td>
<td>0.93 0.13 3.46</td>
<td>0.91 0.15 3.43</td>
</tr>
<tr>
<td>CN</td>
<td>4/10/2002</td>
<td>1/13/2006</td>
<td>942</td>
<td>0.61 0.03 1.02</td>
<td>0.36 0.19 0.65</td>
<td>0.35 0.20 0.57</td>
</tr>
<tr>
<td>CO</td>
<td>10/31/2000</td>
<td>1/13/2006</td>
<td>1297</td>
<td>4.44 1.22 11.00</td>
<td>5.43 1.44 13.19</td>
<td>5.26 1.41 13.31</td>
</tr>
<tr>
<td>KR</td>
<td>2/26/2002</td>
<td>1/13/2006</td>
<td>967</td>
<td>0.88 0.52 1.91</td>
<td>0.54 0.19 1.90</td>
<td>0.54 0.20 1.95</td>
</tr>
<tr>
<td>MX</td>
<td>11/16/1998</td>
<td>1/13/2006</td>
<td>1788</td>
<td>2.43 0.56 6.36</td>
<td>2.62 0.53 11.93</td>
<td>2.45 0.51 12.26</td>
</tr>
<tr>
<td>MY</td>
<td>1/29/2003</td>
<td>1/13/2006</td>
<td>741</td>
<td>0.79 0.47 1.64</td>
<td>0.56 0.20 1.88</td>
<td>0.54 0.20 1.80</td>
</tr>
<tr>
<td>PA</td>
<td>1/2/2001</td>
<td>1/13/2006</td>
<td>1255</td>
<td>3.25 1.18 6.14</td>
<td>3.46 1.29 7.11</td>
<td>3.38 1.28 7.05</td>
</tr>
<tr>
<td>PL</td>
<td>6/28/2002</td>
<td>1/13/2006</td>
<td>886</td>
<td>0.93 0.38 2.29</td>
<td>0.42 0.11 1.12</td>
<td>0.43 0.12 1.02</td>
</tr>
<tr>
<td>RU</td>
<td>1/2/2001</td>
<td>1/13/2006</td>
<td>1255</td>
<td>3.87 0.58 12.36</td>
<td>3.62 0.37 10.87</td>
<td>3.51 0.43 10.82</td>
</tr>
<tr>
<td>TR</td>
<td>1/2/2001</td>
<td>1/13/2006</td>
<td>1255</td>
<td>5.30 1.11 11.16</td>
<td>6.23 1.22 13.69</td>
<td>5.99 1.18 13.91</td>
</tr>
<tr>
<td>ZA</td>
<td>3/25/2002</td>
<td>1/13/2006</td>
<td>948</td>
<td>1.41 0.54 3.73</td>
<td>1.27 0.42 2.83</td>
<td>1.27 0.41 2.73</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.3: OLS estimation

This table provides the regression coefficient and \( R^2 \) of two regressions. \( CDS_t = \alpha + \beta \cdot BYS_t + \epsilon_t \) and \( IBYS_t = \alpha + \beta \cdot BYS_t + \epsilon_t \). Number is the parenthesis is OLS standard error of the estimator.

<table>
<thead>
<tr>
<th>country</th>
<th>CDS Vs. BYS</th>
<th>IBYS vs. BYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( R^2 )</td>
<td>( \hat{\alpha} )</td>
</tr>
<tr>
<td>AR</td>
<td>0.97</td>
<td>-0.038</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>BR</td>
<td>0.97</td>
<td>-0.014</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>CL</td>
<td>0.95</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>CN</td>
<td>0.83</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>CO</td>
<td>0.95</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>KR</td>
<td>0.80</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>MX</td>
<td>0.83</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>MY</td>
<td>0.85</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>PA</td>
<td>0.89</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>PE</td>
<td>0.96</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>PH</td>
<td>0.86</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>PL</td>
<td>0.89</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>RU</td>
<td>0.98</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>TR</td>
<td>0.94</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>VE</td>
<td>0.98</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>ZA</td>
<td>0.91</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.009)</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.4: Unit Root Test

This table provides the ‘Dickey Fuller Tau’ statistics and unit root test results. The null hypothesis is that each process follows a unit root process with single mean or trend.

| Country | Yield Spread | | | CDS Premium | | |
|---------|--------------|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|
|         | Single Mean  | Trend                 | Implied Yield Spread | Single Mean  | Trend                 | CDS Premium | Single Mean  | Trend |
| AR      | 2.92         | 1.46                  | 1.60                | 0.18                  | 1.81                | 0.53 |          |      |
| BR      | -1.63        | -1.89                 | -0.99               | -1.27                 | -1.35               | -1.52 |          |      |
| CL      | -0.89        | -2.64                 | -0.88               | -2.40                 | -0.88               | -2.51 |          |      |
| CN      | -1.85        | -2.19                 | -1.47               | -2.42                 | -1.11               | -2.77 |          |      |
| CO      | -1.39        | -2.43                 | -1.12               | -2.38                 | -1.28               | -2.46 |          |      |
| KR      | -1.70        | -3.39                 | -2.09               | -3.27                 | -1.95               | -3.09 |          |      |
| MX      | -2.49        | -4.39**               | -3.91**             | -4.68**               | -4.44**             | -5.08** |          |      |
| MY      | -2.28        | -2.68                 | -2.31               | -1.88                 | -2.02               | -1.68 |          |      |
| PA      | -0.94        | -2.68                 | -0.73               | -2.13                 | -0.82               | -2.17 |          |      |
| PE      | -0.95        | -2.27                 | -0.98               | -2.46                 | -1.06               | -2.49 |          |      |
| PH      | -1.40        | -2.81                 | -1.54               | -2.75                 | -1.66               | -2.77 |          |      |
| PL      | -2.40        | -2.20                 | -1.79               | -1.77                 | -1.58               | -1.99 |          |      |
| RU      | -2.37        | -2.35                 | -2.18               | -2.43                 | -2.29               | -2.83 |          |      |
| TR      | -1.07        | -3.48*                | -1.26               | -3.09                 | -1.50               | -3.30 |          |      |
| VE      | -1.09        | -1.62                 | -1.90               | -2.23                 | -2.07               | -2.36 |          |      |
| ZA      | -1.37        | -2.13                 | -1.07               | -2.38                 | -0.82               | -2.39 |          |      |

Acronyms for each country are as follows: AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.5: Cointegration Test

The second column provides the results for the Johansen Test, where the null hypothesis is that no two processes are cointegrated. The third column contains results for the hypothesis that the restriction on the cointegration vector is $[1 \ -1 \ d]$. The final column provides results for the hypothesis that the restriction on the cointegration vector is $[1 \ -1 \ 0]$.  

<table>
<thead>
<tr>
<th>Country</th>
<th>Johansen test</th>
<th>Restriction: $[1 \ -1 \ d]$</th>
<th>Restriction: $[1 \ -1 \ 0]$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BYS and IBYS</td>
<td>BYS and IBYS</td>
<td>BYS and IBYS</td>
</tr>
<tr>
<td>AR</td>
<td>35.8</td>
<td>26.0**</td>
<td>30.9**</td>
</tr>
<tr>
<td>BR</td>
<td>66.2</td>
<td>15.7**</td>
<td>26.1**</td>
</tr>
<tr>
<td>CL</td>
<td>26.0</td>
<td>10.5**</td>
<td>10.7**</td>
</tr>
<tr>
<td>CN</td>
<td>73.6</td>
<td>0.5</td>
<td>18.6**</td>
</tr>
<tr>
<td>CO</td>
<td>27.8</td>
<td>8.8**</td>
<td>17.1**</td>
</tr>
<tr>
<td>KR</td>
<td>31.1</td>
<td>0.0</td>
<td>7.3**</td>
</tr>
<tr>
<td>MX</td>
<td>36.2</td>
<td>1.0</td>
<td>3.9**</td>
</tr>
<tr>
<td>MY</td>
<td>19.9</td>
<td>0.3</td>
<td>10.2**</td>
</tr>
<tr>
<td>PA</td>
<td>36.2</td>
<td>6.8*</td>
<td>8.0**</td>
</tr>
<tr>
<td>PE</td>
<td>72.3</td>
<td>30.3**</td>
<td>38.5**</td>
</tr>
<tr>
<td>PH</td>
<td>53.8</td>
<td>0.1</td>
<td>14.0**</td>
</tr>
<tr>
<td>PL</td>
<td>66.3</td>
<td>0.6</td>
<td>6.3**</td>
</tr>
<tr>
<td>RU</td>
<td>60.2</td>
<td>0.3</td>
<td>13.8**</td>
</tr>
<tr>
<td>TR</td>
<td>29.3</td>
<td>5.9</td>
<td>7.0**</td>
</tr>
<tr>
<td>VE</td>
<td>49.4</td>
<td>2.9*</td>
<td>9.2**</td>
</tr>
<tr>
<td>ZA</td>
<td>60.0</td>
<td>0.0</td>
<td>16.1**</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.6: Correlation and Covariance

The first panel provides the correlation between the implied bond yield spread of each country, while the second panel with the correlation between the bond yield spread. The third panel show the ratio of covariance between implied bond yield spread and bond yield spread.

**Panel A: Correlation between the IBYS**

<table>
<thead>
<tr>
<th>Country</th>
<th>BR</th>
<th>CL</th>
<th>CO</th>
<th>PA</th>
<th>PE</th>
<th>VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>1.00</td>
<td>0.97</td>
<td>0.88</td>
<td>0.92</td>
<td>0.97</td>
<td>0.78</td>
</tr>
<tr>
<td>CL</td>
<td>0.97</td>
<td>1.00</td>
<td>0.97</td>
<td>0.96</td>
<td>0.96</td>
<td>0.81</td>
</tr>
<tr>
<td>CO</td>
<td>0.88</td>
<td>0.97</td>
<td>1.00</td>
<td>0.95</td>
<td>0.96</td>
<td>0.79</td>
</tr>
<tr>
<td>PA</td>
<td>0.92</td>
<td>0.96</td>
<td>0.95</td>
<td>1.00</td>
<td>0.96</td>
<td>0.87</td>
</tr>
<tr>
<td>PE</td>
<td>0.97</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>1.00</td>
<td>0.84</td>
</tr>
<tr>
<td>VE</td>
<td>0.78</td>
<td>0.81</td>
<td>0.79</td>
<td>0.87</td>
<td>0.84</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Panel B: Correlation between the BYS**

<table>
<thead>
<tr>
<th>Country</th>
<th>BR</th>
<th>CL</th>
<th>CO</th>
<th>PA</th>
<th>PE</th>
<th>VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>1.00</td>
<td>0.97</td>
<td>0.81</td>
<td>0.84</td>
<td>0.97</td>
<td>0.77</td>
</tr>
<tr>
<td>CL</td>
<td>0.97</td>
<td>1.00</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
<td>0.90</td>
</tr>
<tr>
<td>CO</td>
<td>0.81</td>
<td>0.95</td>
<td>1.00</td>
<td>0.95</td>
<td>0.96</td>
<td>0.76</td>
</tr>
<tr>
<td>PA</td>
<td>0.84</td>
<td>0.96</td>
<td>0.95</td>
<td>1.00</td>
<td>0.96</td>
<td>0.81</td>
</tr>
<tr>
<td>PE</td>
<td>0.97</td>
<td>0.97</td>
<td>0.96</td>
<td>0.96</td>
<td>1.00</td>
<td>0.83</td>
</tr>
<tr>
<td>VE</td>
<td>0.77</td>
<td>0.90</td>
<td>0.76</td>
<td>0.81</td>
<td>0.83</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Panel C: Covariance Ratio \( \left( \frac{COV_{IBYS}}{COV_{BYS}} \right) \)**

<table>
<thead>
<tr>
<th>Country</th>
<th>BR</th>
<th>CL</th>
<th>CO</th>
<th>PA</th>
<th>PE</th>
<th>VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>1.18</td>
<td>1.77</td>
<td>1.40</td>
<td>1.34</td>
<td>1.35</td>
<td>1.40</td>
</tr>
<tr>
<td>CL</td>
<td>1.77</td>
<td>2.63</td>
<td>2.06</td>
<td>1.95</td>
<td>2.00</td>
<td>1.70</td>
</tr>
<tr>
<td>CO</td>
<td>1.40</td>
<td>2.06</td>
<td>1.41</td>
<td>1.38</td>
<td>1.56</td>
<td>1.48</td>
</tr>
<tr>
<td>PA</td>
<td>1.34</td>
<td>1.95</td>
<td>1.38</td>
<td>1.26</td>
<td>1.49</td>
<td>1.46</td>
</tr>
<tr>
<td>PE</td>
<td>1.35</td>
<td>2.00</td>
<td>1.56</td>
<td>1.49</td>
<td>1.54</td>
<td>1.46</td>
</tr>
<tr>
<td>VE</td>
<td>1.40</td>
<td>1.70</td>
<td>1.48</td>
<td>1.46</td>
<td>1.46</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BR: Brazil, CL: Chile, CO: Colombia, PA: Panama, PE: Peru, VE: Venezuela.
Table 1.7: Basis and Bid Ask Spreads

The second column provides the differences between implied bond yield spreads and bond yield spreads. The third column is for the bid-ask spreads in bonds' yields-to-maturity. The final column is for the CDS contracts.

<table>
<thead>
<tr>
<th>country</th>
<th>IBYS - BYS (bp)</th>
<th>Bond Bid Ask Spread(bp)</th>
<th>CDS Bid Ask Spread(bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>AR</td>
<td>5.47</td>
<td>-1011.57</td>
<td>403.42</td>
</tr>
<tr>
<td>BR</td>
<td>91.20</td>
<td>-298.51</td>
<td>632.75</td>
</tr>
<tr>
<td>CL</td>
<td>-10.48</td>
<td>-60.01</td>
<td>155.83</td>
</tr>
<tr>
<td>CO</td>
<td>101.79</td>
<td>-101.45</td>
<td>439.52</td>
</tr>
<tr>
<td>PA</td>
<td>21.51</td>
<td>-126.03</td>
<td>200.92</td>
</tr>
<tr>
<td>PE</td>
<td>81.17</td>
<td>-65.06</td>
<td>281.48</td>
</tr>
<tr>
<td>VE</td>
<td>81.76</td>
<td>-282.86</td>
<td>712.50</td>
</tr>
<tr>
<td>MX</td>
<td>0.52</td>
<td>-113.27</td>
<td>282.36</td>
</tr>
<tr>
<td>CN</td>
<td>-20.27</td>
<td>-40.12</td>
<td>11.77</td>
</tr>
<tr>
<td>KR</td>
<td>-12.47</td>
<td>-52.44</td>
<td>27.85</td>
</tr>
<tr>
<td>MY</td>
<td>-22.83</td>
<td>-51.54</td>
<td>36.55</td>
</tr>
<tr>
<td>PHI</td>
<td>74.55</td>
<td>-95.76</td>
<td>232.03</td>
</tr>
<tr>
<td>PL</td>
<td>-28.31</td>
<td>-56.00</td>
<td>10.99</td>
</tr>
<tr>
<td>RU</td>
<td>-25.11</td>
<td>-238.80</td>
<td>151.23</td>
</tr>
<tr>
<td>TR</td>
<td>90.80</td>
<td>-124.18</td>
<td>502.49</td>
</tr>
<tr>
<td>ZA</td>
<td>-16.05</td>
<td>-268.82</td>
<td>264.89</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Table 1.8: White Noise Test

This table provides the standard deviation of the basis at the second column. Third column is the probability the basis is a white noise process for each country. Following columns are the auto correlation coefficient.

<table>
<thead>
<tr>
<th>Country</th>
<th>Std</th>
<th>Prob</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>0.0102</td>
<td>&lt;0.0001</td>
<td>0.80</td>
<td>0.77</td>
<td>0.72</td>
<td>0.70</td>
<td>0.70</td>
<td>0.64</td>
</tr>
<tr>
<td>BR</td>
<td>0.0077</td>
<td>&lt;0.0001</td>
<td>0.95</td>
<td>0.93</td>
<td>0.91</td>
<td>0.89</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>CL</td>
<td>0.0036</td>
<td>&lt;0.0001</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>0.98</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>CN</td>
<td>0.0005</td>
<td>&lt;0.0001</td>
<td>0.89</td>
<td>0.82</td>
<td>0.77</td>
<td>0.71</td>
<td>0.66</td>
<td>0.62</td>
</tr>
<tr>
<td>CO</td>
<td>0.0069</td>
<td>&lt;0.0001</td>
<td>0.98</td>
<td>0.96</td>
<td>0.95</td>
<td>0.94</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td>KR</td>
<td>0.0012</td>
<td>&lt;0.0001</td>
<td>0.95</td>
<td>0.91</td>
<td>0.88</td>
<td>0.86</td>
<td>0.83</td>
<td>0.81</td>
</tr>
<tr>
<td>MX</td>
<td>0.0050</td>
<td>&lt;0.0001</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td>MY</td>
<td>0.0017</td>
<td>&lt;0.0001</td>
<td>0.98</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>PA</td>
<td>0.0047</td>
<td>&lt;0.0001</td>
<td>0.96</td>
<td>0.93</td>
<td>0.90</td>
<td>0.88</td>
<td>0.85</td>
<td>0.83</td>
</tr>
<tr>
<td>PE</td>
<td>0.0065</td>
<td>&lt;0.0001</td>
<td>0.98</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.92</td>
<td>0.91</td>
</tr>
<tr>
<td>PH</td>
<td>0.0040</td>
<td>&lt;0.0001</td>
<td>0.95</td>
<td>0.91</td>
<td>0.88</td>
<td>0.85</td>
<td>0.82</td>
<td>0.80</td>
</tr>
<tr>
<td>PL</td>
<td>0.0010</td>
<td>&lt;0.0001</td>
<td>0.86</td>
<td>0.84</td>
<td>0.82</td>
<td>0.81</td>
<td>0.79</td>
<td>0.80</td>
</tr>
<tr>
<td>RU</td>
<td>0.0044</td>
<td>&lt;0.0001</td>
<td>0.97</td>
<td>0.95</td>
<td>0.94</td>
<td>0.92</td>
<td>0.91</td>
<td>0.90</td>
</tr>
<tr>
<td>TR</td>
<td>0.0081</td>
<td>&lt;0.0001</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>VE</td>
<td>0.0050</td>
<td>&lt;0.0001</td>
<td>0.91</td>
<td>0.85</td>
<td>0.80</td>
<td>0.78</td>
<td>0.76</td>
<td>0.75</td>
</tr>
<tr>
<td>ZA</td>
<td>0.0019</td>
<td>&lt;0.0001</td>
<td>0.89</td>
<td>0.83</td>
<td>0.80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
This table provides the regression coefficient and $R^2$ of two regression $\Delta CDS_t = \alpha + \beta \cdot \Delta BYS_t + \epsilon_t$ and $\Delta IBYS_t = \alpha + \beta \cdot \Delta BYS_t + \epsilon_t$. Number is the parenthesis is OLS standard error of the estimator.

<table>
<thead>
<tr>
<th>country</th>
<th>CDS Vs. BYS</th>
<th>IBYS vs. BYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2$</td>
<td>$\hat{\alpha}$</td>
</tr>
<tr>
<td>AR</td>
<td>0.28</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>BR</td>
<td>0.47</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>CL</td>
<td>0.05</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>CN</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>CO</td>
<td>0.27</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>KR</td>
<td>0.14</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>MX</td>
<td>0.33</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>MY</td>
<td>0.08</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>PA</td>
<td>0.08</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>PE</td>
<td>0.20</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>PH</td>
<td>0.05</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>PL</td>
<td>0.01</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>RU</td>
<td>0.35</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>TR</td>
<td>0.49</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>VE</td>
<td>0.14</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>ZA</td>
<td>0.03</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.011)</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. AR: Argentina, BR: Brazil, CL: Chile, CN: China, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PA: Panama, PE: Peru, PH: Philippines, PL: Poland, RU: Russia, TR: Turkey, VE: Venezuela, ZA: South Africa.
Chapter 2

Loss Given Default Implied by Cross-sectional No Arbitrage

2.1 Introduction

For the recent several years, credit derivatives markets have grown explosively. A recent report by the (British Bankers’ Association 2006) estimates that by the end of 2006, the size of market would be USD 20 trillion, which is far beyond its own prediction of USD 8.2 trillions made in 2004. It expects that at the end of 2008 the global credit derivatives market will have expanded to USD 33 trillion and continue to grow.\(^1\) In addition to the fast growth of the credit derivatives markets, the composition of obligors also is shifting. AAA-BBB rating classes represent 59\% in 2006 falling from 65\% in 2004 and it is expected to continue to fall to 52\% by end of 2008. In contrast, under investment grade classes have

\(^1\) Single name credit default swap (CDS) represents a substantial portion of the market. It represents 51\% of the total market in year 2004 and 33\% in year 2006 respectively. Index trades, the second largest product, represent 30\% in year 2006 growing from 9\% in year 2004. Synthetic CDOs (collateralized debt obligation) come in the third place at 16\% of the market for both year.
expanded and expected to reach nearly half of the market.\textsuperscript{2} The development of credit derivatives in Emerging Markets parallels that of the "global" credit derivatives market.\textsuperscript{3}

Two main components of default risk are default probability and loss given default. A number of studies have focused on modeling default probability, but research on loss given default are rare.\textsuperscript{4} The difficulties in disentangling default probability and loss given default have been well known since (Duffie and Singleton 1999). In order to identify default probability, both academics and practitioners often treat loss given default as a constant. (Longstaff, Mithal, and Neis 2005) pre-set loss given default as 50\% in their study on credit default swaps and bonds for investment grade corporates. For sovereigns, (Adler and Song 2007) set loss given default as 75\% in their study on the dynamics of emerging markets sovereign CDSs and bonds. (Zhang 2003) and (Pan and Singleton 2006) also treat loss given default as a constant in their work on Sovereign CDS, but their studies are different from the previous ones in that they estimate it using data. However, the separation of default probability and loss given default relying only on CDS may be difficult as shown in (Duffie 1999).

Despite of difficulties of separation of default probability and loss given default, it is crucial in many pricing circumstances. Even the basic CDS requires the separation when traders do mark-to-market of premium payment leg of a contract. We need to calculate the

\textsuperscript{2} In contrast, the BB-B classes have expanded from 13\% to 23\% and are expected to grow to 27\% by end 2008 according to the report. Under B classes represent the remaining portion of the market.

\textsuperscript{3} CDSs are the most basic product for Emerging Markets as well. They are based on standard ISDA contract documentation, and enjoy an active broker market with dealers quoting two-way pricing for standard contract sizes (see (Dages, Palmer, and Turney 2005) for more details). More interestingly and importantly, there are quotes for CDS premiums from 1-10 years for the EM sovereigns, whereas the quotes are heavily concentrated on the 5 year contract for the corporate both in the U.S. and in the Emerging Markets. For more details, see (Packer and Suthiphongchai 2003) and (Pan and Singleton 2006).

\textsuperscript{4} Altman and Kishore (1996) and Acharya, Bharath, and Srinivasan (2004), for example, provide analysis on actual recoveries of defaulted securities. Note that this study is on the actual loss given default, not the risk neutral one. (Bakshi, Madan, and Zhang 2006) provide the analysis on the role of the recovery on defaultable debt prices. For a survey paper on the recovery risk, see (Das 2005).
risky PV01, the present value of a one-basis-point annuity with the maturity of the credit default swap that terminates following a credit event, for the mark-to-market purpose. And the risky PV01 is a function of default probability, not a function of loss given default. Digital default swap (DDS) also require a separate measure of default probability in their pricing. As shown in (Bakshi, Madan, and Zhang 2006), loss given default plays important role in the price of basic defaultable debt prices. Furthermore, we need a separate measure of default probability when we price the bond with embedded options. As the market for credit risk continues to develop, there will be more trading of contingent credit securities that depend on default probability and loss given default separately, rather than in combination.

In this paper, I suggest frameworks for the separation by imposing cross-sectional no-arbitrage restrictions between different securities. I develop, first, pricing models for various credit instruments including spot and forward credit default swap (CDS), digital default swap (DDS) and defaultable bonds. Pricing functions of those securities are derived in term of default probability and loss given default of underlying reference entity. Then, I impose cross-sectional no-arbitrage restrictions between them. Due to cross default provisions and absolute priority rules, each credit instrument with the same level of seniority is exposed to the same level of risk out of default probability and loss given default of a certain reference entity. Default probability or loss given default in a pricing model for a certain type of security is replaced with (observable) prices of other securities. Once either default probability or loss given default is identified, the remaining component can be sequentially estimated.

Forward CDS premiums, implied by no-arbitrage, are derived in terms of default probability and other CDS premiums. Loss given default is canceled out with a cross-sectional no-arbitrage restriction between spot and forward CDSs with only default probability remaining. One of the merits of this framework is that the separation does not require any assumption on the process specification of loss given default. It can be a constant or time varying. Furthermore, it can be correlated or uncorrelated to other model parameters such as default probability. The fact that spot and forward CDS contracts are with constant
maturities is also convenient since we do not need to do maturity matching.

Stand alone digital default swap (DDS) premiums reveals a pure measure of default probability, since loss given default in DDS is a contractually fixed number. Protection buyer pays premiums until the maturity or the time of default. In exchange, the protection seller pays a pre-specified loss amount to the protection buyer in the event of default. Differences between DDS and CDS are, first, the amount of payment from the protection seller is pre-specified. In addition to it, DDS contract is usually cash settled, while CDS contract, in many cases, requires physically delivery of reference obligation when default occurs. Therefore, DDS transfer of default event risk while usual CDS transfer both default event risk and default loss risk. A cross-sectional no-arbitrage restriction between CDS and DDS, interestingly, leads to a measure of expected loss given default.

Bond price can also be used in extracting a pure measure of default probability with cross-sectional restrictions with CDS. When bond is floating rate note and at par, it does not add additional information over CDS. However, when it is not at par, the parity relation between bond yield spread and CDS premiums does not hold as pointed out in (Adler and Song 2007).

I find that loss given defaults around 75% prevails in the sovereign CDS markets based on the cross-sectional restriction between spot and forward CDSs. 75% level of loss given default persistently generates the smallest pricing error in the pricing of forward CDS premiums for all sovereigns in the sample; 10 emerging market sovereigns are in the sample and sample periods are from 1999 to 2005. This finding is in contrast with the result found in (Pan and Singleton 2006). Estimates in (Pan and Singleton 2006) are 24%, 23% and 83% for Turkey, Mexico, and Korea. Loss given default around 25% leads to the pricing error of about 100-200bp in forward CDS premiums for Turkey while loss given default of 75% leads to only about 10bp pricing error. For Mexico, loss given default around 25% leads to the

5 Countries include Bulgaria, Brazil, Colombia, Korea, Mexico, Malaysia, Philippines, Poland, Turkey, and Venezuela.

6 Bid-ask spreads for 5 year Turkey CDS for corresponding periods are about 25-50bp.
pricing error of about 20bp in forward CDS premiums for Turkey while loss given default of 75% leads to only about 2bp pricing error.\footnote{Bid-ask spreads for 5 year Mexico CDS for corresponding periods are about 10bp.} The difference in pricing error depending on loss given default is less than bid ask spread for Korea.

The remainder of this paper is organized as follows. Section 2 investigates loss given default in the actual and risk neutral probability space. It shows that the expectation of loss given default in the risk neutral space is time varying and positively correlated with default probability. Section 3 presents pricing models for stand-alone spot credit default swaps, forward credit default swaps, digital defaults swaps, and defaultable bond. Section 4 combines stand-alone pricing model and provides the framework for the separation of default probability and loss given default by imposing cross-sectional no-arbitrage restrictions. No-arbitrage restrictions are imposed between spot CDS and forward CDS, resulting in the pure measure of default probability. The pure measure of loss given default is obtained by imposing the restriction between spot CDS and digital default swaps. No arbitrage restriction between CDSs and bonds also lead to the separation of default probability. Section 5 documents the empirical findings on loss given default in the CDS market. Section 6 summarizes the results and offers concluding remarks.

### 2.2 Default Probability and Loss Given Default

Although loss given default is critical to the pricing of credit-related securities, convention within both academic analysis and industry practice is to treat it as a constant (e.g., (Zhang 2003) and (Pan and Singleton 2006)) and it is often pre-specified based on a historical average (e.g., (Longstaff, Mithal, and Neis 2005) and (Adler and Song 2007)). It is set to lie in the 50 – 60% range for U.S. corporates, and about 75% for sovereigns (see (Das and Hanouna 2006) and (Pan and Singleton 2006) for more details). However, historical averages of loss given default are measured in the actual probability space.

Furthermore, there were significant cross-sectional variations in loss given default in
corporate default cases (see (Altman, Brady, Resti, and Sironi 2005)). In addition, loss
given default on recent sovereign defaults also exhibits significant variations according to
(Moody’s 2006). Loss given default in the actual probability space cannot proxy loss
given default in the risk neutral space, unless there is no risk premiums on recovery risk.
The significant cross-sectional variation of loss given default bring questions about the
risk premiums on loss asides from the default event risk. In a recent study by (Bakshi,
Madan, and Zhang 2006) show that risk neutral loss given default should be higher than
its counterpart in the actual probability space.

In this section, I will show the loss given default in the risk neutral probability space will
be time varying, with bigger expectation than its counterpart in the actual probability space.
In additions, an explanation for the positive correlation between probability of default and
loss given default is provided.

2.2.1 Illustration

In this section, I assume a three-state economy for the exposition of the relation between
loss given default in the actual and risk neutral probability space. By construction, the
payoff space is complete and the unique state price is defined. However, the result holds
when the asset span is not complete.

---

8 Loss given default is as following with defaulted year in parenthesis: Dominican Republic (2005) 8%;
issuer weighted, trading price on a sovereign’s bonds thirty days after its initial missed interest payment,
or in cases in which the initial default event was the distressed exchange itself, it reports the average price
shortly before the distressed exchange. Interestingly, at the announcement of exchange offers, which often
occurred months after the first default event, the loss were substantially lower except Ukraine and Argentina:
Dominican Republic 5%; Ukraine 40%; Moldova N/A; Uruguay 15%; Grenada N/A; Pakistan 35%; Ecuador
(1999) 40%; Argentina 70%; Ivory Coast N/A, Russia 50%. For valuing CDS contracts, it is the loss in value
on the underlying bonds within a month when an actual physical delivery occurs between the insurer and
the insured. (Pan and Singleton 2006) quotes traders that recovery depends on the size of the country (and
the size and distribution of its external debt).
Suppose a three-state economy. State one represents no default of an obligor. State two represents the case of default of the obligor and a big loss ($L_B$). Finally the last state is for the case of default of the obligor with a small loss ($L_S$). The marginal rate of substitution (the pricing kernel) is respectively denoted as $m_1$, $m_2$, and $m_3$ for each state with probability of $P^p_1$, $P^p_2$, and $P^p_3$. Generally $m_1 < m_3 < m_2$ holds for increasing utility function. Let $P^p_2$ denote the probability of default in the actual probability space. Let $P^p_{B,S}$ denote the joint probability of default with a big loss and $P^p_{S}$ denote the joint probability of default with a small loss in actual probability space. For state prices denoted $q_1$, $q_2$, and $q_3$, following equations hold.

$$q_1 = P^p_1 \cdot m_1 = (1 - P^p_2) \cdot m_1$$
$$q_2 = P^p_2 \cdot m_2 = P^p_{B,S} \cdot m_2$$
$$q_3 = P^p_3 \cdot m_3 = P^p_{S} \cdot m_3$$

Risk neutral probability for each state is defined as

$$P^Q_1 = \frac{q_1}{q_1 + q_2 + q_3} = (1 - P^Q)$$
$$P^Q_2 = \frac{q_2}{q_1 + q_2 + q_3} = P^Q_{B,S}$$
$$P^Q_3 = \frac{q_3}{q_1 + q_2 + q_3} = P^Q_{S}$$

where $P^Q$, and $P^Q_{B,S}$ ($P^Q_{S}$) respectively denotes the probability of default and the joint probability of default with a big (small) loss in the risk neutral probability space. Note that the risk neutral probability for each state satisfies $0 < P^Q < 1$ and $\sum P^Q = 1$. Here we can define the default probability in the risk neutral space as below.

$$P^Q_2 = \frac{q_2 + q_3}{q_1 + q_2 + q_3}$$

$$P^Q_2 = \frac{P^p \cdot P^p_{B,S} \cdot m_2 + P^p \cdot (1 - P^p_{B,S}) \cdot m_3}{(1 - P^p_2) \cdot m_1 + P^p_2 \cdot P^p_{B,S} \cdot m_2 + P^p_2 \cdot (1 - P^p_{B,S}) \cdot m_3}$$
$$\geq P^p \cdot P^p_{B,S} + P^p \cdot (1 - P^p_{B,S}) = P^p_{2} \cdot (1 - P^p_{B,S}) = P^p_{2}$$ (2.2.1)
First, note that \( P^{Q}_{D} \geq P^{P}_{D} \) as in equation (2.2.1). Risk averse investors require compensation for the default event risk. The increase of default probability in the risk neutral space may come from increase in the big default probability and/or increase in the small default probability. Next analysis shows that the increase of default probability comes from the increase of default probability of big loss.

\[
P^{Q}_{D,B} = \frac{q_2}{q_1 + q_2 + q_3} = \frac{P^{P}_{D} \cdot P^{P}_{b|D} \cdot m_2}{(1 - P^{P}_{D}) \cdot m_1 + P^{P}_{D} \cdot P^{P}_{b|D} \cdot m_2 + P^{P}_{D} \cdot (1 - P^{P}_{b|D}) \cdot m_3} \geq P^{P}_{D,B}
\]

(2.2.2)

However it is not certain whether the probability of default with small loss will also increase in the risk neutral probability space. It may increase or decrease depending on the magnitude of marginal rate of substitution in each state. From \( E^{P}[m] = \frac{1}{1+r} \) and \( m_1 < m_3 < m_2 \), it is clear that \( m_2 > \frac{1}{1+r} \) and \( m_1 < \frac{1}{1+r} \). However \( m_3 \geq \frac{1}{1+r} \) depending on the probability distribution of the marginal rate of substitution.

\[
P^{Q}_{D,S} = \frac{q_3}{q_1 + q_2 + q_3} = \frac{P^{P}_{D} \cdot (1 - P^{P}_{b|D}) \cdot m_3}{(1 - P^{P}_{D}) \cdot m_1 + P^{P}_{D} \cdot P^{P}_{b|D} \cdot m_2 + P^{P}_{D} \cdot (1 - P^{P}_{b|D}) \cdot m_3} = P^{P}_{D,S} \cdot m_3 \cdot (1 + r) \leq P^{P}_{D,S}
\]

(2.2.3)

Conditional distributions may show different pattern. In the following, I show the probability of big loss conditioning on default is bigger in the risk neutral probability space than in the actual probability space, whereas the probability of small loss conditioning on default is smaller in the risk neutral probability space. It implied that the expectation of loss given
default will be bigger in the risk neutral probability space.

\[
P^Q_{B|D} = \frac{P^Q_{D,B}}{P^Q_D} = \frac{P^P \cdot P^P_{B|D} \cdot m_2}{P^P_D \cdot P^P_{B|D} \cdot m_2 + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot m_3} \\
= \frac{P^P_D \cdot P^P_{B|D}}{P^P_D \cdot P^P_{B|D} + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot \frac{m_3}{m_2}} \\
\geq P^P_{B|D} 
\tag{2.2.4}
\]

\[
P^Q_{S|D} = \frac{P^Q_{D,S}}{P^Q_D} = \frac{P^P \cdot P^P_{S|D} \cdot m_3}{P^P_D \cdot P^P_{S|D} \cdot m_2 + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot m_3} \\
= \frac{P^P_D \cdot P^P_{S|D} \cdot m_3 + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot \frac{m_2}{m_3}}{\leq P^P_{S|D}} 
\tag{2.2.5}
\]

More formally, the expectation of loss given default \( L \) in the risk neutral probability space is

\[
E^Q[L|D] = L_B \cdot P^Q_{B|D} + L_S \cdot P^Q_{S|D} \\
= (L_B - L_S) \cdot \left(\frac{P^P \cdot P^P_{B|D} \cdot m_2}{P^P_D \cdot P^P_{B|D} \cdot m_2 + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot m_3}\right) + L_S \tag{2.2.6}
\]

and the expectation of loss given default \( L \) in the actual probability space is,

\[
E^P[L|D] = L_B \cdot P^P_{B|D} + L_S \cdot P^P_{S|D} = (L_B - L_S) \cdot P^P_{B|D} + L_S \tag{2.2.7}
\]

The difference between them is positive as shown below. It implied that risk averse investors requires risk compensation not only for default probability, but also for loss given default.

\[
E^Q[L|D] - E^P[L|D] = (L_B - L_S) \cdot \left(\frac{P^P \cdot P^P_{B|D} \cdot m_2}{P^P_D \cdot P^P_{B|D} \cdot m_2 + P^P_D \cdot \left(1 - P^P_{B|D}\right) \cdot m_3}\right) \\
- (L_B - L_S) \cdot P^P_{B|D} \\
= (L_B - L_S) \cdot \left(\frac{(m_2 - m_3) \cdot \left(1 - P^P_{B|D}\right) \cdot P^P_{B|D}}{P^P_{B|D} \cdot m_2 + \left(1 - P^P_{B|D}\right) \cdot m_3}\right) \geq 0 \tag{2.2.8}
\]
The correlation between default probability and loss given default has been documented in previous empirical studies. (Altman, Brady, Resti, and Sironi 2005) find default probability and loss given default are positively correlated at the aggregate level. They explain the correlated relation in U.S. corporates based on a business-cycle and asset fire sales. However, their explanation is not directly applicable to the relations in the risk neutral probability space. From equation (2.2.1), default probability in the risk neutral probability space, $P^Q$, increases in the default probability in the actual probability space, $P^P$, the conditional probability of big default, $P^P_{D}$, and the conditional expectation of the pricing kernel, $E^P[m|D]$. In contrast, expectation of loss given default, $E^Q[L|D]$ increases in $P^P_{D}$. $E^Q[L|D]$ does not change with a change of $P^P_{D}$. The expectation increases in $E^P[m|D]$ when the increase of the conditional expectation of the pricing kernel is driven by the increase of $P^P_{D}$ or $\frac{m^2}{m^3}$. This finding implies that there would be co-movement of default probability and loss given default when they are driven by the increase of the conditional probability of big default.

### 2.2.2 Default Probability and Loss Given Default

In this section, I generalize the finding in the previous section. Suppose that an insurance buyer faces the following maximization problem, where his utility function is denoted by $U_t(\cdot)$. It is assumed that $U_t'(\cdot) \geq 0$, $U_t''(\cdot) \leq 0$. $c_t$ denotes the consumption at time $t$, $e_t$ denotes the endowment at time $t$ and $P_t$, $\xi_t$ and $X_t$ respectfully denote a price vector of securities, number of holdings of each security and payoff. There is defaultable security with probability of default, $P^P_{D}$, under the actual probability space. In case of default, $L_{t+1}$, loss given default, out of the unit payoff occurs with probability density function $f^P_t(L_{t+1})$.

$$\max \quad U_t(c_t) + e^{-\beta}E^P[U_t(c_{t+1})]$$

s.t.

$$c_t \leq e_t - P^P_t\xi_t$$

$$c_{t+1} \leq e_{t+1} + \xi_tX_{t+1}$$
Assume that $\xi^*_t$, $c^*_t$ and $c^*_t+1$ is the solution of the problem.

Then the price of insurance $P_{t,I}$, which provides $I(L_{t+1})$ to the insurance buyer will be

$$P_{t,I} = \mathbb{E}^I\left[ \frac{-\beta U'_t(c^*_t+1)}{U'_t(c^*_t)} \cdot I(L_{t+1}) \cdot \mathbb{I}_{\mathcal{D}_{t+1}} \right]$$

$$= \int_{\mathcal{D}_{t+1}} \int_0^1 \int_{c^*_t+1} e^{-\beta U'_t(c^*_t+1)} \cdot I(L_{t+1}) \cdot f^P_t(c^*_t+1|L_{t+1},\mathcal{D}_{t+1}) \cdot dc^*_t+1 \cdot f^P_t(L_{t+1}|\mathcal{D}_{t+1}) \cdot dL_{t+1} \cdot f^P_t(\mathcal{D}_{t+1})d\mathcal{D}_{t+1}$$

(2.2.9)

where $\mathcal{D}_{t+1}$ indicates default states of the reference entity at time $t+1$ and $\frac{-\beta U'_t(c^*_t+1)}{U'_t(c^*_t)}$ is a marginal rate of substitution. I will denote the marginal rate of substitution as $m_{t,t+1}$ as commonly used in literature. We need to rearrange equation (2.2.9) such that

$$P_{t,I} = \frac{\int_{\mathcal{D}_{t+1}} \int_0^1 I(L_{t+1})f^Q_t(L_{t+1}|\mathcal{D}_{t+1})dL_{t+1} \cdot f^Q_t(\mathcal{D}_{t+1})d\mathcal{D}_{t+1}}{1 + r_t}$$

(2.2.10)

Let’s define $f^Q_t(\mathcal{D}_{t+1})$ as

$$f^Q_t(\mathcal{D}_{t+1}) = (1 + r_t) \cdot \int_0^1 \int_{c^*_t+1} m_{t,t+1} \cdot f^P_t(c^*_t|L_{t+1},\mathcal{D}_{t+1}) \cdot dc^*_t \cdot f^P_t(L_{t+1}|\mathcal{D}_{t+1}) \cdot dL_{t+1}f^P_t(\mathcal{D}_{t+1})$$

(2.2.11)

Then the risk neutral default probability density, $f^Q_t(\mathcal{D}_{t+1})$ is an equivalent probability measure of $f^P_t(\mathcal{D}_{t+1})$. It is obvious that $0 \leq f^Q_t(\mathcal{D}_{t+1})$ since $r_t$ and $m_{t,t+1}$ is positive in general. From equation(2.2.11),

$$\int_{\mathcal{D}_{t+1}} f^Q_t(\mathcal{D}_{t+1})d\mathcal{D}_{t+1} = \int_{\mathcal{D}_{t+1}} (1 + r_t) \cdot \int_0^1 \int_{c^*_t+1} m_{t,t+1} \cdot f^P_t(c^*_t+1|L_{t+1},\mathcal{D}_{t+1}) \cdot dc^*_t+1 \cdot f^P_t(L_{t+1}|\mathcal{D}_{t+1}) \cdot dL_{t+1}f^P_t(\mathcal{D}_{t+1})d\mathcal{D}_{t+1}$$

$$= 1$$

(2.2.12)

The risk neutral default probability, $P^Q_{t,D}$ is greater than the actual probability of default $P^P_{t,D}$ for increasing and concave utility function if there is a loss at the aggregate level, leading to the increase of the marginal rate of substitution at default. From equation(2.2.11),

$$P^Q_{t,D} = \int_{\mathcal{D}_{t+1}} f^Q_t(\mathcal{D}_{t+1}) \cdot \mathbb{I}_{\mathcal{D}_{t+1}} d\mathcal{D}_{t+1}$$

$$= (1 + r_t) \cdot \mathbb{E}^P_t\left[ m_{t,t+1} \cdot \mathbb{I}_{\mathcal{D}_{t+1}} \right]$$

$$= P^P_{t,D} + (1 + r_t) \cdot COV^P_t\left[ m_{t,t+1} \cdot \mathbb{I}_{\mathcal{D}_{t+1}} \right]$$

$$\geq P^P_{t,D}$$

(2.2.13)
From equations (2.2.10) and (2.2.11), we can specify \( f_t^Q(L_{t+1}|D_{t+1}) \) as below.

\[
f_t^Q(L_{t+1}|D_{t+1}) = \frac{\int_{c_{t+1}^*} f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1})}{\int_0^1 \int_{c_{t+1}^*} m_{t,t+1} \cdot f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1}) \cdot dL_{t+1}}
\]

(2.2.14)

It follows that

\[
E_t^Q[L_{t+1}|D_{t+1}] = \int_0^1 L_{t+1} \cdot f_t^Q(L_{t+1}|D_{t+1}) dL_{t+1}
\]

\[
= \int_0^1 L_{t+1} \cdot \frac{\int_{c_{t+1}^*} m_{t,t+1} \cdot f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1})}{\int_0^1 \int_{c_{t+1}^*} m_{t,t+1} \cdot f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1}) \cdot dL_{t+1}} dL_{t+1}
\]

\[
\frac{E_t^P}{E_t^Q} \left[ L_{t+1} \cdot m_{t,t+1} \left| D_{t+1} \right. \right]
\]

(2.2.15)

The expectation of loss given default in the risk neutral space is time varying even then the loss distribution in the actual probability space is stationary. From equation (2.2.15), \( E_t^Q[L_{t+1}|D_{t+1}] \) is a function of loss distribution and marginal rate of substitution. As more information accumulated, may the distribution of loss in the actual probability space change leading to the time varying expectation of the loss. More importantly, time variation of marginal rate of substitution cause the expectation to vary over time.

The expectation of loss given default in the risk neutral space is bigger than the one in the actual probability space. From equation (2.2.15),

\[
E_t^Q[L_{t+1}|D_{t+1}] - E_t^P[L_{t+1}|D_{t+1}]
\]

\[
= \int_0^1 L_{t+1} \cdot \frac{\int_{c_{t+1}^*} m_{t,t+1} \cdot f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1})}{\int_0^1 \int_{c_{t+1}^*} m_{t,t+1} \cdot f_t^P(c_{t+1}^*|L_{t+1}, D_{t+1}) \cdot dc_{t+1}^* \cdot f_t^P(L_{t+1}|D_{t+1}) \cdot dL_{t+1}} dL_{t+1}
\]

\[
- \int_0^1 L_{t+1} \cdot f_t^P(L_{t+1}|D_{t+1}) dL_{t+1}
\]

\[
= \text{COV}_t \left[ L_{t+1}, m_{t+t+1} \left| D_{t+1} \right. \right] \geq 0
\]

(2.2.16)
The last relation hold because $m_{t,t+1}$ increases as $L_{t+1}$ increases; higher $L_{t+1}$ implies less payoff at default states. Since we assume $U''(\cdot) < 0$, marginal utility is bigger when payoff is less.

The expectation of loss given default and probability of default in the risk neutral space are positively correlated when loss distribution in the actual probability space changes in a manner that probability density increases with higher loss while the same magnitude of the density decrease with lower loss. From equation (2.2.13), $P^Q_{t,D}$ increases with the change in $f^P_t(L_{t+1} | \mathcal{D}_{t+1})$ since $P^Q_{t,D}$ increases in $\text{COV}^P_t\left[m_{t,t+1}, \mathbb{I}_{\mathcal{D}_{t+1}}\right]$. 

$$ P^Q_{t,D} = P^P_{t,D} + (1 + r_t) \cdot \text{COV}^P_t\left[m_{t,t+1}, \mathbb{I}_{\mathcal{D}_{t+1}}\right] $$ (2.2.17)

From equation (2.2.15), it is not obvious whether $E^Q[L_{t+1} | \mathcal{D}_{t+1}]$ increase with the change in $f^P_t(L_{t+1} | \mathcal{D}_{t+1})$. $E^P_t\left[m_{t,t+1} | \mathcal{D}_{t+1}\right]$ increases in the case, which leads to the increase in the denominator in equation (2.2.18).

$$ E^Q[L_{t+1} | \mathcal{D}_{t+1}] = \frac{E^P_t\left[L_{t+1} \cdot m_{t,t+1} | \mathcal{D}_{t+1}\right]}{E^P_t\left[m_{t,t+1} | \mathcal{D}_{t+1}\right]} $$ (2.2.18)

Note that the probability density of loss given default in the risk neutral space, $f^Q_t(L_{t+1} | \mathcal{D}_{t+1})$, increases with a such change in $f^P_t(L_{t+1} | \mathcal{D}_{t+1})$. It implies that the expectation $E^Q[L_{t+1} | \mathcal{D}_{t+1}]$ increase, resulting in the positive correlation.

It is worth noting that the mere increase in the probability of default in the actual probability space does not cause the increase in the expectation of loss given default. Therefore, when the increase of credit spreads is attributed to the increase of the real default probability, loss given default would not increase.

### 2.3 Pricing Models

In this section, I derive pricing formulae for credit default swaps, forward credit default swaps, digital default swaps, and defaultable bonds. The stand-alone pricing formula for
each security is derived in terms of default probability and loss given default. Digital default swap is an exception in that it provides default probability not contaminated by the loss given defaults. It is because loss given default in digital default swaps is contractually pre-fixed. Other than that, the separate estimation of default probability and loss given default is not feasible and they should be jointly estimated. However the accuracy of the joint estimation is questionable (see (Longstaff, Mithal, and Neis 2005), (Duffie 1999) and (Pan and Singleton 2006) for more details). Though the difficulties of identification of default probability and loss given default in stand-alone pricing model are well known, stand-alone models form bases for the separation when they are used in combinations via cross-sectional no-arbitrage restrictions.

I, first, set-up the common notations to be used in this paper. A risk neutral probability space \((\Omega, \mathcal{F}, Q)\) is well defined, where the filtration \(\mathcal{F} = \{\mathcal{F}_t|0 \leq t \leq T\}\) satisfies \(\mathcal{F}_T = \mathcal{F}\) and it is complete, increasing and right continuous. I also assume a locally risk-free short rate process \(r_t\). Let \(s(t, T)\) be a survival probability of the reference entity until time \(T\) under the risk neutral measure. \(L\) denote loss given default.

2.3.1 Spot Credit Default Swap

In this section, I derive a pricing model for CDSs. Suppose that two parties make a spot CDS contract at time \(t\) with maturity of \(\tau_c\). A buyer of protection periodically pays premiums, \(s_{t, \tau_c}\), to a seller. The payment is made \(M_c\) times a year until any one of the following events happens: the underlying reference entity defaults on its reference obligation or the maturity of the CDS contract comes. The payment begins at \(t + \frac{1}{M_c}\).

The protection seller receives periodic premium payment and its present value at \(t\) is

\[
\frac{s_{t, \tau_c}}{M_c} \sum_{j=1}^{M_c(\tau_c-t)} E^Q \left[ e^{-\int_t^{t+\frac{1}{M_c}} \mathcal{F}_s} r(s) ds \cdot s(t, t + \frac{j}{M_c}) \right]_{\mathcal{F}_t}
\]

The protection buyer will receive a unit face value of the reference obligation in exchange of the physical delivery of the obligation when a credit event happens. Then the present
value of the protection payment is
\[
\lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\frac{i}{N}} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_c}{N}) - s(t, t + \frac{i \cdot \tau_c}{N}) \right) \right] F_t
\]

Since the net present value of a spot CDS at its initiation be zero, the spot CDS premium can be obtained by equating the value of the two legs

\[
\frac{s_{t, \tau_c}}{M_c} = \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\frac{i}{N}} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_c}{N}) - s(t, t + \frac{i \cdot \tau_c}{N}) \right) \right] F_t
\]

\[
\sum_{j=1}^{M_c \cdot (\tau_c - \tau_f)} E^Q \left[ e^{-\int_{t}^{t+\frac{j}{M_c}} r(s) ds} \cdot s(t, t + \frac{j}{M_c}) \right] F_t
\] (2.3.1)

### 2.3.2 Forward Credit Default Swap

A forward CDS contract is an obligation to buy or sell a CDS on a specified reference entity for a specified spread at a specified future time. Suppose that two parties make a forward CDS contract at time \( t \) with maturity of \( \tau_c \). A buyer of protection will begin to pay premiums, \( s_{t, \tau_c} \), to a seller at a certain pre-set future time (expiry of a forward contract), which is denoted as \( \tau_f \). The payment is made \( M_c \) times a year until any one of the following events happens: the underlying reference entity defaults on its reference obligation or the maturity of the forward CDS contract comes.

The seller of protection receives the premium payment and its present value at \( t \) is

\[
\frac{s_{t, \tau_c}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_c - \tau_f)} E^Q \left[ e^{-\int_{t}^{t+\frac{j}{M_c}} r(s) ds} \cdot s(t, \tau_f + \frac{j}{M_c}) \right] F_t
\]

The buyer of protection will receive a unit face value of the reference obligation in exchange of the physical delivery of the obligation when a credit event happens. Then the present value of the protection payment is

\[
\lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\frac{i}{N}} r(s) ds} \cdot \left( s(t, \tau_f + \frac{(i-1) \cdot \tau_c}{N}) - s(t, \tau_f + \frac{i \cdot \tau_c}{N}) \right) \right] F_t
\]

Since the net present value of a forward CDS at its initiation is zero, the forward CDS
premium can be obtained by equating the values of the two legs

\[
\frac{s_{\tau_f \tau_c}}{M_c} = \lim_{N \to \infty} \sum_{i=1}^{N} \mathbb{E}^Q \left[ \ln \cdot e^{-\int_{t}^{\tau_f + \frac{\tau_c}{N}} r(s) ds} \cdot \left( s(t, \tau_f + \frac{(i-1)\tau_c}{N}) - s(t, \tau_f + \frac{i\tau_c}{N}) \right) \right] \mathcal{F}_t
\]

\[
\sum_{j=1}^{M_c(\tau_c - \tau_f)} \mathbb{E}^Q \left[ e^{-\int_{t}^{\tau_f + \frac{\tau_c}{M_c}} r(s) ds} \cdot s(t, \tau_f + \frac{j\tau_c}{M_c}) \right] \mathcal{F}_t
\]

(2.3.2)

Pricing formula for a forward CDS is quite similar to the one for a spot CDS; They are virtually identical except the beginning point of the premium payment. With \( \tau_f = t \), equation (2.3.2) is identical to equation (2.3.1).

2.3.3 Digital Default Swap

In this section, I develop a pricing model for digital default swaps.\(^9\) Digital default swaps contract is an obligation that a protection seller pays a pre-specified dollar amount to a protection buyer in the event of default. Spot and forward credit default swaps and digital default swaps are designed to protect against different types of risk. The credit default swaps transfer the risk of loss of the obligation holder in the time of default. Therefore pricing function contains both default probability and loss given default. However, digital default swaps transfer only the risk of a default event. Regardless of the magnitude of loss, pre-specified amount is paid. As a result the pricing function contains only default probability.

Suppose that two parties make a digital default swaps contract at time \( t \) with the maturity of \( \tau_c \). A buyer of protection will begin to pay premiums, \( s_{t, \tau_c}^D \), to a seller at time \( t + \frac{1}{M_c} \). The payment is made \( M_c \) times a year until any one of the following events happens:

---

\(^9\) (Berd and Kapoor 2003) also derived the pricing formula for digital default swaps. Their model is different from mine with two respects. Their model is derived under the actual probability space while mine is under the risk neutral probability space. For the consistency with other pricing model in this paper and future use in the next section, a model under risk neutral measure is necessary. More importantly, my model is a model for the absolute pricing. Their model is derived using the hedge ratio in the relative pricing set up. Their pricing function is expressed with hedging instrument.
the underlying reference entity defaults on its reference obligation or the maturity of the CDS contract comes. In the event of default, the seller of a protection pay the pre-specified \( \mathcal{L} \) to the buyer.

The seller of protection receives the premium payment and its present value at \( t \) is

\[
\frac{\mathcal{L}}{M_{c}} \sum_{j=1}^{M_{c} - (r_{c} - t)} \mathbb{E}^{Q}\left[ e^{-\int_{t}^{t + \frac{1}{M_{c}} r_{c}} r(s) ds} \cdot s(t, t + \frac{j}{M_{c}}) \bigg| \mathcal{F}_{t} \right]
\]

The buyer of protection will receive the pre-specified dollar amount \( \mathcal{L} \) when a credit event happens. Then the present value of the protection payment is

\[
\mathcal{L} \cdot \lim_{N \to \infty} \sum_{i=1}^{N} \mathbb{E}^{Q}\left[ e^{-\int_{t}^{t + \frac{i}{N} r_{c}} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot r_{c}}{N}) - s(t, t + \frac{i \cdot r_{c}}{N}) \right) \bigg| \mathcal{F}_{t} \right]
\]

Since the net present value of a digital default swaps at its initiation is zero, the digital default swap premium can be obtained by equating the value of the two legs

\[
\frac{s_{D}^{D} \cdot \mathcal{L}}{M_{c}} = \lim_{N \to \infty} \sum_{i=1}^{N} \mathbb{E}^{Q}\left[ e^{-\int_{t}^{t + \frac{i}{N} r_{c}} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot r_{c}}{N}) - s(t, t + \frac{i \cdot r_{c}}{N}) \right) \bigg| \mathcal{F}_{t} \right]
\]

(2.3.3)

Note that pricing formula DDS premiums is similar to that of spot CDS. The only difference is that loss given default in the numerator of equation (2.3.1) is pulled out as a constant \( \mathcal{L} \) in equation (2.3.3).

### 2.3.4 Defaultable Bond

Let \( P_{t} \) denote a bond price at time \( t \) with the maturity of \( \tau_{b} \). A bond holder receives a periodic coupon payment until maturity conditional on no default at each coupon payment time. Coupon is paid \( M_{b} \) times a year and \( C \) denotes an annualized coupon rates for the bond. If there is no default until its maturity, the investor receives the principal (normalized as one). In the event of default, the bond holder only receive \( R \) at the time of default.

The value of coupon payment until default is

\[
\frac{C}{M_{b}} \sum_{j=1}^{M_{b} - (r_{c} - t)} \mathbb{E}^{Q}\left[ e^{-\int_{t}^{t + \frac{1}{M_{b}} r_{c}} r(s) ds} \cdot s(t, t + \frac{j}{M_{b}}) \bigg| \mathcal{F}_{t} \right]
\]
The value of principal conditional on no default until maturity is
\[ E^Q \left[ e^{- \int_t^T r(s) ds} \cdot s(t, \tau_b) \bigg| \mathcal{F}_t \right] \]

Finally, the value of recovery at default is
\[ \lim_{N \to \infty} \sum_{i=1}^N E^Q \left[ R \cdot e^{- \int_t^{t+\frac{i}{N} \tau_b} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_b}{N}) - s(t, t + \frac{i \cdot \tau_b}{N}) \right) \bigg| \mathcal{F}_t \right] \]

Then, the price of the bond is derived by summing up the value of coupon, principals and recovery.

\[ P_t = \frac{C}{M_b} \sum_{j=1}^{M_b} e^{- \int_t^{t+\frac{j}{M_b} \tau_b} r(s) ds} \cdot s(t, t + \frac{j}{M_b}) \bigg| \mathcal{F}_t \bigg] + E^Q \left[ e^{- \int_t^T r(s) ds} \cdot s(t, \tau_b) \bigg| \mathcal{F}_t \right] + \lim_{N \to \infty} \sum_{i=1}^N E^Q \left[ R \cdot e^{- \int_t^{t+\frac{i}{N} \tau_b} r(s) ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_b}{N}) - s(t, t + \frac{i \cdot \tau_b}{N}) \right) \bigg| \mathcal{F}_t \right] \] (2.3.4)

### 2.4 Cross Sectional Restriction and Separation

In this section, I develop frameworks for the separate identification of default probability and loss given default. The separate identification comes from the cross-sectional no-arbitrage restriction between securities with exposure to the credit risk of the common reference entity. Spot CDS, forward CDS, digital default swaps (DDS) and defaultable bonds are among the most common single name securities with credit exposure. Imposing the restrictions between stand-alone pricing functions of each security, which are derived in terms of default probability and loss given default in the previous section, I derive new pricing formulae for forward CDS, DDS and defaultable bonds in terms of spot CDS premiums and one of the two components, either default probability or loss given default. These pricing methods are different from those in the previous section. While the pricing functions in the previous section are 'absolute' pricing in the sense that they are derived in terms of default probability and loss given default of the reference entity, the pricing functions in this section are 'relative' pricing in that they are expressed with other securities' price.\(^{10}\)

\(^{10}\) Prior studies such as (Madan and Unal 1998), Unal, Madan, and Guntay (2001) and (Bakshi, Madan, and Zhang 2001) use multiple debt securities for the separation. (Madan and Unal 1998) requires the
2.4.1 Separation with Cross-Sectional Restriction: Illustration

In spite of the shortfall of the historical average as a proxy, it has been used mainly because of the econometrical infeasibility of the separation of two components; when contracts are priced under the fractional recovery of market value convention (RMV) introduced by (Duffle and Singleton 1999), the product of default probability and loss given default determines prices. Arbitrary choice of loss given default is compensated by the corresponding adjustment of default probability. In this case, random choice of a fixed number for loss given default does not affect the statistical fit of the model being tested.

Default probability and loss given default can be identified in principle using CDSs. However, at practical level, several sets of loss given default and default probability provide equally good fits for observed CDS premiums.\(^{11}\)

However, a certain set of loss given default and default intensity providing good fits for CDS may not work well for other securities, e.g. 'classic' bullet bonds. Figure 2.1 illustrates this. For the simplicity, the short rate is set as a constant, 5%. Bond pays semi-annual coupon with coupon rate, 8%. default intensity, \(\lambda\), is set with a range of \([0.01,0.2]\) and loss given default, \(L\) is set with \([0.1,0.9]\).\(^{12}\) With this set-up, the range of CDS premiums generated is within \([0.0,0.2]\) (figure 2.1(a)). It should be note that many combination of \(\{L,\lambda\}\) fit a given CDS premium. The intersection between the plane, ‘premium = \(f(L,\lambda)\)’, existence of two debt securities with different seniorities. (Bakshi, Madan, and Zhang 2001) needs large cross-section of bonds in their estimation.

\(^{11}\) see (Duffie 1999) for details. Recently, (Pan and Singleton 2006) jointly estimates loss given default and default probability using CDS data for sovereigns. They take loss given default as a constant and estimate it using the (quasi) maximum likelihood estimation method. Estimates for loss given default in their study are 23%, 24% and 83% for Mexico, Turkey and Korea. However, it should be noted the maximum likelihood with unrestricted loss given default is about the same with the case where they impose the 75% restriction. Likelihood are 32.030 (32.126), 27.213 (27.700), and 36.626 (36.626) for Mexico, Turkey and Korea in restricted (unrestricted) model. It illustrates the difficulties of identification of loss given default and default probability by solely using CDS data.

\(^{12}\) In this simple set-up of constant default intensity and loss given default, \(\lambda = -\frac{\ln s(t,T)}{T-t}\) holds.
where $f$ is the graph such that $f : (L, \lambda) \rightarrow \text{premiums}$ and the other plane $\text{premium } = k$ is generally a line, not a point. All points on the line are combinations of $\{L, \lambda\}$ that perfectly fit a given CDS premium.

As with CDS, many combinations of $\{L, \lambda\}$ fit a given bond price. The intersection between the plane, $\text{Price } = g(L, \lambda)$, where $g$ is the graph such that $g : (L, \lambda) \rightarrow \text{Price}$ and the other plane $\text{Price } = k'$ is generally a line, not a point. All points on the line are combinations of $\{L, \lambda\}$ that perfectly fit a given bond price. With the same range of default probability and loss given default, bond price is in $[0.5, 1.2]$ (figure 2.1(b)).

However, combinations that match both CDS premiums and bond price are not as many as those which match only one of them. In this example, cross-sectional restriction between CDS and bond not only explores the additional price information in both securities, but also significantly improves the identification of loss given default and default probability. This fact is illustrated in figure 2.2; Given a pair of observed bond price and CDS premium, the $L$ is uniquely identified. It is also notable that when CDS premiums are low, bond prices do not vary a lot as $L$ varies. However, as CDS premiums get high, bond prices significantly varies.

Cross-sectional restrictions among different securities improve the identification. Usually, for a certain reference entity, there are several types of securities traded with exposure to the credit risk of that entity. With cross-section of these securities, we can improve the identification of loss given default and default probability.

2.4.2 Implied Forward CDS Premiums:

No Arbitrage Restriction between Spot CDS and Forward CDS

In this section, I impose a cross-sectional no-arbitrage restriction between spot CDS and forward CDS and develop a new pricing framework for forward CDS. I refer the new pricing
equation for the forward CDS premiums as 'implied forward CDS premiums', since the price is implied by the no-arbitrage restriction. The new pricing formula has two distinctive features. First, it allows the separation between default probability and loss given default. In equation (2.3.2), the forward CDS premium is derived in terms of default probability and loss given default. However, the implied forward CDS premiums are derived in terms of other observable spot CDS premiums and default probability. In the derivation of the implied CDS premiums, loss given default is canceled out. It leads to the separate identification of default probability.

Suppose a forward CDS contract, with expiry \( \tau_f \), to buy and sell a CDS with time to maturity \((\tau_c - \tau_f)\). Suppose also two spot CDS contracts, at time \( t \), with time to maturity \((\tau_f - t)\) and \((\tau_c - t)\). From equation (2.3.1), two spot CDS premiums with time to maturity \((\tau_f - t)\) and \((\tau_c - t)\) are respectively priced as below.

\[
\frac{s_{\tau_f}}{M_c} \sum_{j=1}^{M_c} \frac{M_c^{\tau_f-t}}{N} E^Q \left[ e^{-\int_t^{\tau_f} r(s) ds} \cdot s(t, t + \frac{j}{M_c}) \right] F_t
\]

\[
= \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_t^{\tau_f} r(s) ds} \cdot s(t, t + \frac{i}{N}) \right] F_t
\]

(2.4.1)

\[
\frac{s_{\tau_c}}{M_c} \sum_{j=1}^{M_c} \frac{M_c^{\tau_c-t}}{N} E^Q \left[ e^{-\int_t^{\tau_c} r(s) ds} \cdot s(t, t + \frac{j}{M_c}) \right] F_t
\]

\[
= \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_t^{\tau_c} r(s) ds} \cdot s(t, t + \frac{i}{N}) \right] F_t
\]

(2.4.2)

From equation (2.3.2), the following equation holds for the forward CDS.

\[
\frac{s_{\tau_f}}{M_c} \sum_{j=1}^{M_c} \frac{M_c^{\tau_c-\tau_f}}{N} E^Q \left[ e^{-\int_t^{\tau_c} r(s) ds} \cdot s(t, \tau_f + \frac{j}{M_c}) \right] F_t
\]

\[
= \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_t^{\tau_c} r(s) ds} \cdot \left( s(t, \tau_f + \frac{i}{N}) - s(t, \tau_f + \frac{i-1}{N}) \right) \right] F_t
\]

(2.4.3)
When I add equation (2.4.1) to equation (2.4.3), it leads to equation (2.4.2). It is notable that the equality should always hold regardless of the process specification of default probability and loss given default. For right hand side,

\[
\lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\tau_i} r(s)ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_f}{N}) - s(t, t + \frac{i \cdot \tau_c}{N}) \right) \bigg| \mathcal{F}_t \right]
\]

\[
+ \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\tau_i} r(s)ds} \cdot \left( s(t, \tau_f + \frac{(i-1) \cdot \tau_c}{N}) - s(t, \tau_f + \frac{i \cdot \tau_c}{N}) \right) \bigg| \mathcal{F}_t \right]
\]

\[
= \lim_{N \to \infty} \sum_{i=1}^{N} E^Q \left[ L \cdot e^{-\int_{t}^{t+\tau_i} r(s)ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_c}{N}) - s(t, t + \frac{i \cdot \tau_c}{N}) \right) \bigg| \mathcal{F}_t \right]
\]

For left hand side,

\[
\frac{s_{t, \tau_f}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_f - t)} E^Q \left[ e^{-\int_{t}^{t+\tau_j} r(s)ds} \cdot s(t, t + \frac{j}{M_c}) \bigg| \mathcal{F}_t \right]
\]

\[
+ \frac{s_{t, \tau_f \cdot r_c}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_c - \tau_f)} E^Q \left[ e^{-\int_{t}^{t+\tau_j} r(s)ds} \cdot s(t, \tau_f + \frac{j}{M_c}) \bigg| \mathcal{F}_t \right]
\]

\[
= \frac{s_{t, \tau_c}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_c - t)} E^Q \left[ e^{-\int_{t}^{t+\tau_j} r(s)ds} \cdot s(t, t + \frac{j}{M_c}) \bigg| \mathcal{F}_t \right]
\]

Then the forward CDS premiums, \( s_{t, \tau_f \cdot r_c} \), is

\[
= \frac{s_{t, \tau_c}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_c - t)} E^Q \left[ e^{-\int_{t}^{t+\tau_j} r(s)ds} \cdot s(t, t + \frac{j}{M_c}) \bigg| \mathcal{F}_t \right]
\]

\[
\times \frac{M_c \cdot \tau_f}{M_c \cdot \tau_f + M_c \cdot \tau_c} \frac{M_c \cdot \tau_c}{M_c \cdot \tau_f + M_c \cdot \tau_c} \frac{M_c \cdot \tau_f}{M_c \cdot \tau_f + M_c \cdot \tau_c}
\]

\[
= \frac{s_{t, \tau_c}}{M_c} \sum_{j=1}^{M_c \cdot (\tau_c - t)} E^Q \left[ e^{-\int_{t}^{t+\tau_j} r(s)ds} \cdot s(t, \tau_f + \frac{j}{M_c}) \bigg| \mathcal{F}_t \right]
\]

\[
\times \frac{M_c \cdot \tau_f}{M_c \cdot \tau_f + M_c \cdot \tau_c} \frac{M_c \cdot \tau_c}{M_c \cdot \tau_f + M_c \cdot \tau_c} \frac{M_c \cdot \tau_f}{M_c \cdot \tau_f + M_c \cdot \tau_c}
\]

\[
= \left( 2.4.4 \right)
\]

It should be noted that, in equation (2.4.4) for the forward CDS premium, \( s_{t, \tau_f \cdot r_c} \), loss given default, \( L \) is canceled out. Implied forward premiums is derived in terms of other observable spot and forward CDS premiums and default probability only. More importantly, equation (2.4.4) holds regardless of the process specification of the default arrival intensities and loss given default. Unlike the separation through the ratio of CDS premiums with
different maturity, proposed by (Pan and Singleton 2006), the assumption that loss given default is a constant, is not necessary any more.

2.4.3 Implied DDS Premiums:

No Arbitrage Restriction between CDS and DDS

In this section, I impose a cross-sectional no-arbitrage restriction between CDS and digital default swaps (DDS) and develop a new pricing framework for DDS. I refer the new pricing equation for DDS premiums as a ‘implied DDS premiums’, since the price is implied by the no-arbitrage restriction. The implied DDS premiums have a remarkable feature that they result in the separation where loss given default remains with the absence of default probability. We can directly get a measure of expected loss given default by comparing the CDS and DDS premiums. It is notable that in equation (2.3.3), DDS premiums are derived in terms of default probability, not loss given default. However, implied DDS premiums derived in this section are expressed in term of loss given default, not default probability.

Suppose that two parties make a digital default swaps contract with maturity $\tau_c$ at time $t$, with premiums $s^D_{t,\tau_c}$. The payment is made $M_c$ times a year until any one of the following events happens: the underlying reference entity defaults on its reference obligation or the maturity of the CDS contract comes. In the event of default, the seller of a protection pay the pre-specified amount, $L$, to the protection buyer. Then from equation (2.3.3),

$$
\frac{s^D_{t,\tau_c}}{M_c} = \lim_{N \to \infty} \sum_{i=1}^{N} \frac{e^{-\int_{t}^{t+\frac{i+\tau_c}{N}} r(s)ds} \cdot \left(s(t, t + \frac{i-1}{N} \tau_c) - s(t, t + \frac{i}{N} \tau_c)\right)}{\sum_{j=1}^{M_c (\tau_c-t)} \frac{e^{-\int_{t}^{t+\frac{j\tau_c}{M_c}} r(s)ds} \cdot s(t, t + \frac{j}{M_c})}{F_t}}
$$

(2.4.5)

From equation (2.3.1), a spot CDS contract with the same maturity with premiums, $s_{t,\tau_c}$, is prices as below

$$
\frac{s_{t,\tau_c}}{M_c} = \lim_{N \to \infty} \sum_{i=1}^{N} \frac{e^{-\int_{t}^{t+\frac{i+\tau_c}{N}} r(s)ds} \cdot \left(s(t, t + \frac{i-1}{N} \tau_c) - s(t, t + \frac{i}{N} \tau_c)\right)}{\sum_{j=1}^{M_c (\tau_c-t)} \frac{e^{-\int_{t}^{t+\frac{j\tau_c}{M_c}} r(s)ds} \cdot s(t, t + \frac{j}{M_c})}{F_t}}
$$

(2.4.6)
From equations (2.4.5) and (2.4.6),

\[
\lim_{W \to 00} E_i = E \cdot \left( \begin{array}{c}
\frac{\sum_{i=1}^N E^Q \left[ e^{-f_t^{t+i} \cdot r(s)ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_e}{N}) - s(t, t + \frac{i \cdot \tau_e}{N}) \right) \mid \mathcal{F}_t \right]}{\sum_{i=1}^N E^Q \left[ e^{-f_t^{t+i} \cdot r(s)ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_e}{N}) - s(t, t + \frac{i \cdot \tau_e}{N}) \right) \mid \mathcal{F}_t \right]}
\end{array} \right)
\]

(2.4.7)

When we assume that \( L \) is not correlated with short rate process,

\[
\lim_{W \to 00} E_i = \frac{E \cdot s_{t, \tau_c}}{E^Q \left[ L \mid \mathcal{F}_t \right]}
\]

(2.4.8)

Note that the implied DDS premiums are derived in terms of risk neutral expectation of loss given default. Extension to the forward DDS premium pricing is straightforward; replace subscript \( t \) in equation (2.4.8) with \( \tau_f \), the expiry of the forward contract.

### 2.4.4 Implied Bond Price:

**No Arbitrage Restriction between CDS and Bond**

In this section, I impose a cross-sectional no-arbitrage restriction between CDS and bond, and develop a new pricing framework for bond. I refer the new pricing equation for bond price as a ‘implied bond price’, since the price is implied by the no-arbitrage restriction. The implied bond price is derived in term of default probability, not loss given default.

Suppose a bond with an annualized coupon \( C \), number of payment \( M_b \) and maturity \( \tau_b \). From equation (2.3.4), bond price \( P_t \) is as below

\[
P_t = \frac{C}{M_b} \sum_{j=1}^{M_b} \frac{(\tau_c - t)}{(j + \frac{1}{M_b})} \left[ E^Q \left[ e^{-f_t^{t+j} \cdot r(s)ds} \cdot s(t, t + \frac{j}{M_b}) \mid \mathcal{F}_t \right] + E^Q \left[ e^{-f_t^{t+j} \cdot r(s)ds} \cdot s(t, \tau_c) \mid \mathcal{F}_t \right] \right] + \lim_{N \to \infty} \sum_{i=1}^N E^Q \left[ R \cdot e^{-f_t^{t+i} \cdot r(s)ds} \cdot \left( s(t, t + \frac{(i-1) \cdot \tau_b}{N}) - s(t, t + \frac{i \cdot \tau_b}{N}) \right) \mid \mathcal{F}_t \right] \]

(2.4.9)

Suppose a spot CDS contract with premiums \( s_{t, \tau_c} \), number of payment \( M_c \) and maturity
\( \tau_c \). From equation (2.3.1),

\[
\frac{s_{t, \tau_c}}{M_c} = \lim_{N \to \infty} \sum_{i=1}^{N} \mathbb{E}^Q \left[ L \cdot e^{-\int_{t}^{t+\frac{\tau_c}{N}} r(s) ds} \cdot \left( s(t, t + \frac{i-1}{N} \cdot \tau_c) - s(t, t + \frac{i}{N} \cdot \tau_c) \right) \right] \mathcal{F}_t \\
\sum_{j=1}^{M_c-(\tau_c-1)} \mathbb{E}^Q \left[ e^{-\int_{t}^{t+\frac{\tau_c}{M_c}} r(s) ds} \cdot s(t, t + \frac{j}{M_c}) \right] \mathcal{F}_t
\]

(2.4.10)

When \( M_b = M_c \) and \( \tau_b = \tau_c \),

\[
P_t = \frac{C - s_{t, \tau_c}}{M_b} \sum_{j=1}^{M_b-(\tau_c-1)} \mathbb{E}^Q \left[ e^{-\int_{t}^{t+\frac{j}{M_b}} r(s) ds} \cdot s(t, t + \frac{j}{M_b}) \right] \mathcal{F}_t + \mathbb{E}^Q \left[ e^{-\int_{t}^{\tau_c} r(s) ds} \cdot s(t, \tau_b) \right] \mathcal{F}_t
\]

\[+ \lim_{N \to \infty} \sum_{i=1}^{N} \mathbb{E}^Q \left[ e^{-\int_{t}^{t+\frac{i}{N} \cdot \tau_c} r(s) ds} \cdot \left( s(t, t + \frac{(i-1)}{N} \cdot \tau_c) - s(t, t + \frac{i}{N} \cdot \tau_c) \right) \right] \mathcal{F}_t \]

(2.4.11)

2.5 Estimation of Loss Given Default

2.5.1 Loss Given Default in Spot and Forward CDS of Sovereigns

In this section, I provide the empirical estimate of loss given default prevailing in the CDS market. I impose a cross-sectional restriction between spot and forward CDS premiums. The cross-sectional restriction between spot CDSs and forward CDSs is crucial, since it cancel out loss given default in the pricing model. For forward CDS contract, the premiums are function of default probability and loss given default as in equation (2.4.1). However, with cross-sectional restriction, forward CDS premiums are derived in terms of observable spot CDS premiums and default probability as in equation (2.4.4).

2.5.1.1 Data

Daily data from 1999 to 2005 for spot and forward CDS premiums are supplied by J.P. Morgan Securities, one of the leading players in the CDS market. Countries in the sample are Bulgaria, Brazil, Colombia, Korea, Mexico, Malaysia, Philippines, Poland, Turkey, and Venezuela. These CDS contracts are standard ISDA contracts for physical settlement for Emerging Market (EM) Sovereigns. The notional value of contract (lot size) is between five
to ten million USD for a large market like Brazil, while it is typically between two to five million for small markets. The prices hold at 'close of business.' For riskless rates, I collect data for the constant maturity rate for six-month, one-year, two-year, three-year, five-year, seven-year, and ten-year rates from the Federal Reserve.

2.5.1.2 Summary Statistics

Table 2.1 provides the basic statistic for spot CDS premiums with one, five and ten year maturities. Noticeable pattern in spot CDS premiums is that mean, median, minimum of CDS premiums increase in maturity for all countries. However, maximum of CDS premiums with short maturities are often higher than ones with long maturities, which results from the inverted CDS premiums curve during the high credit risk period. (Pan and Singleton 2006) document the positive slope of spread curve as a prominent feature of the CDS data. Spread curves for Mexico and Korea never show inversion in their study even though they find inversion for Turkey (Figure 2.3). In my sample, curves for Korea and Mexico are also inverted during the Long Term Capital Management and Russian Default crisis (Figure 2.4 and 2.5).

[Insert Table 2.1 here]

[Insert Figure 2.3 here]

[Insert Figure 2.4 here]

[Insert Figure 2.5 here]

Table 2.2 provides the basic statistic for forward CDS premiums with one, five, and seven year expiry. They all have the same maturity of ten years. Similar patterns to spot CDS premiums appear in forward CDS premiums; mean, median, minimum of CDS premiums increase in maturity for all countries. But the inversion occurs for maximum of CDS premiums, particularly with high level of CDS premiums.
One interesting movement occurs for Brazil during 2002. Spot CDS premiums reached the highest levels in the sample; one year premiums are 4,645bp and ten year premiums are 3,315bp. Around the highest premium period, the level of premiums of one year expiry and ten year maturity forward CDS also peaks. However, other forward premiums with longer expiry decreased rather than increased (Figure 2.6). This pattern implies that market believe the near term default is very likely, but conditional on no default in near term, the default likelihood is not high for longer term and it would even get lower.

[Insert Table 2.2 here]

[Insert Figure 2.6 here]

The bid-ask spreads for spot CDS with 5 year maturity range between 10 and 110 for Brazil, 10 and 60 for Korea, 10 and 90 for Mexico, 10 and 15 for Malaysia, 6 and 60 for Panama, 30 and 60 for Turkey, and 2 and 120 for Venezuela. The bid-ask spreads for contracts with other maturities are comparable in magnitude to those of the five-year contracts.

[Insert Table 2.3 here]

2.5.1.3 Estimation of Loss Given Default

I use CDS premiums with maturity $\tau_c$ to construct a combination of default probability and loss given default. I vary loss given default by 0.01 (equivalent to 1%) from 0.01 to 0.99. At each loss given default, accompanying default probability is calibrated to CDS premiums. The pricing error in forward CDS premiums with expiry $\tau_f$ and maturity $\tau_c$ given the expectation of loss given default $L = E^Q \left[ L \bigg| \mathcal{F}_t \right]$ is defined as

$$
\epsilon(t, \tau_f, \tau_c, L) = \frac{s_{\tau_f, \tau_c}}{M_c} \sum_{j=1}^{M_c} \left( \tau_c - t \right) E^Q \left[ e^{-\int_t^{\tau_f+\frac{T_c}{M_c}} r(s)ds} \cdot g(t, t + \frac{j}{M_c}) \bigg| \mathcal{F}_t, L \right] 
$$

$$
+ \frac{s_{\tau_f, \tau_f}}{M_c} \sum_{j=1}^{M_c} \left( \tau_f - t \right) E^Q \left[ e^{-\int_t^{\tau_f+\frac{T_f}{M_c}} r(s)ds} \cdot g(t, \tau_f + \frac{j}{M_c}) \bigg| \mathcal{F}_t, L \right] 
$$

(2.5.1)
Pricing error, $e(t, \tau_f, \tau_c; L)$, is obtained on the daily basis. As shown in the Figure 2.7, loss given default of 75% prevails in CDS markets for Mexico. Similar patterns are observed for other countries.

[Insert Figure 2.7 here]

Market implied expected loss given default does not show time variation in most of cases. Expectation of loss given default in the risk neutral probability space is a function of loss given default in the actual probability space and the marginal rate of substitution. No time variation of expected loss given defaults implies that the probability density of loss in the actual probability space and the relative magnitude of the pricing kernel for each loss states do not change. When the size of loss is not a significant portion of the wealth, its impacts on the pricing kernel may be small. Credit deterioration of each sovereigns under this study was not likely spread out as a regional crisis such as Asian Financial Crisis in 1997. When default event is idiosyncratic for each reference obligation, there would not be a big compensation for the risk of loss.  

Recent severe credit deteriorations of emerging market sovereigns come from political circumstances. Spike in CDS premiums in Brazil corresponds to the period when Luiz Inacio Lula da Silva, known as Lula, won presidential elections and began to lead the first left-wing government in 40 years. Venezuelan crisis also corresponds to the period of political turmoil in the country. Political instability may lead to Sovereign default. Furthermore it may adversely affect the negotiation process after the default, leading to higher likelihood for a big loss. If investors change the probability density function in that way, it leads to both

---

13 Sovereign credit crisis is likely to be idiosyncratic unless it spread over the regional crisis. (Chichilnisky and Wu 2006) show how individual risk event can be propagated and magnified into a major widespread default. They show that in an open set of economies, individual default leads to a widespread default no matter how large the economy is. The propagation of default may cause the devaluation of the assets, leading to the positive correlation between loss given default and default probability.

14 Armed forces head announced Chavez has resigned and Chavez was taken into military custody in April, 2002. A few days later, Chavez returned to office. Opposition party demanded that Chavez resign.
time variation of the loss and positive correlation with default probability.

[Insert Figure 2.8 here]

Based on the finding that loss given default are not time-varying in most cases, I calculate $RMSE(L)$, defined as below, to find out the prevailing loss given default and pricing error associated with it.

$$RMSE(L) = \sqrt{\frac{1}{\sum_{t=1}^{T} \sum_{\tau} c^2(t, \tau_f, \tau_c; L)}}$$

(2.5.2)

Table 2.4 reports the $RMSE$ for various $L$ with various maturities. Some noticeable patterns are observed. First of all, loss given default around 75% provides the smallest pricing error for most cases. Furthermore, pricing errors exhibits ‘V’ shaped pattern: they initially decrease in loss given default, reach the bottom with $L$ around 75%, and increase thereafter. Pricing errors get larger with lower level of loss given default. 25% level of loss given default generates the pricing error amounting to several multiples of bid-ask spreads of corresponding spot CDS.

[Insert Table 2.4 here]

Another feature of the result is that different level of loss given default does not induce the pricing error beyond its transaction cost for countries with good credit quality. In my sample, Korea, Malaysia and Panama exhibit relatively flat and small pricing errors comparing to the other countries. These three countries are those with best credit quality in the sample. With loss given default varying from 25% to 75%, the differences in the pricing errors are only about a few basis points, which could be negligible considering the transaction cost.

---

15 They have the smallest CDS premiums during the sample period where both spot and forward CDS premiums are available.
I also estimate loss given default using equation (2.4.4).

\[
\frac{s_{\tau_f, \tau_c} - s_{t, \tau_c}}{s_{t, \tau_c} - s_{t, \tau_f}} = \frac{\sum_{j=1}^{M_C} \tau_j - t} {\sum_{j=1}^{M_C} \tau_j - t} \mathbb{E}^Q \left[ e^{-\int_t^{t + \frac{M_C}{C}} \tau(s) ds} \cdot \mathcal{F}(t, t + \frac{M_C}{C}) \right]
\]

(2.5.3)

From the observed forward and spot CDS premiums, I extract the value of right hand side of equation (2.5.3). Loss given default implied by the value is backed out using CDS premiums data and result is provided in table (2.5)

[Insert Table 2.5 here]

Except Brazil, Turkey and Venezuela, the result show small standard deviation. It reconfirm that loss given default does not show time variation in most countries under study.

### 2.6 Conclusion

Two major components of credit risk, default probability and loss given default, can be separately identified with cross-sectional no-arbitrage restrictions. I develop various frameworks for the separation by imposing cross sectional no-arbitrage restrictions between credit instruments, including spot and forward credit default swaps, digital default swaps and bonds. These frameworks allow the pure measure of default probability not contaminated by loss given default. Particularly, the restriction between spot and forward CDS provides the separation of default probability independent of process specification of loss given default; it allows time varying loss given default and various correlation structures between loss given default and default probability. Using spot and forward CDS premiums of 10 emerging market sovereigns, I find that 75% level of loss given default prevails in the sovereign CDS markets across countries over time. Positive correlation between loss given default and default probability is found in Brazil and Venezuela during the period of political turmoils in each country. Loss given default below 75% generates negative pricing errors in forward
CDS and the magnitude of them is economically significant. These persistent negative pricing errors with mis-specified loss given default higher than the true one are consistent with the model developed. Assessing loss given default with other securities remains for further research.
Figure 2.1: CDS Premiums and Bond Prices

(a) CDS Premiums

(b) Bond Prices
Figure 2.2: Identification of $L^Q$
Figure 2.3: Spot CDS Premiums

Spot CDS premiums with Various Maturity for Turkey

(a) Spot CDS
Figure 2.4: Spot CDS Premiums

Spot CDS premiums with Various Maturity for Korea

(a) Spot CDS
Figure 2.5: Spot CDS Premiums

Spot CDS premiums with Various Maturity for Mexico
country=mx

(a) Spot CDS
Figure 2.6: Spot and Forward CDS Premiums

Spot CDS premiums with Various Maturity for Brazil

(a) Spot CDS

Forward CDS premiums with Various Maturity for Brazil

(b) Forward CDS
Figure 2.7: Forward CDS Pricing Error: Mexico

Mexico Forward Pricing Error with 0-5-10 Maturity
Figure 2.8: Optimal Loss Given Default

(a) Brazil

(b) Venezuela

(c) Mexico
Table 2.1: Basic Statistics: Spot CDS Premiums

This table provides the basic statistics of spot CDS premiums.

<table>
<thead>
<tr>
<th>country</th>
<th>Maturity</th>
<th>beg. date</th>
<th>end. date</th>
<th>obs. Num.</th>
<th>mean</th>
<th>median</th>
<th>std</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>1</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1,903</td>
<td>182.6</td>
<td>95.0</td>
<td>231.4</td>
<td>11.0</td>
<td>2,000.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1,903</td>
<td>335.8</td>
<td>320.0</td>
<td>246.8</td>
<td>22.0</td>
<td>1,782.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1,903</td>
<td>393.8</td>
<td>390.0</td>
<td>259.3</td>
<td>35.0</td>
<td>1,743.0</td>
</tr>
<tr>
<td>BR</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,117</td>
<td>584.4</td>
<td>285.0</td>
<td>866.5</td>
<td>20.0</td>
<td>4,645.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>836.7</td>
<td>634.2</td>
<td>653.4</td>
<td>120.0</td>
<td>3,960.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>835.6</td>
<td>707.3</td>
<td>516.8</td>
<td>183.0</td>
<td>3,315.0</td>
</tr>
<tr>
<td>CO</td>
<td>1</td>
<td>8/25/1998</td>
<td>2/17/2006</td>
<td>1,868</td>
<td>294.7</td>
<td>295.0</td>
<td>208.2</td>
<td>30.0</td>
<td>1,100.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8/25/1998</td>
<td>2/17/2006</td>
<td>1,868</td>
<td>573.2</td>
<td>580.0</td>
<td>219.9</td>
<td>110.0</td>
<td>1,380.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>8/25/1998</td>
<td>2/17/2006</td>
<td>1,868</td>
<td>624.9</td>
<td>635.0</td>
<td>203.2</td>
<td>173.0</td>
<td>1,380.0</td>
</tr>
<tr>
<td>KR</td>
<td>1</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,376</td>
<td>125.6</td>
<td>37.1</td>
<td>198.2</td>
<td>6.0</td>
<td>1,000.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,376</td>
<td>156.0</td>
<td>65.0</td>
<td>210.4</td>
<td>21.0</td>
<td>1,056.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,376</td>
<td>170.8</td>
<td>82.0</td>
<td>201.3</td>
<td>32.0</td>
<td>1,016.0</td>
</tr>
<tr>
<td>MX</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,070</td>
<td>116.4</td>
<td>80.0</td>
<td>161.9</td>
<td>15.0</td>
<td>1,350.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>260.1</td>
<td>221.8</td>
<td>197.1</td>
<td>52.0</td>
<td>1,423.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>315.2</td>
<td>270.0</td>
<td>203.9</td>
<td>85.0</td>
<td>1,461.0</td>
</tr>
<tr>
<td>MY</td>
<td>1</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,105</td>
<td>165.6</td>
<td>17.5</td>
<td>320.0</td>
<td>6.6</td>
<td>1,700.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,105</td>
<td>181.2</td>
<td>49.5</td>
<td>276.1</td>
<td>20.0</td>
<td>1,501.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,105</td>
<td>198.1</td>
<td>71.5</td>
<td>262.3</td>
<td>32.1</td>
<td>1,376.0</td>
</tr>
<tr>
<td>PH</td>
<td>1</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,618</td>
<td>204.0</td>
<td>189.0</td>
<td>109.8</td>
<td>42.0</td>
<td>800.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,618</td>
<td>437.1</td>
<td>440.0</td>
<td>109.9</td>
<td>196.0</td>
<td>899.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1,618</td>
<td>521.6</td>
<td>523.0</td>
<td>121.4</td>
<td>235.0</td>
<td>990.0</td>
</tr>
<tr>
<td>PL</td>
<td>1</td>
<td>9/1/1998</td>
<td>2/17/2006</td>
<td>1,862</td>
<td>22.8</td>
<td>19.0</td>
<td>22.6</td>
<td>4.0</td>
<td>160.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>57.7</td>
<td>47.0</td>
<td>42.4</td>
<td>10.0</td>
<td>293.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>78.6</td>
<td>64.0</td>
<td>52.0</td>
<td>17.0</td>
<td>339.0</td>
</tr>
<tr>
<td>TR</td>
<td>1</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,958</td>
<td>450.3</td>
<td>375.0</td>
<td>347.6</td>
<td>24.0</td>
<td>1,550.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,958</td>
<td>610.2</td>
<td>610.0</td>
<td>291.6</td>
<td>132.0</td>
<td>1,440.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1,900</td>
<td>646.3</td>
<td>650.0</td>
<td>271.0</td>
<td>-</td>
<td>1,400.0</td>
</tr>
<tr>
<td>VE</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,029</td>
<td>733.4</td>
<td>485.0</td>
<td>815.3</td>
<td>23.0</td>
<td>8,000.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>871.7</td>
<td>775.0</td>
<td>517.3</td>
<td>130.0</td>
<td>3,896.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2,126</td>
<td>894.9</td>
<td>805.0</td>
<td>464.5</td>
<td>200.0</td>
<td>3,420.0</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BG: Bulgaria, BR: Brazil, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PH: Philippines, PL: Poland, TR: Turkey, VE: Venezuela.
This table provides the basic statistics of forward CDS premiums.

<table>
<thead>
<tr>
<th>country</th>
<th>begin</th>
<th>end</th>
<th>beg. date</th>
<th>end. date</th>
<th>obs. Num.</th>
<th>mean</th>
<th>median</th>
<th>std</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>415.7</td>
<td>428.0</td>
<td>262.8</td>
<td>38.0</td>
<td>998.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>494.8</td>
<td>481.0</td>
<td>311.6</td>
<td>52.0</td>
<td>1,200.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>508.3</td>
<td>475.5</td>
<td>325.2</td>
<td>57.0</td>
<td>2,014.0</td>
</tr>
<tr>
<td>BR</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>912.1</td>
<td>829.5</td>
<td>426.3</td>
<td>208.0</td>
<td>2,555.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>813.7</td>
<td>821.0</td>
<td>234.7</td>
<td>178.0</td>
<td>1,500.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>832.2</td>
<td>838.0</td>
<td>247.4</td>
<td>227.0</td>
<td>1,546.0</td>
</tr>
<tr>
<td>CO</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>683.1</td>
<td>692.0</td>
<td>212.0</td>
<td>195.0</td>
<td>1,514.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>718.7</td>
<td>729.0</td>
<td>177.9</td>
<td>265.0</td>
<td>1,380.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>722.4</td>
<td>714.0</td>
<td>188.8</td>
<td>264.0</td>
<td>1,380.0</td>
</tr>
<tr>
<td>KR</td>
<td>1</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>83.1</td>
<td>82.0</td>
<td>33.1</td>
<td>35.0</td>
<td>224.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>100.5</td>
<td>98.0</td>
<td>36.6</td>
<td>45.0</td>
<td>244.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>109.4</td>
<td>105.0</td>
<td>39.0</td>
<td>49.0</td>
<td>250.0</td>
</tr>
<tr>
<td>MX</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>311.1</td>
<td>262.4</td>
<td>179.3</td>
<td>96.0</td>
<td>1,312.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>362.3</td>
<td>307.0</td>
<td>189.6</td>
<td>130.0</td>
<td>1,352.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>369.9</td>
<td>315.0</td>
<td>194.3</td>
<td>137.0</td>
<td>1,349.0</td>
</tr>
<tr>
<td>MY</td>
<td>1</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>104.7</td>
<td>78.0</td>
<td>57.4</td>
<td>36.0</td>
<td>225.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>129.6</td>
<td>102.5</td>
<td>64.7</td>
<td>48.0</td>
<td>271.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>10/10/2001</td>
<td>2/17/2006</td>
<td>1,052</td>
<td>141.6</td>
<td>116.0</td>
<td>71.1</td>
<td>53.0</td>
<td>312.0</td>
</tr>
<tr>
<td>PH</td>
<td>1</td>
<td>10</td>
<td>1/11/2001</td>
<td>2/17/2006</td>
<td>1,239</td>
<td>603.5</td>
<td>598.0</td>
<td>98.2</td>
<td>315.0</td>
<td>857.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>1/11/2001</td>
<td>2/17/2006</td>
<td>1,239</td>
<td>710.7</td>
<td>694.0</td>
<td>127.1</td>
<td>396.0</td>
<td>1,110.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>1/11/2001</td>
<td>2/17/2006</td>
<td>1,239</td>
<td>760.7</td>
<td>729.0</td>
<td>156.2</td>
<td>389.0</td>
<td>1,296.0</td>
</tr>
<tr>
<td>PL</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>69.8</td>
<td>66.0</td>
<td>35.5</td>
<td>19.0</td>
<td>220.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>88.2</td>
<td>81.0</td>
<td>44.1</td>
<td>26.0</td>
<td>243.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>92.7</td>
<td>84.0</td>
<td>46.0</td>
<td>28.0</td>
<td>240.0</td>
</tr>
<tr>
<td>TR</td>
<td>1</td>
<td>10</td>
<td>10/2/2000</td>
<td>2/17/2006</td>
<td>1,308</td>
<td>699.3</td>
<td>697.5</td>
<td>292.1</td>
<td>222.0</td>
<td>1,357.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>5/20/2003</td>
<td>2/17/2006</td>
<td>503</td>
<td>473.2</td>
<td>457.0</td>
<td>112.9</td>
<td>288.0</td>
<td>983.9</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>5/20/2003</td>
<td>2/17/2006</td>
<td>503</td>
<td>468.3</td>
<td>457.0</td>
<td>100.1</td>
<td>311.0</td>
<td>960.0</td>
</tr>
<tr>
<td>VE</td>
<td>1</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>954.2</td>
<td>914.0</td>
<td>391.1</td>
<td>227.0</td>
<td>2,071.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>956.2</td>
<td>884.2</td>
<td>398.9</td>
<td>304.0</td>
<td>2,750.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>11/30/1998</td>
<td>2/17/2006</td>
<td>1,772</td>
<td>940.4</td>
<td>875.5</td>
<td>406.8</td>
<td>317.0</td>
<td>2,856.0</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BG: Bulgaria, BR: Brazil, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PH: Philippines, PL: Poland, TR: Turkey, VE: Venezuela
Table 2.3: Basic Statistics: Bid Ask Spreads in Spot CDS

This table provides the basic statistics of bid ask spreads for spot CDS.

<table>
<thead>
<tr>
<th>country</th>
<th>Maturity</th>
<th>beg. date</th>
<th>end. date</th>
<th>obs. Num.</th>
<th>mean</th>
<th>median</th>
<th>std</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>1</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1903</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>BG</td>
<td>5</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1903</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>BG</td>
<td>10</td>
<td>7/6/1998</td>
<td>2/17/2006</td>
<td>1903</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>BR</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2117</td>
<td>56</td>
<td>60</td>
<td>16</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>BR</td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>51</td>
<td>50</td>
<td>16</td>
<td>10</td>
<td>110</td>
</tr>
<tr>
<td>BR</td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>44</td>
<td>40</td>
<td>17</td>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>KR</td>
<td>1</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1376</td>
<td>51</td>
<td>60</td>
<td>19</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>MX</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2070</td>
<td>46</td>
<td>50</td>
<td>15</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>MX</td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>50</td>
<td>50</td>
<td>14</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>MX</td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>44</td>
<td>40</td>
<td>18</td>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>MY</td>
<td>1</td>
<td>6/15/1998</td>
<td>2/17/2006</td>
<td>1105</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>PL</td>
<td>1</td>
<td>9/1/1998</td>
<td>2/17/2006</td>
<td>1862</td>
<td>17</td>
<td>20</td>
<td>5</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>PL</td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>27</td>
<td>20</td>
<td>16</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>PL</td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>28</td>
<td>20</td>
<td>16</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>TR</td>
<td>5</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1958</td>
<td>57</td>
<td>60</td>
<td>9</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>TR</td>
<td>10</td>
<td>4/16/1998</td>
<td>2/17/2006</td>
<td>1900</td>
<td>57</td>
<td>60</td>
<td>9</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>VE</td>
<td>1</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2029</td>
<td>65</td>
<td>70</td>
<td>13</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>VE</td>
<td>5</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>52</td>
<td>50</td>
<td>15</td>
<td>20</td>
<td>120</td>
</tr>
<tr>
<td>VE</td>
<td>10</td>
<td>7/14/1997</td>
<td>2/17/2006</td>
<td>2126</td>
<td>54</td>
<td>50</td>
<td>14</td>
<td>40</td>
<td>130</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BG: Bulgaria, BR: Brazil, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PH: Philippines, PL: Poland, TR: Turkey, VE: Venezuela
Table 2.4: RMS of Pricing Error

This table provides the root mean square (RMS) of forward CDS pricing error.

A: Spot CDS with 1 and 10 year maturity, Forward CDS with 1 year expiry and 10 year maturity

<table>
<thead>
<tr>
<th>Country</th>
<th>10</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>90</th>
<th>99</th>
</tr>
</thead>
<tbody>
<tr>
<td>bg</td>
<td>183.0</td>
<td>68.7</td>
<td>47.1</td>
<td>33.1</td>
<td>17.8</td>
<td>9.8</td>
<td>5.2</td>
<td>2.8</td>
<td>2.6</td>
<td>2.9</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>br</td>
<td>508.3</td>
<td>241.6</td>
<td>175.5</td>
<td>133.7</td>
<td>80.9</td>
<td>47.3</td>
<td>26.7</td>
<td>17.2</td>
<td>17.7</td>
<td>20.1</td>
<td>27.3</td>
<td>33.8</td>
</tr>
<tr>
<td>co</td>
<td>441.4</td>
<td>136.7</td>
<td>87.6</td>
<td>61.1</td>
<td>34.1</td>
<td>21.5</td>
<td>15.5</td>
<td>13.2</td>
<td>12.9</td>
<td>13.5</td>
<td>14.3</td>
<td></td>
</tr>
<tr>
<td>kr</td>
<td>5.0</td>
<td>4.2</td>
<td>4.2</td>
<td>4.1</td>
<td>4.1</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>mx</td>
<td>80.6</td>
<td>29.2</td>
<td>20.5</td>
<td>15.1</td>
<td>9.7</td>
<td>5.7</td>
<td>4.1</td>
<td>3.5</td>
<td>3.4</td>
<td>3.5</td>
<td>3.9</td>
<td>4.3</td>
</tr>
<tr>
<td>my</td>
<td>5.1</td>
<td>2.9</td>
<td>2.7</td>
<td>2.5</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>ph</td>
<td>229.5</td>
<td>86.3</td>
<td>60.0</td>
<td>44.1</td>
<td>28.0</td>
<td>21.5</td>
<td>19.0</td>
<td>18.3</td>
<td>18.2</td>
<td>18.3</td>
<td>18.7</td>
<td>19.1</td>
</tr>
<tr>
<td>pl</td>
<td>4.4</td>
<td>3.9</td>
<td>3.9</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>tr</td>
<td>131.1</td>
<td>60.2</td>
<td>45.0</td>
<td>35.3</td>
<td>22.3</td>
<td>15.5</td>
<td>12.1</td>
<td>10.8</td>
<td>10.6</td>
<td>10.9</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>ve</td>
<td>286.4</td>
<td>109.5</td>
<td>78.4</td>
<td>56.9</td>
<td>32.7</td>
<td>20.3</td>
<td>14.3</td>
<td>12.4</td>
<td>12.5</td>
<td>13.0</td>
<td>14.5</td>
<td>16.1</td>
</tr>
</tbody>
</table>

B: Spot CDS with 5 and 10 year maturity, Forward CDS with 5 year expiry and 10 year maturity

<table>
<thead>
<tr>
<th>Country</th>
<th>10</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>90</th>
<th>99</th>
</tr>
</thead>
<tbody>
<tr>
<td>bg</td>
<td>577.7</td>
<td>525.5</td>
<td>488.1</td>
<td>241.3</td>
<td>98.1</td>
<td>47.8</td>
<td>22.9</td>
<td>10.9</td>
<td>9.5</td>
<td>10.8</td>
<td>15.7</td>
<td>19.9</td>
</tr>
<tr>
<td>br</td>
<td>671.5</td>
<td>613.4</td>
<td>517.2</td>
<td>360.0</td>
<td>198.6</td>
<td>133.3</td>
<td>106.9</td>
<td>99.7</td>
<td>96.4</td>
<td>97.6</td>
<td>102.4</td>
<td>108.8</td>
</tr>
<tr>
<td>co</td>
<td>702.3</td>
<td>541.0</td>
<td>261.7</td>
<td>143.8</td>
<td>64.2</td>
<td>34.2</td>
<td>20.2</td>
<td>14.5</td>
<td>13.8</td>
<td>14.1</td>
<td>15.8</td>
<td>17.8</td>
</tr>
<tr>
<td>kr</td>
<td>14.4</td>
<td>6.5</td>
<td>5.6</td>
<td>5.2</td>
<td>4.8</td>
<td>4.6</td>
<td>4.6</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>mx</td>
<td>326.8</td>
<td>135.9</td>
<td>80.0</td>
<td>54.3</td>
<td>30.2</td>
<td>17.3</td>
<td>9.4</td>
<td>5.1</td>
<td>4.5</td>
<td>5.1</td>
<td>7.1</td>
<td>8.9</td>
</tr>
<tr>
<td>my</td>
<td>28.7</td>
<td>8.5</td>
<td>6.2</td>
<td>4.9</td>
<td>3.7</td>
<td>3.3</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>3.3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>ph</td>
<td>721.8</td>
<td>657.6</td>
<td>473.9</td>
<td>274.1</td>
<td>115.2</td>
<td>60.3</td>
<td>35.7</td>
<td>26.3</td>
<td>25.3</td>
<td>25.8</td>
<td>28.7</td>
<td>32.0</td>
</tr>
<tr>
<td>pl</td>
<td>15.4</td>
<td>8.0</td>
<td>6.8</td>
<td>6.3</td>
<td>5.9</td>
<td>5.9</td>
<td>5.9</td>
<td>5.9</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>tr</td>
<td>339.9</td>
<td>145.6</td>
<td>91.1</td>
<td>64.7</td>
<td>37.2</td>
<td>24.7</td>
<td>18.3</td>
<td>15.7</td>
<td>15.2</td>
<td>15.1</td>
<td>15.5</td>
<td>16.1</td>
</tr>
<tr>
<td>ve</td>
<td>499.8</td>
<td>363.4</td>
<td>215.5</td>
<td>133.5</td>
<td>69.9</td>
<td>59.1</td>
<td>61.8</td>
<td>64.8</td>
<td>65.8</td>
<td>65.3</td>
<td>64.9</td>
<td>64.6</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BG: Bulgaria, BR: Brazil, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PH: Philippines, PL: Poland, TR: Turkey, VE: Venezuela
Table 2.5: Optimal Loss Given Default

This table provides the estimation result of loss given default for each forward and CDS contract.

<table>
<thead>
<tr>
<th>Country</th>
<th>Expiry 1</th>
<th>Expiry 3</th>
<th>Expiry 5</th>
<th>Expiry 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>75.4</td>
<td>74.9</td>
<td>74.6</td>
<td>74.3</td>
</tr>
<tr>
<td></td>
<td>(2.1)</td>
<td>(2.4)</td>
<td>(2.5)</td>
<td>(3.3)</td>
</tr>
<tr>
<td>BR</td>
<td>73.9</td>
<td>73.7</td>
<td>73.5</td>
<td>73.4</td>
</tr>
<tr>
<td></td>
<td>(9.6)</td>
<td>(9.3)</td>
<td>(9.4)</td>
<td>(9.9)</td>
</tr>
<tr>
<td>CO</td>
<td>75.0</td>
<td>75.1</td>
<td>74.8</td>
<td>75.0</td>
</tr>
<tr>
<td></td>
<td>(5.2)</td>
<td>(4.4)</td>
<td>(3.4)</td>
<td>(3.1)</td>
</tr>
<tr>
<td>KR</td>
<td>76.3</td>
<td>76.1</td>
<td>76.1</td>
<td>76.2</td>
</tr>
<tr>
<td></td>
<td>(3.2)</td>
<td>(3.6)</td>
<td>(3.5)</td>
<td>(4.6)</td>
</tr>
<tr>
<td>MX</td>
<td>75.2</td>
<td>75.3</td>
<td>75.4</td>
<td>75.2</td>
</tr>
<tr>
<td></td>
<td>(2.9)</td>
<td>(3.1)</td>
<td>(3.1)</td>
<td>(4.1)</td>
</tr>
<tr>
<td>MY</td>
<td>75.6</td>
<td>75.6</td>
<td>75.6</td>
<td>75.6</td>
</tr>
<tr>
<td></td>
<td>(2.1)</td>
<td>(2.0)</td>
<td>(2.3)</td>
<td>(2.4)</td>
</tr>
<tr>
<td>PH</td>
<td>74.9</td>
<td>74.9</td>
<td>74.3</td>
<td>73.1</td>
</tr>
<tr>
<td></td>
<td>(8.7)</td>
<td>(6.9)</td>
<td>(5.7)</td>
<td>(6.1)</td>
</tr>
<tr>
<td>PL</td>
<td>74.7</td>
<td>74.8</td>
<td>75.0</td>
<td>75.1</td>
</tr>
<tr>
<td></td>
<td>(5.2)</td>
<td>(5.4)</td>
<td>(5.5)</td>
<td>(5.5)</td>
</tr>
<tr>
<td>TR</td>
<td>74.6</td>
<td>73.5</td>
<td>74.3</td>
<td>74.2</td>
</tr>
<tr>
<td></td>
<td>(10.1)</td>
<td>(13.5)</td>
<td>(11.1)</td>
<td>(11.0)</td>
</tr>
<tr>
<td>VE</td>
<td>73.8</td>
<td>71.0</td>
<td>69.5</td>
<td>69.2</td>
</tr>
<tr>
<td></td>
<td>(10.3)</td>
<td>(13.8)</td>
<td>(15.8)</td>
<td>(15.8)</td>
</tr>
</tbody>
</table>

Acronyms for each country are as follows. BG: Bulgaria, BR: Brazil, CO: Colombia, KR: Korea, MX: Mexico, MY: Malaysia, PH: Philippines, PL: Poland, TR: Turkey, VE: Venezuela.
Bibliography


