ROBECO
The Investment Engineers

Emerging Sovereign Quant Strategy

Master Thesis

Erwin Hazeveld

vrije Universiteit amsterdam

Master Thesis

Emerging Sovereign Quant Strategy

Author:	Erwin Hazeveld
Student Number:	1777785
Master Program:	Business Mathematics and Informatics
Supervisors Robeco:	Johan Duyvesteyn
	Martin Martens
Supervisor VU:	Sandjai Bhulai

July 2010

Robeco
Quantitative Strategies
Coolsingel 120
3011 AG Rotterdam

Vrije Universiteit Amsterdam
Faculteit der Exacte Wetenschappen
De Boelelaan 1081a
1081 HV Amsterdam

Preface

The Master program Business Mathematics and Informatics of the VU Amsterdam is concluded by an external Master project. I had the pleasure to complete my Master program with the “Super Quant” internship of the Quantitative Strategies department of Robeco. The results of this internship are documented in this thesis.

The topic of my research is sovereign credit risk and this type of financial risk has become very current during my internship. It contributed to an animated period where I have learned much and met a lot of interesting people. There are so many aspects of sovereign credit risk that are interesting to research, but I had to focus on only one: the new sovereign CCA model by Gray et al. (2007) to measure sovereign credit risk. It was a good choice because although this one model delivered me plenty of work it gave me a valuable insight in the topic of sovereign credit risk. My master thesis has greatly benefited from my additional insight in sovereign credit risk.

I conclude this preface with a special word of thanks to the supervisors of my Master project. First of all, I want to thank Sandjai Bhulai for his positive feedback that helped me to improve this thesis. Second, I want to thank Johan Duyvesteyn and Martin Martens for the opportunity that they gave me to finish my Master program at Robeco. Like all colleagues of Quantitative Strategies they were always very helpful and they provided me with the necessary professional input for my research. I think that I could not have wished for a better coach than Johan. Finally, I want to thank my family and friends who have been a great motivation for me because they have always showed interest in the progress of my study.

Erwin Hazeveld
July 2010

Abstract

Gray et al. (2007) propose a new model to measure, analyze, and manage sovereign credit risk based on the theory of contingent claims analysis. We have thoroughly investigated this new model to analyze whether a profitable trading strategy is possible that would benefit active asset managers like Robeco. We find that the model is best suited for emerging markets with a considerable amount of debt denominated in a hard foreign currency (like the US Dollar and the Euro). We give a detailed description to implement the model with Bloomberg data and publicly available data. We use a general, up-to-date, quantitative approach that we apply with daily data to eight emerging countries, also for the recent years. We confirm the tight relationship with the risk measure distance to distress and actual CDS data of the eight countries. The most important input factor of the model is the FX volatility (the volatility of the local currency and US Dollar exchange rate). We test trading strategies with 5 year CDS contracts that are based on the distance to distress and the FX volatility. The trading strategy that is based on the FX volatility is the most successful and has a statistical significant positive average return. We find that the FX volatility has predictive power on the future CDS spread which can be exploited in successful trading strategies that profit from the spillover effect between the currency market and the CDS market.

Table of contents

1 INTRODUCTION 1

1.1 ROBECO 1
1.2 QUANTITATIVE STRATEGIES 1
1.3 RESEARCH TOPIC 2
1.4 RESEARCH QUESTIONS 3
1.5 STRUCTURE 3

2 SOVEREIGN CREDIT RISK 5

2.1 DEFINITION 5
2.2 FROM HISTORY TO PRESENT 7
2.3 FIXED INCOME MARKETS 10

3 SOVEREIGN CONTINGENT CLAIMS ANALYSIS 15

3.1 THE CCA MODEL 15
3.2 BLACK-SCHOLES OPTION MODEL 16
3.3 CONTINGENT CLAIMS PRICING 21
3.4 EXTENSION OF CCA TO SOVEREIGNS 24
3.5 RISK MEASURES 27

4 CASE STUDY BRAZIL 31

4.1 DATA PREPARATION 32
4.2 SOFTWARE APPLICATION 38
4.3 RESULTS 40
4.4 MODEL DISCUSSION 44
4.5 TRADING OPPORTUNITIES 49
4.6 CONCLUSION 53

5 TRADING STRATEGIES 55

5.1 UNIVERSE 55
5.2 COUNTRY ALLOCATION 62
5.3 RESULTS 67
5.4 DISCUSSION 74
5.5 CONCLUSION 78

6 CONCLUSIONS 81

7 FOLLOW UP 85

LITERATURE 87

APPENDIX A - ABBREVIATIONS 89

APPENDIX B - BOND DATA 91

APPENDIX C - FX DATA 97

APPENDIX D - CDS DATA 99

APPENDIX E - CONTEMPORARY CORRELATIONS AND T-VALUES 101

APPENDIX F - LEAD - LAG CORRELATIONS AND T-VALUES 103

Chapter 1

Introduction

In this chapter we provide background information on Robeco and the department Quantitative Strategies. Subsequently, the research topic and its added value for Robeco, the research questions, and the purpose of the Master project are described. Finally, the structure of this thesis is described.

1.1 Robeco

Robeco is an asset manager established in Rotterdam (the Netherlands) in 1929 as the "Rotterdamsche Beleggings Consortium" (Rotterdam Investment Consortium). Robeco successfully managed to grow since its founding and in the mid 1970s it became the largest supplier of investment funds in the Netherlands as well as on the European continent. Since 1990, Robeco closely cooperated with the Dutch Rabobank which ultimately led to the takeover of Robeco by the Rabobank in 2001. After the takeover Robeco maintained its own independent investment policy within the Rabobank concern.

Robeco offers active investment products and services to their clients who consist of 50% institutional clients (e.g. pension funds, central banks) and 50% retail clients. As of 31 December 2009, Robeco has over 1600 employees and manages around 135 billion Euros in assets. Robeco has investment teams at the head office in Rotterdam and in Boston, Hong Kong, New York, Paris, and Zurich. Institutional and professional clients are served at offices located in Bahrain, Belgium, China, France, Germany, Hong Kong, Japan, Luxemburg, the Netherlands, Singapore, South Korea, Spain, Switzerland, and the United States. Robeco has a banking license in the Netherlands and France from where they can sell their products directly to retail clients.

1.2 Quantitative Strategies

The analysis that is done by the department Quantitative Strategies plays an important role in Robeco's investment decisions. The department Quantitative Strategies has an advising role in Robeco's investment decisions and the department also develops models that automatically make investment decisions. Robeco holds over 15 billion Euro in portfolios that are completely driven by quantitative models. The key activities of Quantitative Strategies are research and development of quantitative forecasting models, design and development of quantitative investment strategies, and knowledge sharing with clients. Many of the 20 employees at Quantitative Strategies are PhD or CFA charter holder. Quantitative Strategies applications are both in developed and emerging markets on equity, fixed income assets (credits and governments), and currencies. The researchers of the Quantitative Strategies department are specialized in one of these different asset classes and they fruitfully cooperate as one team which is extraordinary in the field of asset management.

Quantitative models are developed with use of thoroughly checked data of high quality. The models consist of variables that make intuitive economic sense and that are combined to give more consistent results. The models are developed in consultation with Robeco's portfolio managers. The quantitative models are not made more complicated than necessary, must succeed an out-of-sample test, and are validated with conservative assumptions. The ultimate application of a quantitative model is a quantitative strategy which is the integration of the model within a portfolio construction algorithm or a risk management model. One example of such a quantitative strategy for the fixed income asset class is the duration model that drives "Lux-o-rente" which is one of the largest Robeco funds.

1.3 Research topic

Robeco is interested in new quantitative model(s) to measure and analyze the credit risk of sovereign countries. Since the financial crisis of 2008-2009 sovereign credit risk has become more and more important and does not only apply to emerging markets but to developed markets as well. A thorough analysis of the creditworthiness of multiple sovereigns could be a successful tool in the investment decisions of Robeco. The analysis could be used in different trading strategies for a single country or between countries by making use of investment instruments like credit default swaps (CDS) and credit spreads on bonds that are issued by sovereign countries, foreign exchange (FX) options, and FX spot and forwards contracts. A promising new model to make such an analysis is recently proposed by Gray, Merton and Bodie (2007).

Gray et al. propose a new model to measure, analyze, and manage sovereign credit risk based on the theory of contingent claims analysis (CCA). The model uses the structure and market value of the liabilities of a sovereign combined with information on interest rates and foreign exchange rates as input to find several risk measures of the sovereign. With the new model one should be able to more accurately and timely forecast the nonlinear behavior of bond prices and credit spreads than traditional models like the debt-to-GDP ratio. Moreover, Gray et al. claim that the risk measures of the model have a very tight relationship with actual CDS spread data. The International Monetary Fund (IMF) and several central banks have successfully adopted the new model by Gray et al. to manage sovereign credit risk. However, little is known about applications of the model to trading strategies.

1.4 Research questions

Further research has to be done on developing successful trading strategies based on the model. Before we can develop such a strategy the model has to be studied in more detail to obtain more practical intuition and a better understanding of the advantages, the disadvantages, and the dynamics of the model. Although literature shows only applications of the model to emerging countries and not to developed countries it is not stated if the model can only be applied to emerging countries. By studying the model in more detail we can evaluate whether the model is applicable to developed countries or not. Furthermore, research has to be done on the practical implementation of the model to find out if we can obtain the same tight relationship with actual CDS data when we use the input data that is available at Robeco. This leads us to the following three research questions concerning the sovereign CCA model:

1. To what extent is the model applicable to developed countries?
2. How can we implement the model and confirm the tight relationship with actual CDS data?
3. How can we develop a successful trading strategy based on the model?

The purpose of the Master project is to investigate the model more specifically and to analyze whether a profitable trading strategy is possible that would benefit asset managers like Robeco.

1.5 Structure

This thesis answers the research questions of the previous section and discusses sovereign credit risk and the new sovereign CCA model by Gray et al. It does so by first providing the reader information on the background, the history, and the application of sovereign credit risk in Chapter 2. Chapter 3 explains the theory of the original CCA model on corporations and which adjustments Gray et al. made on the CCA model in order to make the theory applicable to sovereigns. Here, we also describe whether the new model is applicable to developed markets and, if so, what adjustments are needed. Chapter 4 shows a practical implementation of the sovereign CCA model for Brazil. In this chapter we compare the results that we found with the results from examples in literature to see if we could obtain the same tight relationship with actual CDS data. We also select variables of the sovereign CCA model that are promising to use in trading strategies. In Chapter 5 we test trading strategies that are based on the model for multiple countries. Finally, Chapter 6 and 7 show the conclusions of the research and the follow up ideas, respectively.

Chapter 2

Sovereign Credit Risk

In this chapter we put the new model by Gray et al. (2007) into context by providing background information on sovereign credit risk. First, we give a definition of credit risk and point out the difference between corporate and sovereign credit risk. Second, we put sovereign credit risk in a historical context and address the sovereign credit crisis in southern Europe that started end 2009. Finally, we describe the application of sovereign credit risk in fixed income markets. Here, we also discuss the difficulties of measuring and analyzing sovereign credit risk and give a brief overview of the different models that are used for this purpose.

2.1 Definition

Financial institutions (FIs) like banks, insurance companies, pension funds, and investment funds can invest their capital in different asset classes. They can namely choose to invest in a wide variety of assets (or derivatives of assets) from corporations, households and governments that need capital to fund their projects. The financial institutions thus provide this capital by lending it to the corporate-, household-, and public sector. When making their investment decisions, financial institutions basically weight the expected return on the investment with the financial risk of the investment. Table 2.1 shows various important types of financial risk and their definitions quoted from Saunders and Cornett (2008).

Table 2.1 Definition of various financial risks.

Type	Definition
Interest rate risk	The risk incurred by an FI when the maturities of its assets and liabilities are mismatched.
Market risk	The risk incurred from assets and liabilities in an FI's trading book due to changes in interest rates, exchange rates, and other prices.
Credit risk	The risk that promised cash flows from loans and securities held by FIs may not be paid in full.
Off-balance-sheet risk	The risk incurred by an FI as the result of activities related to its contingent assets and liabilities held off the balance sheet.
Foreign exchange risk	The risk that exchange rate changes can affect the value of an FI's assets and liabilities denominated in nondomestic currencies.
Country or sovereign risk	The risk that repayments to foreign lenders or investors may be interrupted because of restrictions, intervention, or interference from foreign governments.
Technology risk	The risk incurred by an FI when its technological investments do not produce anticipated cost savings.
Operational risk	The risk that existing technology, auditing, monitoring, and other support systems may malfunction or break down.
Liquidity risk	The risk that a sudden surge in liability withdrawals may require an FI to liquidate assets in a very short period of time and at less than fair market prices.
Insolvency risk	The risk that an FI may not have enough capital to offset sudden decline in the value of its assets.

Source: Saunders and Cornett (2008).

The financial risk we focus on in this research project is sovereign credit risk, which is a type of credit risk that applies to sovereign countries. Sovereign credit risk applies when investors lend capital to a country's government. Commonly, this is done by buying bonds that are issued by governments. Bonds are debt contracts which oblige the issuer to pay interest and the principal at given date(s) to the holder of the bond. Sovereign credit risk is thus the risk that the government of a sovereign country defaults on paying the full amount of the debt contract at the contractually defined date(s).

Governments of countries are not the only issuers of bonds at financial markets. Also corporations issue bonds and the credit risk that applies to these bonds is obviously called corporate credit risk. But there are some important differences between sovereign credit risk and corporate credit risk that follow from the different properties of countries and corporations. These differences are pointed out in the next paragraph and are worth to mention because they make sovereign credit risk less tangible than corporate credit risk.

First of all, there are many more recorded defaults of corporations than countries simply due to the scale difference. Of course, there are many more corporations that possibly could default than countries. Second, for technical reasons the consequences of default on payment differ for corporations and countries. Ultimately, creditors that are harmed by a defaulting corporation could legally request for a bankruptcy of the corporation in court. There is no official organization that could administer the bankruptcy of a country. Finally, in contrary to corporations most countries have the possibility to create money instead of defaulting on payment by raising taxes, cutting expenditures, or expanding the debt stock.

The consequences of a country that defaults on payment are in the field of debt restructuring and difficulties in acquiring new credits. But why would a country default on paying their debt in a stress situation when they could print money to make the payment? The answer to this question is that there are limits and drawbacks on printing money because in the end someone has to carry the costs. When a country pays debt by printing new money instead of defaulting on a debt payment this could lead to a devaluation of the country's currency. Therefore, we could argue that the potential loss due to default is shifted away from the investor and spread to everyone with capital denominated in the currency of that country. In turn, having a weakening currency could make it harder and more costly for countries to borrow new capital to fund projects. The decision of a country to default on payment is a comparison between the benefits and the costs of a default.

2.2 From History to Present

Although the great majority of recorded defaults concern corporate defaults there are still many examples of sovereign defaults through history. Sturzenegger and Zettelmeyer (2007) give a historical overview of sovereign defaults and debt restructurings. Information from their research is summarized in the following paragraphs to point out the characteristics, causes and consequences of sovereign defaults.

Since countries borrow money there have been sovereign debt crises and defaults. This goes all the way back to the fourth century B.C., when the first recorded sovereign default took place in ancient Greece. But it was only in the nineteenth century when the number of sovereign defaults heavily increased due to the expanding debt lending between countries, the independence of former European colonies, and the development of financial markets. Figure 2.1 shows the hundreds of sovereign defaults that followed ever since.

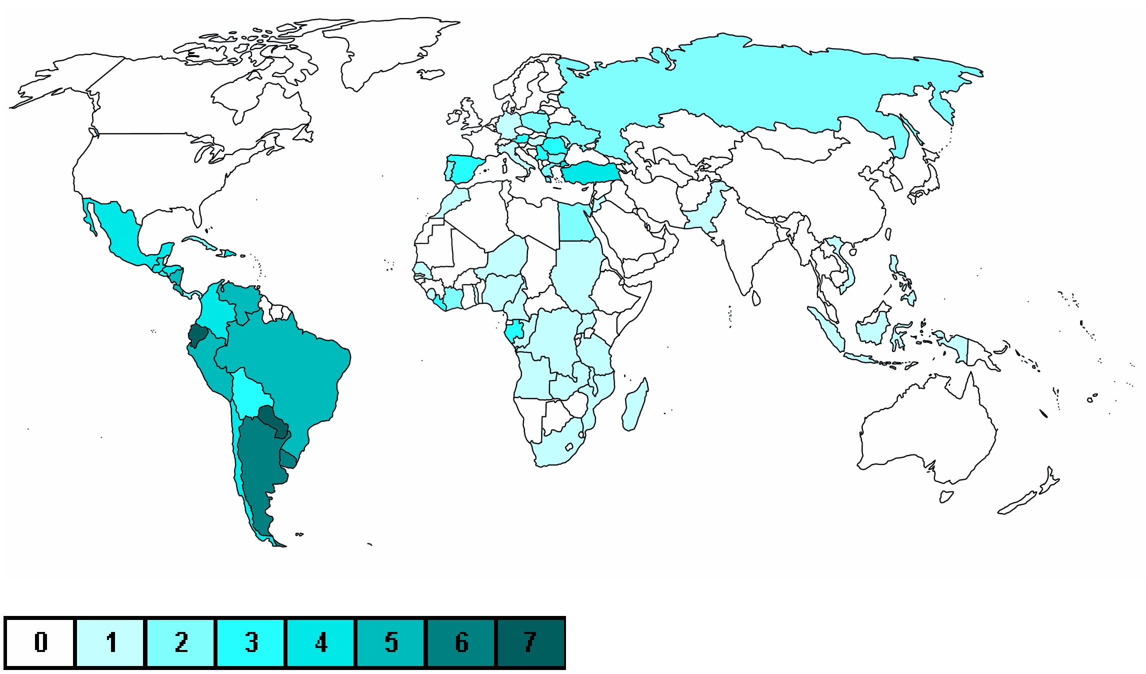


Figure 2.1 World map indicating the number of recorded sovereign defaults and debt restructurings since the nineteenth century (Sturzenegger and Zettelmeyer, 2007).

Most of the sovereign defaults are caused by economic shocks, only a few are caused by wars or revolutions (these defaults are left out of Figure 2.1). Figure 2.1 shows that most countries in Latin America repeatedly suffered from default and that there are many countries and regions across the world that never defaulted. The sovereign defaults could also be clustered by period. Since the Second World War sovereign defaults never occurred in developed countries. Instead, sovereign defaults mainly occurred in developing countries with emerging markets (countries with rapidly growing industries). Table 2.2 distinguishes seven time periods since the nineteenth century when sovereign defaults occurred.

Table 2.2 Time clusters when sovereign defaults and debt restructurings occurred, 1824-2004.

Period	Countries
1824-1834	Greece, Portugal, Spain, Latin American countries.
1867-1882	Austria, Spain, Turkey, Latin American countries, Egypt, Liberia.
1890-1900	Greece, Portugal, Yugoslavia, Latin American countries.
1911-1921	Some European countries, Latin American countries, Liberia.
1931-1940	European countries, Latin American countries.
1976-1989	Poland, Romania, Yugoslavia, Turkey, Latin American countries, African countries, Jordan, Philippines, Pakistan, Vietnam.
1998-2004	Moldova, Russia, Ukraine, some Latin American countries including Argentina, Côte d'Ivoire, Gabon, Seychelles, Indonesia, Pakistan.

Source: Sturzenegger and Zettelmeyer (2008).

Combined with the lending booms that preceded these time clusters with several sovereign defaults, the time periods are called boom-bust cycles. Lending booms start by political or economic changes in debtor countries leading to new investment opportunities. Also favorable financial changes like economic growth and improved liquidity in the creditor countries have an important role in initiating a lending boom. All lending booms have resulted in busts in which a subset of the debtor countries defaulted. Causes of these busts are usually a decline in the terms of trade of debtor countries, a recession in the major creditor countries, an increase of international borrowing costs, or an internationally transmitted crisis in a major debtor country.

Most of the sovereign defaults are resolved by negotiations for a settlement between the creditors and the debtor country on a debt restructuring deal. First, negotiations were done by ad hoc committees but they were inefficient for creditors due to inadequate experience and specialization. In 1868, the British Corporation of Foreign Bondholders (CFB) was established and they were able to negotiate settlements with the most important defaulting countries up to and including the sovereign defaults of the great depression of the 1930s. The power of the CFB was based on the fact that they determined which countries were officially on a default list and therefore were refused by the London stock exchange to issue new bonds.

When the bust of the 1970s started the CFB was no longer active and instead a Bank Advisory Committee (BAC) coordinated the negotiation process. BACs consisted of a syndicate of around fifteen commercial banks and like the CFB they derived their power from blocking new lending to a defaulted debtor country prior to a settlement. BACs still played a role in the negotiations after the default of Russia and Pakistan in the last bust period. However, all other sovereign defaults of 1998-2004 concerned mostly non-bank creditors and the negotiations for debt restructuring were not coordinated by an official committee. Surprisingly, these negotiations went relatively quick (except for the debt restructuring of Argentina) due to the introduction of take-it-or-leave-it offers where existing old bonds were replaced by new bonds of lower value. The strength of these exchange offers, which were designed with the help of an investment bank, is that they were contingent on the acceptance of a great majority of creditors.

From the 1820s up and till the 1930s debt restructuring agreements were typically on the capitalization of interest payment arrears, maturity extension, or reduction of interest or principal payment. Also, in this time frame settlements could involve control over property or tax incomes. After the Second World War this country revenue control by the creditor disappeared, but the idea remained in the debt-equity swaps of the 1980s. In 1989, an important type of debt restructuring was introduced by the United States with the Brady Plan. The Brady deals concern a debt reduction in change of an adjustment program monitored by the International Monetary Fund (IMF). The debt restructuring of 1998-2004 is in line with the Brady deals and offered a debt reduction through a reduction in interest or principal payments, or maturity extension.

Governments of creditor countries rarely intervene in negotiations between creditors and defaulted sovereign debtors. And if these governments intervene their role is limited to diplomatic pressure. In contrast, international organizations and in particular the IMF plays an important role in settlements between creditors and sovereign debtors. The IMF was founded at the end of the Second World War to rebuild national economies. The IMF provides crisis lending to countries that have difficulties in servicing their debt. Moreover, the IMF helps countries with a program to improve the management of their economies.

Currently in 2010, we could be just at the beginning of a new bust period in which sovereign defaults will take place. After a lending-boom that took place to recover from the financial crisis of 2008-2009, which include funding capital for the bailout of large financial institutions, governments are burdened with a large debt stock. For the first time since the Second World War the main countries in stress are not emerging countries but developed countries. Iceland acquired a crisis loan from the IMF after the default of the three largest banks of Iceland (Glitnir, Landsbanki and Kaupthing). Spain, Portugal, and Ireland have large deficits in their national budgets and the creditworthiness of these countries is doubted. The most urgent troubles are in Greece: their large budget deficit combined with large debt stock led to crisis lending from the IMF combined with guarantees from the European Union.

2.3 Fixed Income Markets

Governments issue bonds on the fixed income market (also called bond, credit, or debt market). Bonds can be directly purchased at issuance from the issuer and can also be traded on the secondary market at several trading locations. In this section we describe various features of bonds and the difficulties in the pricing and rating of bonds. The most important source of this section is the well-known book by Fabozzi (2007) on fixed income markets.

As mentioned before in this chapter, bonds are debt contracts which oblige the issuer to pay interest and the principal at given date(s) to the holder of the bond. From here, we immediately derive some important features of the contract. First of all, the time over which the issuer has promised to meet the contract is called the maturity of the bond (also referred to as term to maturity or term). Second, the amount of money that the issuer is obliged to pay at the bondholder at maturity is called the principal value (also referred to as the nominal, redemption, maturity, par, or face value). Third, the interest rate that the issuer has agreed to pay each year is called the coupon rate (also referred to as nominal rate). Most bonds have either a predetermined fixed coupon rate or a floating coupon rate. In the latter case, the coupon is reset periodically based on a reference rate. In the United States, interest is usually paid semiannually. It is common practice that short term bonds do not pay interest; these are called zero coupon bonds. Finally, the issuer could either be the federal government and its agencies (where we focus on), municipal governments, or corporations.

With the basic characteristics of a bond we can find the relationship between the price and the required yield of the bond by accumulating the present value of the expected cash flows of the bond (1):

$$P = \frac{C}{1+r} + \frac{C}{(1+r)^2} + \ldots + \frac{C}{(1+r)^n} + \frac{F}{(1+r)^n},$$
$$P = \sum_{t=1}^{n} \frac{C}{(1+r)^t} + \frac{F}{(1+r)^n}, \qquad (1)$$

where P is the price of the bond, n is the number of periods, C is the coupon amount per period, r is the required yield, F is the face value, and t is the time. Table 2.3 shows an example of calculating the bond price of a 5 year 10% coupon bond with a face value of 1000.

Table 2.3 Bond price of a 5 year 10% coupon bond with face value 1000; the required yield is set at 5% (a) and 10% (b), respectively.

t	CF	PV
1	100	95.24
2	100	90.70
3	100	86.38
4	100	82.27
5	1100	861.88
Bond Price		**1216.47**

(a)

t	CF	PV
1	100	90.91
2	100	82.64
3	100	75.13
4	100	68.30
5	1100	683.01
Bond Price		**1000.00**

(b)

For a bond with a fixed coupon rate all variables are known except the required yield of the bond. The required yield of the bond is equal to the yield that an investor gets in the market for bonds with comparable features and risk. As we can see in Table 2.3 the bond price is calculated for different yields. If the required yield equals the coupon rate as in Table 2.3 (b) the bond price equals the face value of the bond. A key property of bonds is that the price changes are opposite to the yield changes of the bond: the higher the yield, the lower the price (and vice versa). Figure 2.2 shows the nonlinear price-yield relationship of bonds with a fixed coupon rate.

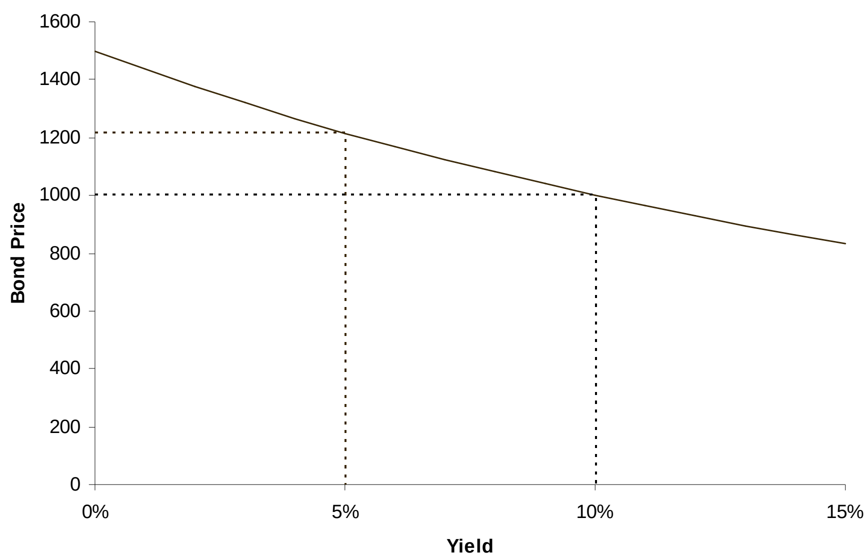


Figure 2.2 Price-yield relationship of a 5 year 10% coupon bond with face value 1000.

If the required yield of a bond rises above the coupon rate in the fixed income market, the price will fall so that an investor that wants to purchase the bond still obtains the market yield. Otherwise, the investor would not buy the bond because the bond price is too high compared to similar bonds. Because there will be no demand for this particular bond the price will automatically fall. Simultaneously, if the required yield decreases the bond price will increase. This is how a bond could be priced below face value (at a discount) or above face value (at a premium).

For bonds with a floating coupon rate the value of the future cash flows is uncertain. This is because the coupon rate is based at a reference rate, which will change over time, plus a quoted margin or spread. Widely used reference rates are the London Interbank Offered Rate (LIBOR), the Euro Interbank Offered Rate (EURIBOR), and the United States federal fund rate. In general, the price of bonds with a floating coupon rate will trade close to the face value of the bond if the spread upon the reference rate that the market requires does not change.

The duration D is a measure of the sensitivity of a bond to changes in the required yield. We can use formula (2) to calculate the duration of a bond; this is called the Macaulay duration:

$$D = \frac{\sum_{t=1}^{n} \frac{C * t}{(1+r)^t} + \frac{F * n}{(1+r)^n}}{P}, \tag{2}$$

where P is the price of the bond, n is the number of periods, C is the coupon amount per period, r is the required yield, F is the face value, and t is the time. The change in price of a bond due to a change in the required yield of the bond is linearly estimated by minus the duration times the change in the required yield. In this estimation we use the modified duration D^* which is the duration adjusted by the required yield (3):

$$D^* = \frac{D}{1+r} \tag{3}$$

The price of a bond changes over time because of changes in the required yield or simply because a discount or premium bond is moving towards maturity. Basically, the required yield exists of two components: a base interest rate and a spread. The spread is the risk premium that an investor demands for the credit risk of the bond. We are particularly interested in determining the fair value of the height of this spread. However, first the base interest rate needs some introduction. The base interest is the minimum interest rate that an investor wants to receive for bonds that have no credit risk. Examples of bonds that are perceived of having no credit risk are bonds that are issued and backed by the government of economic developed countries and that have a high liquid bond market such as the United States and Germany.

In our example of Table 2.3 we discounted all cash flows of the bond with the same yield. However, in the market we observe different yields for comparable bonds with different maturities. For example, comparable Treasury securities of the United States with different maturities could have different yields. The graphical depiction of this relationship is called the yield curve. Three different shapes have been observed for the yield curve in the market: upward sloping (normal), downward sloping (inverted) and flat. From this we derive that in fact the base interest rate component of the required yield is unique for every single cash flow. Therefore, all cash flows should be discounted with its corresponding spot rate found on the spot rate curve. We could derive a theoretical spot rate curve from Treasury bills, which are actually traded short term zero coupon bonds, and other longer term Treasury securities. The theoretical spot rate curve graphically represents the term structure of interest rates.

The spread component of the required yield depends on the creditworthiness of the issuer of the bond. Credit rating agencies give an indication of the creditworthiness of sovereigns. The three largest commercial rating agencies are Moody's, Standard & Poor's, and Fitch Ratings. These rating agencies divide the bond issuers into notches depending on the level of creditworthiness. The first four classes (triple A, double A, single A, and triple B) are considered as investment-grade bonds. Moody's (2008) state that countries with these ratings have the capacity to repay their debts even if confronted with a severe economic shock. All lower classes are considered as noninvestment-grade bonds and are called high-yield bonds or junk bonds. Countries with these ratings are potentially not able to repay their debts in case of an economic shock. Table 2.4 shows the investment-grade and noninvestment-grade bond ratings.

Table 2.4 Credit Ratings by Moody's, Standard & Poor's, and Fitch Ratings.

Moody's	S&P and Fitch	Quality Description	Grade
Aaa	AAA	Prime	Investment-grade
Aa1	AA+	High	
Aa2	AA	High	
Aa3	AA-	High	
A1	A+	Upper medium	
A2	A	Upper medium	
A3	A-	Upper medium	
Baa1	BBB+	Lower medium	
Baa2	BBB	Lower medium	
Baa3	BBB-	Lower medium	
Ba1	BB+	Low, speculative	Noninvestment-grade
Ba2	BB	Low, speculative	
Ba3	BB-	Low, speculative	
B1	B+	Highly speculative	
B2	B	Highly speculative	
B3	B-	Highly speculative	

It is possible that countries have different ratings for bonds denominated in a foreign currency and bonds denominated in the domestic currency of the country, respectively. Some emerging countries have issued bonds in a foreign currency (like the US Dollar, the Euro, or the Japanese Yen). These countries gain access to additional sources to finance the government because the market for bonds denominated in their domestic currency is too small to cover their demand for capital. In history, some emerging countries showed different behavior in servicing these two types of bonds and therefore the ratings for the local currency bonds and the foreign currency bonds sometimes differ with in general higher ratings for the local currency bonds (Moody's, 2008).

Most FIs use the credit ratings of the commercial rating agencies in their analysis of the creditworthiness of countries. However, large FIs and investment funds do not solely rely on the credit ratings and have there own credit analysis department. There are multiple reasons why credit ratings are insufficient to determine a fair value for the spread of a bond. First, ratings are discrete while the spread is continuous. Second, the ratings are updated infrequently and tend to have a time lag. Finally, there is no clear maturity for a credit rating while the credit risk logically increases for longer term bonds. Moreover, Hull and White (2010) raise doubts about the models used by the rating agencies by stating that the high ratings of the Collateralized Debt Obligations (CDOs) cannot be justified. The global trade in CDOs transferred credit risk of US subprime mortgages to the balance sheets of FIs all over the world contributing to the financial crisis of 2008-2009. This led to criticism of the independence of the three leading rating agencies which are all commercial US corporations.

Credit risk models that are used in the analysis of the creditworthiness of countries are relatively new. Until recent, only macroeconomic variables like the debt-to-GDP ratio were taken into account. But as emerging markets become more transparent and liquid and nowadays credit risk also applies to bond markets that are considered to be developed, more research is done in developing credit risk models for sovereigns like the sovereign CCA model that we analyze in our research project. An important input for the research on sovereign credit risk models is the work that is already achieved in the field of corporate credit risk. There are several credit risk models that can be used in the analysis of corporate credit risk. These models find a fair value of the spread by estimating the default probability of the issuer of the bond. Credit risk models can be divided into structural models and reduced form models. Structural models look at the corporate financial structure to find default probabilities. The CCA model of Merton (1974) and the KMV model adapted by Moody's and described in detail by Crosbie and Bohn (2003) are examples of structural models which are discussed in Chapter 3. Reduced form models like the models of Jarrow and Turnbull (1995) and Duffie and Singleton (1999) look at exogenous variables to find default probabilities of corporations.

With the use of credit risk models we can find a fair value of spread that is incorporated in the required yield of a bond. But we can also apply the output of credit risk models directly to credit derivatives without adjusting for the term structure of interest rates. Credit derivatives are products that provide protection against credit risk. The Credit Default Swap (CDS) is by far the most used credit derivative. By buying a CDS, the holder of a bond can shift its credit exposure to the seller of the CDS. It is also possible to buy a CDS without holding the underlying bond and thus speculating on a default of the issuer of the bond. The CDS buyer pays a premium equal to the market value of the credit risk to the CDS seller. In turn, in case of default, the CDS seller is obliged to pay the face value of the underlying bond (this could either be a physical delivery or cash delivery depending on the contract). CDS contracts can be on single bonds or on a basket of bonds and have different maturities. The most liquid CDS market is the 5 year CDS market.

Chapter 3

Sovereign Contingent Claims Analysis

The sovereign CCA model of Gray et al. (2007) is an application of a structural credit risk model to the relatively new field of sovereign credit risk. The sovereign CCA model is an extension of the CCA model of Merton (1974). This model is widely used and a proven approach to measure the credit risk of corporations. Because the theory of CCA is originally invented to analyze the capital structure of corporations, the theory is best explained on corporations before elaborating CCA on countries. That is why this chapter first describes the CCA model applied to the analysis and measurement of the credit risk of a corporation. Finally, we describe the extension by Gray et al. to make CCA suitable for the measurement and analysis of sovereign credit risk.

3.1 The CCA Model

Gapen, Gray, Lim, and Xiao (2004) define a contingent claim as “any asset whose future payoff depends on the outcome of an uncertain event”. European call and put options are examples of contingent claims which are widely traded on financial markets. A call option gives the buyer the right, but not the obligation, to buy a stock at a predetermined price and date. A put option gives the buyer the right, but not the obligation, to sell a stock at a predetermined price and date. The payoff of options thus depends on the value of the underlying stock at the expiry date, which is uncertain beforehand. Black and Scholes (1973) developed the well-known Black-Scholes option model to theoretically price options.

Merton (1974) developed the CCA model which is an application of the theoretical work of Black and Scholes to analyze the capital structure of corporations. Because the value of the corporation’s assets must always be equal to the value of the corporation’s liabilities which consist of equity and debt, we can see the liabilities as contingent claims on the underlying assets of the corporation. With CCA we can analyze the change in value of the contingent claims as the market value of the corporation’s assets changes over time. CCA is based on the corporation’s marked-to-market balance sheet information and the principle that the future value of the corporation’s assets is uncertain. Figure 3.1 shows the corporation’s balance sheet with on the left side the corporation’s assets and on the right side the corporation’s liabilities.

Figure 3.1 Assets, risky debt, and equity on the corporation's balance sheet.

The claim of the debt holders on the corporation's assets is considered to be senior to the claim of the equity holders (the shareholders or owners of the corporation). The debt of a corporation is "risky" because there is a probability that in future the corporation is not able to repay its debt holders and will default. Therefore, the value of the risky debt is equal to the value of the default-free value of the debt minus the expected loss when the value of the corporation's assets is too low to meet the promised payments. In this sense, the debt holder offers an implicit guarantee against default, since it must suffer the losses in case of default of the corporation. The debt claim satisfies the following equation (4):

$$\text{Risky Debt} \equiv \text{Default-free Debt} - \text{Expected Loss.} \tag{4}$$

The value of the equity is equal to the residual value of the corporation's assets after the promised payments on debt have been made. In the CCA model the expected loss on the risky debt is modeled as an implicit put option on the corporation's assets, while the value of the equity is modeled as an implicit call option on the corporation's assets. The CCA model prices these implicit options with the Black-Scholes formula which is discussed in the following section.

3.2 Black-Scholes Option Model

Call and put options are financial instruments that are classified as financial derivatives because their value is derived from an underlying asset (e.g., a stock). A call (put) option gives the buyer the right, but not the obligation, to buy (sell) a stock S at a predetermined strike price K and expiry date T. The value of such an option at its expiry date is called the payoff and is easy to determine because it depends on the difference between the value of the underlying stock and the strike price. If at expiry date the underlying stock is worth more than the strike price, the holder of a call option would of course exercise its right to buy the stock at the lower strike price. In this case the owner of the call option gains the difference between the value of the underlying stock minus the strike price. If at expiry date the underlying stock is worth less than the strike price, the holder of a call option would of course not exercise its right to buy the asset at the higher strike price. The scenario for the owner of a put option is exactly the other way around: the put option becomes profitable if the value of the underlying stock drops below the strike price. Equations (5) and (6) give the formula of the payoff of a call option *C* and put option *P*, respectively:

$$C(S,T) = \max(S - K;0), \tag{5}$$
$$P(S,T) = \max(K - S;0). \tag{6}$$

Figure 3.2 shows the payoff diagrams of a call and put option[1].

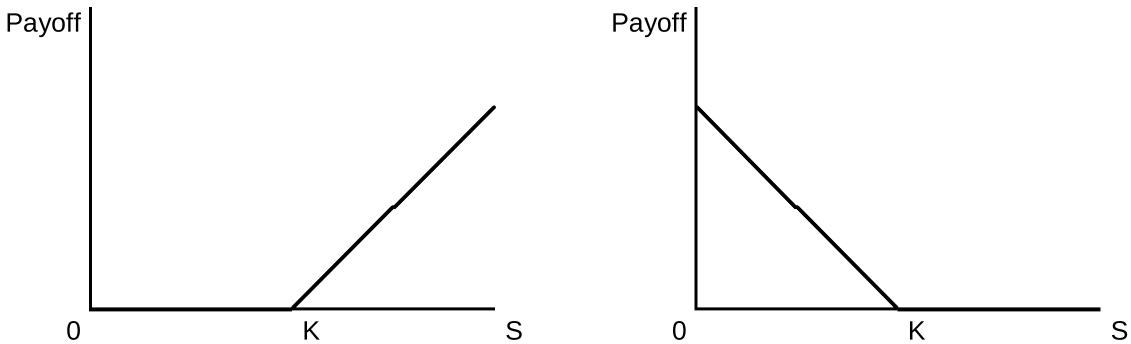


Figure 3.2 Payoff of a European call option (left) and a European put option (right).

The value of the option at the expiry date *T* is thus known, but it is more challenging to find the value of the option at any time *t* on the time interval $0 \le t \le T$. Black and Scholes (1973) derive their famous Black-Scholes formula to value the option at any time of the time interval. Below are quoted the assumptions they use to create "ideal conditions" in the market for the stock and for the option under which options could be priced straightforwardly:

1. The short-term interest rate is known and is constant over time.
2. The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus the distribution of possible stock prices at the end of any finite interval is lognormal. The variance rate of the return on the stock is constant.
3. The stock pays no dividends or other contributions.
4. The option is "European", that is, it can only be exercised at maturity.
5. There are no transaction costs in buying or selling the stock or option.
6. It is possible to borrow any fraction of the price of a security to buy it or to hold it at the short-term interest rate.
7. There are no penalties to short selling. A seller who does not own a security will simply accept the price of the security from a buyer, and will agree to settle with the buyer on some future date by paying him an amount equal to the price of the security on that date.

[1] To determine the profit or loss on the option we have to deduct the purchase price of the option from the payoff.

From assumption 2 we derive the stochastic differential equation (7) that describes the return dS/S on the stock price:

$$\frac{dS}{S} = \sigma\, dX + \mu\, dt\,, \tag{7}$$

where σ is the volatility of the stock price (the standard deviation of the returns on the stock price), dX is a Wiener process (a random variable drawn from a normal distribution with mean zero and variance dt), μ is the drift term (average rate of growth of the stock price), and dt is a small time interval on which the stock return is measured.

The value V of the option at any time t on the time interval is a function of the stock price S which contains a random component and a deterministic component. With Itô's lemma (1951) we can relate a small change in a function of a random variable to a small change in the random variable itself similar to Taylor's theorem on functions of deterministic variables. Applying Itô's lemma to V, we can write (8):

$$dV = \sigma S \frac{\partial V}{\partial S} dX + \left(\mu S \frac{\partial V}{\partial S} + \tfrac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} \right) dt. \tag{8}$$

Constructing a portfolio Π that contains one option and a number of –Δ of the underlying stock, we find the value of the portfolio with equation (9) and the jump in the value of the portfolio for a fixed Δ during the time step dt with equation (10):

$$\Pi = V - \Delta S, \tag{9}$$
$$d\Pi = dV - \Delta dS. \tag{10}$$

Substituting (7) and (8) into (10), we find that the portfolio Π is a function with a random component and a deterministic component (11):

$$d\Pi = \sigma S \left(\frac{\partial V}{\partial S} - \Delta \right) dX + \left(\mu S \frac{\partial V}{\partial S} + \tfrac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + \frac{\partial V}{\partial t} - \mu \Delta S \right) dt. \tag{11}$$

We can eliminate the random component dX and the drift term μ of formula (11) by choosing (12) at the start of the time step dt:

$$\Delta = \frac{\partial V}{\partial S}. \tag{12}$$

The result is a portfolio that can be described completely deterministic (13):

$$d\Pi = \left(\frac{\partial V}{\partial t} + \tfrac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} \right) dt. \tag{13}$$

Now the random component is removed, the portfolio Π does not include any uncertainty and hence we can consider it as risk-free. Assuming no arbitrage, which is the opportunity to make a profit without taking any risk, the jump in value $d\Pi$ of the portfolio must be the same as all risk-free portfolios of value Π and thus grow with the risk-free interest rate r (14):

$$d\Pi = r\Pi dt = \left(rV - rS\frac{\partial V}{\partial S} \right) dt. \tag{14}$$

Combining (13) and (14) and dividing throughout by dt we find the Black-Scholes partial differential equation (15):

$$\frac{\partial V}{\partial t} + \tfrac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0. \tag{15}$$

Wilmott, Howison, and Dewynne (2007) show in detail how the partial differential equation (15) can be rewritten to the heat equation and solved analytically for European call and put options. In order to find a unique solution we must consider final and boundary conditions which are different for call and put options. For a call option we use the final condition that the value of the option equals the payoff formula (5), and boundary conditions (16) and (17) that assume that the value of the call option is zero if the stock price S is zero and the value of the call option equals the stock price if the stock price goes to infinity:

$$C(0,t) = 0, \tag{16}$$
$$C(S,t) \sim S \quad \text{as} \quad S \to \infty. \tag{17}$$

For a put option we use the final condition that the value of the option equals the payoff formula (6), and boundary conditions (18) and (19) that assume that the value of the put option equals the discounted strike price K if the stock price is zero and the value of the put option is zero if the stock price goes to infinity:

$$P(0,t) = Ke^{-r(T-t)}, \tag{18}$$
$$P(S,t) \sim 0 \quad \text{as} \quad S \to \infty. \tag{19}$$

This yields the Black-Scholes formula to value a European call option at any time t on the time interval $0 \le t \le T$ (20):

$$C(S,t) = SN(d_1) - Ke^{-r(T-t)}N(d_2), \tag{20}$$

where

$$d_1 = \frac{\ln(S/K) + (r + \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \tag{21}$$

and

$$d_2 = \frac{\ln(S/K) + (r - \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} = d_1 - \sigma\sqrt{T-t}. \tag{22}$$

$N(x)$ is the cumulative probability of the standard normal density function below x.

The Black-Scholes formula to value a European put option at any time t on the time interval $0 \le t \le T$ equals (23):

$$P(S,t) = Ke^{-r(T-t)}N(-d_2) - SN(-d_1). \tag{23}$$

The value of American options, which can be exercised at any time before expiry, and other more exotic options can be found either by solving equation (15) numerically respecting the final and boundary conditions or by simulating a large number of sample paths of the price process (7) of the underlying stock and discounting the average payoff. Finally, it is worth to mention the "put-call parity" relationship between a European call and put option (24):

$$\begin{aligned}
S &= C(S,t) + Ke^{-r(T-t)} - P(S,t), \\
S &= SN(d_1) - Ke^{-r(T-t)}N(d_2) + Ke^{-r(T-t)} - Ke^{-r(T-t)}N(-d_2) + SN(-d_1), \\
S &= S\big(N(d_1) + N(-d_1)\big) + Ke^{-r(T-t)} - Ke^{-r(T-t)}\big(N(d_2) + N(-d_2)\big), \\
S &= S + Ke^{-r(T-t)} - Ke^{-r(T-t)} = S.
\end{aligned} \tag{24}$$

3.3 Contingent Claims Pricing

Merton (1974) uses the Black-Scholes formula in his CCA model to value contingent claims. This is best explained with an example of a corporation with a simplified capital structure. In this example we consider the situation where a corporation has assets with market value A of which the future value is uncertain. The liabilities of the corporation exist of equity with market value E and only one type of risky debt with value D. The risky debt is a senior claim on the corporation's assets, while the equity is a junior- or residual claim on the corporation's assets. The risky debt only consists of a single bond maturing at time T (this is also called the time horizon in the CCA model). The corporation promises to pay the amount of B to the holders of the bond at time T and does not issue new debt in the meantime.

At time T we know the value of the risky debt and the equity because there are two possible situations:

1. $A_T \geq B$: The corporation has enough assets to pay the bondholders.
2. $A_T < B$: Default: The corporation has not enough assets to pay the bondholders.

In the first situation the bondholders receive the promised payment B, while the equity owned by the shareholders is worth $E_T = A_T - B$. In the second situation the promised payments cannot be met and the bondholders will claim the corporation's assets leaving the shareholders empty handed. So, the bondholders receive A_T, and thus suffer a loss of $B - A_T$, and the shareholders receive $E_T = 0$. Figure 3.3 shows the situation at time T for different values of A in payoff diagrams for the shareholders and bondholders.

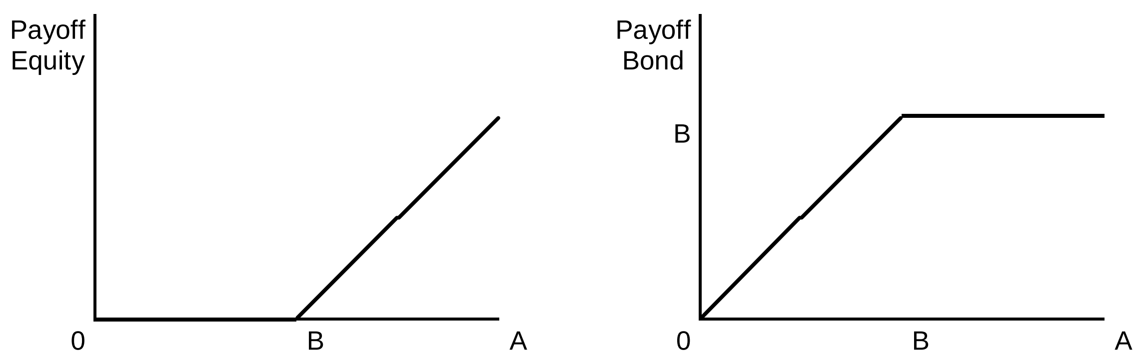


Figure 3.3 Payoff to the shareholders (left) and bondholders (right).

From this information it is easy to see that the value of equity at time T is exactly the same as the payoff of a call option on the assets, with an exercise price equal to B and maturity T (25):

$$E_T = \max(A_T - B; 0). \quad (25)$$

The value of the risky debt at time T is exactly the same as B minus the payoff of a put option on the assets, with an exercise price equal to B and maturity T (26):

$$\begin{aligned} D_T &= B - P_T\,, \\ D_T &= B - \max(B - A_T\,; 0). \end{aligned} \tag{26}$$

Since the liabilities of the corporation are equal to the assets of the corporation, we could also derive the value of the risky debt by subtracting the value of the equity from the assets (27):

$$\begin{aligned} D_T &= A_T - E_T\,, \\ D_T &= A_T - \max(A_T - B; 0). \end{aligned} \tag{27}$$

Equation (28) shows that (26) and (27) are similar to the put-call parity we found in the previous section:

$$\begin{aligned} A_T - E_T &= B - P_T\,, \\ A_T - \max(A_T - B; 0) &= B - \max(B - A_T\,; 0). \end{aligned} \tag{28}$$

The CCA model assumes that the value of the corporation's assets follows the same stochastic process as the price of the underlying stock in the Black-Scholes option model with μ_A being the growth rate of the assets and σ_A being the volatility of the assets (29):

$$\frac{\mathrm{d}A}{A} = \mu_A \mathrm{d}t + \sigma_A \mathrm{d}Z. \tag{29}$$

When we also use the other assumptions of the Black-Scholes model, we can use the model to immediately value the corporation's equity and risky debt at any given time. The equity of the corporation is modeled as an implicit call option on the assets, with an exercise price equal to B and maturity T. The value of the risky debt is the value of B discounted with the risk-free rate minus the expected loss which is valued as an implicit put option on the assets, with an exercise price equal to B and maturity T.

The value of the equity at time t = 0 is (30):

$$E = AN(d_1) - Be^{-rT} N(d_2), \tag{30}$$

where

$$d_1 = \frac{\ln(A/B) + (r + \frac{1}{2}\sigma_A{}^2)T}{\sigma_A \sqrt{T}} \tag{31}$$

and

$$d_2 = \frac{\ln(A/B) + (r - \frac{1}{2}\sigma_A{}^2)T}{\sigma_A \sqrt{T}} = d_1 - \sigma_A \sqrt{T}. \tag{32}$$

The value of the risky debt at time t = 0 is (33):

$$\begin{aligned} D &= Be^{-rT} - P, \\ D &= Be^{-rT} - \left(Be^{-rT} N(-d_2) - AN(-d_1)\right). \end{aligned} \tag{33}$$

In reality the debt structure of corporations is more complicated than debt that exists of one single bond as the corporation in the example. Usually corporations issue multiple bonds with different maturities and coupon payments. Therefore, instead of a single promised payment we specify the distress barrier *B*. The distress barrier is based on the promised payments and represents the level of the corporation’s assets that triggers an incidence of default.

Theoretically, a corporation defaults when the value of their assets is less than the promised payments on the debt. In practice, corporations default at much higher asset levels due to illiquidity or because they prefer to default and start negotiations to restructure their debt instead of selling their assets. Therefore, the distress barrier lies somewhere in between the book value of the corporation’s short-term debt and the book value of the corporation’s total debt. The KMV model – the most used practical implementation of the CCA model – uses an empirical rule (34) to construct the distress barrier. According to Gapen et al. (2004) the parameter α is commonly set at 0.5.

$$B = \textit{Short-term Debt} + \alpha * \textit{Long-term Debt} + \textit{Interest Payments}. \tag{34}$$

Over time, different extensions and applications have been built on the basic CCA model. Examples of extensions are CCA models with multiple distress barriers, incorporated stochastic interest rates and interest rate term structures, empirical or skewed probability distributions, and the possibility that a corporation defaults before the end of the time horizon. We concentrate on the application of the basic CCA model to sovereigns.

3.4 Extension of CCA to Sovereigns

Gray et al. (2007) adapt the CCA model on corporations in order to make it applicable to sovereign countries. They take a close look at the relationship between the assets and the liabilities of two partners in the country's public sector: the government and the monetary authority also known as the central bank. Due to the existing cross-holdings and financial guarantees between the two partners the balance sheets of the government and the monetary authority are interlinked. Figure 3.4 shows a generalized structure of these balance sheets.

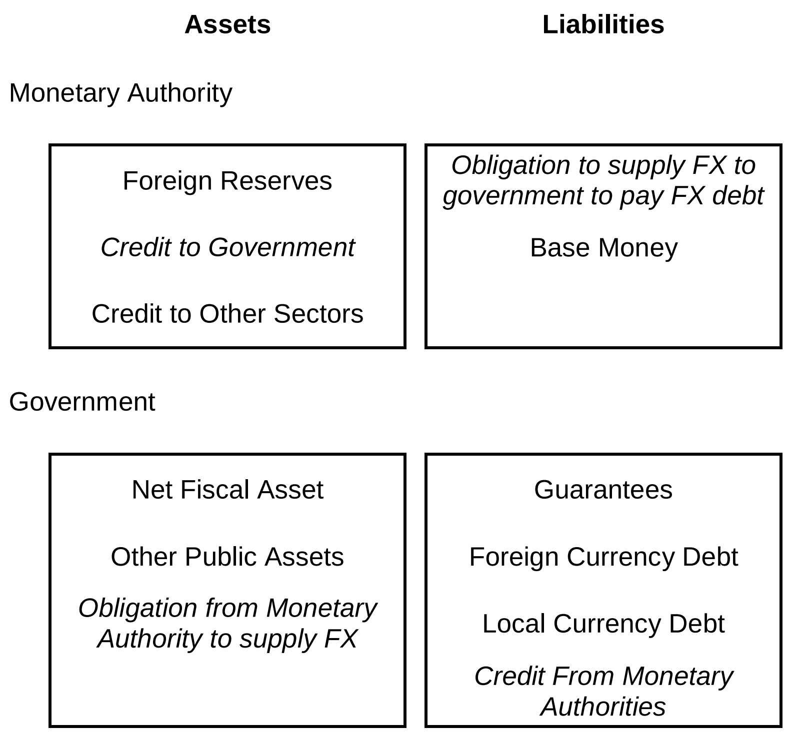


Figure 3.4 Balance sheet structure of the public sector of a country.

Figure 3.4 shows the cross-holdings of the government and the monetary authority in italics. The credit from the monetary authority to the government is an asset on the balance sheet of the monetary authority and a liability on the balance sheet of the government. The financial guarantee from the monetary authority to supply foreign currency to the government to pay the foreign currency debt is an asset on the balance sheet of the government and a liability on the balance sheet of the monetary authority. When we consolidate the balance sheets of the government and the monetary authority these two entries drop out. Figure 3.5 shows the combined balance sheet of the country's public sector.

Public Sector

Assets	Liabilities
Foreign Reserves	Guarantees
Net Fiscal Asset	Foreign Currency Debt
Credit to Other Sectors	Local Currency Debt
Other Public Assets	Base Money

Figure 3.5 Combined balance sheets of the government and monetary authority.

The assets of the sovereign country exist of four items:

1. Foreign currency reserves including actual reserves and contingent reserves from international financial institutions such as the IMF and other governments;
2. The net fiscal asset which equals the government's budget surplus (or deficit) on taxes and revenues minus expenditures;
3. Credit to other sectors such as the corporate-, financial-, and household sector;
4. Other public assets such as the equity of public enterprises.

The liabilities of the sovereign country exist of four items:

1. (Implicit) financial guarantees to the so called too-big-to-fail entities as we have seen in the government support and bail outs of big financial institutions like the American International Group (AIG) during the financial crisis of 2008-2009;
2. Foreign currency debt which is issued by the public sector and denominated in a foreign currency;
3. Local currency debt which is issued by the public sector and denominated in the domestic currency;
4. The monetary base (or base money) which is related to the money supply in the country's economy.

Gray et al. (2007) argue that the balance sheet of the country's public sector and the balance sheet of a corporation show important similarities in both structure and priority of the claims. Local currency debt and the monetary base are called local currency liabilities and have certain features similar to the equity of a corporation. The public sector controls the money supply and therefore they have the option to repay their local currency debt by creating more domestic currency. However, expansion of the money supply can cause inflation which lowers the real value of the payments to the local currency debt holders. This is similar to equity of corporations because excessive issue of shares dilutes existing holders' claims and reduces the price per share on the balance sheet of a corporation. The foreign currency debt is analogous to the risky debt of a corporation because here the public sector cannot easily create more foreign currency since excessively creating domestic currency will lower the demand of the domestic currency and hence depreciate the foreign exchange rates. Moreover, Sims (1999) considers foreign currency debt to be senior to local currency liabilities because in stress situations most governments prefer to inflate local currency debt instead of defaulting on foreign currency debt.

The sovereign CCA model is similar to the corporate CCA model with local currency liabilities modeled as an implicit call option on the country's assets and foreign currency debt modeled as a distress barrier minus an implicit put option on the country's assets. The distress barrier is based on the book values of the foreign currency debt using the empirical rule of equation (34). The financial guarantees can be modeled as implicit put options on the finance sector assets. Gray and Malone (2008) provide more insight in transferring financial risks by interlinking the balance sheets of different sectors with put options. However, analyzing all sectors of a sovereign will be very time consuming and beyond the scope of our research project where we look at the basics of the sovereign CCA model without the financial guarantees. An important feature of the sovereign CCA model is that the balance sheet items are measured in one currency unit, commonly a "hard" currency such as the US Dollar or the Euro, with the corresponding risk-free interest rate.

Essentially, the sovereign CCA model is the same as the corporate CCA model described by equations (30), (31), (32), and (33). Instead of the notation E for equity we use the notation LCL for local currency liabilities, and instead of the distress barrier B we introduce the foreign distress barrier B_f. Input parameters of the model are the value and volatility of the assets, the book value of the foreign currency debt, the marked-to-market value of the local currency liabilities consisting of the local currency debt and the monetary base, and the risk-free interest rate. The foreign exchange rate is indirectly an important input parameter because it largely influences the value and volatility of the assets and the local currency liabilities. All input parameters are directly observable except for the market value and volatility of the assets of the sovereign which, therefore, must be estimated. One approach to estimate the market value and volatility of the assets, which is also applied to corporations, is to use an implied value from the observed value of the liabilities. Remember that in CCA the value of the assets must always be equal to the value of the liabilities. Therefore, we could determine the implied value and volatility of the assets from the observed market prices of the local currency liabilities LCL and their volatility σ_{LCL}. The balance sheet relationships between the assets and the liabilities are used to iteratively calculate the implied value of the two unknowns (the implied asset value A and the implied asset volatility σ_A) with equations (35) and (36):

$$LCL = AN(d_1) - B_f e^{-rT} N(d_2), \tag{35}$$

$$LCL\sigma_{LCL} = A\sigma_A \frac{\partial LCL}{\partial A} = A\sigma_A N(d_1). \tag{36}$$

From the description of the sovereign CCA model we presume that the sovereign CCA model is designed for emerging countries. There are several reasons why the sovereign

CCA model is not applicable to developed countries. First, developed countries have direct access to large and liquid international markets to issue debt in their domestic currency and that is why developed countries have no or few foreign debt. Therefore, the foreign distress barrier of most developed countries will be zero. Moreover, countries from the Economic and Monetary Union (EMU) of the European Union have very limited control over the money supply of the European Central Bank (ECB) and therefore the analogy between local currency liabilities and equity disappears. After the financial crisis of 2008-2009, sovereign credit risk especially applied to EMU countries like Greece, Ireland, Portugal, and Spain. Finally, the main source that causes an increase in credit risk of these countries was the budget deficit which is not taken into account as input parameter of the sovereign CCA model. This leads us to the conclusion that the sovereign CCA model is best suited for emerging countries. This property of the sovereign CCA model is never stated in literature, but confirmed in a conference call with Dale Gray who said that the model works best on emerging countries with a considerable amount of foreign currency debt.

3.5 Risk measures

The sovereign CCA model provides us with a number of country specific risk- and sensitivity measures. In this section we describe three important risk measures of the sovereign CCA model:

1. Credit spread: s,
2. Default probability: $N(-d_2)$,
3. Distance to distress: d_2.

Equation (37) below recalls the formula of d_2:

$$d_2 = \frac{\ln(A/B_f) + (r - \tfrac{1}{2}\sigma_A{}^2)T}{\sigma_A\sqrt{T}}. \tag{37}$$

The credit spread follows from the yield-to-maturity y of the risky debt D which is valued by the sovereign CCA model. The yield-to-maturity of the risky debt is (38):

$$\begin{aligned} D &= B_f e^{-yT}, \\ y &= \frac{\ln(B_f / D)}{T}. \end{aligned} \tag{38}$$

The difference between the yield-to-maturity of the risky debt and the risk-free interest rate is the credit spread s (39):

$$s = y - r = -\frac{1}{T}\ln\left(1 - \frac{P}{B_f e^{-rT}}\right). \tag{39}$$

Another important indicator of credit risk is the default probability. The default probability is the probability that the sovereign country will default on paying its foreign debt at the end of the time period. The sovereign CCA model provides us with the "risk adjusted" default probability $N(d_2)$. To see how this corresponds with the "actual" default probability, we show how the formula of the "actual" default probability is derived.

The value of the assets at time T can be derived from the assets' stochastic process (29) and is described by (40):

$$A_T = A_0 \exp\left[\left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T + \sigma_A \varepsilon \sqrt{T}\right]. \tag{40}$$

The probability that the country defaults is equal to the probability that the value of the assets is lower than the foreign distress barrier (41):

$$\text{Prob}\left(A_T < B_f\right) = \text{Prob}\left(A_0 \exp\left[\left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T + \sigma_A \varepsilon \sqrt{T}\right] < B_f\right). \tag{41}$$

By rearranging the terms we find that this is equivalent to the probability that the random term ε is smaller than the term $-d_{2,\mu}$ (42):

$$\begin{aligned}
&\text{Prob}\left(A_0 \exp\left[\left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T + \sigma_A \varepsilon \sqrt{T}\right] < B_f\right), \\
&\text{Prob}\left(\ln\left(A_0\right) + \left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T + \sigma_A \varepsilon \sqrt{T} < \ln\left(B_f\right)\right), \\
&\text{Prob}\left(\sigma_A \varepsilon \sqrt{T} < \ln\left(B_f\right) - \ln\left(A_0\right) - \left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T\right), \\
&\text{Prob}\left(\varepsilon < -\frac{\ln\left(\dfrac{A_0}{B_f}\right) + \left(\mu_A - \tfrac{1}{2}\sigma_A{}^2\right)T}{\sigma_A \sqrt{T}} = -d_{2,\mu}\right).
\end{aligned} \tag{42}$$

The error term ε is assumed to be standard normally distributed, thus the "actual" default probability is $N(-d_{2,\mu})$. Figure 3.6 shows the "actual" and the "risk adjusted" default probability as the area below the distress barrier.

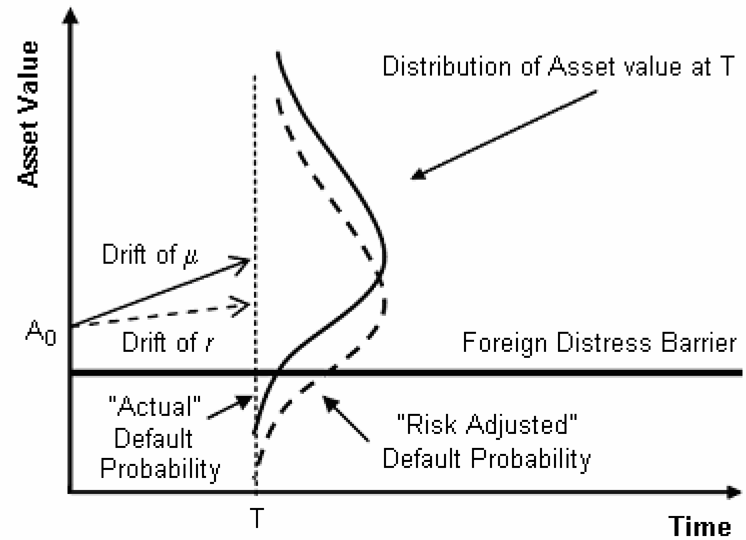


Figure 3.6 The "risk adjusted" and the "actual" default probability.
Source: Gray et al. (2007).

From Figure 3.6 we can see that the "risk adjusted" default probability is larger than the "actual" default probability. This is because the sovereign CCA model does not use the "actual" but the "risk adjusted" asset-return probability to value the contingent claims and therefore the assets grow at the lower risk-free rate r instead of μ. Next to this, the default probability also depends on the distribution from which it is drawn. In reality assets do not have a perfect normal distribution, especially not at the tail of the distribution were defaults occurs. However, Gray et al. (2007) claim to find a tight relationship between the "risk adjusted" default probability and actual CDS data. On a contrary, the KMV model that is used by Moody's does not use the normal distribution to determine the default probability of corporations. They use the Expected Default Frequency (EDF) to map the distance to distress d_2 into a default probability. The EDFs come from a large proprietary historical database with corporate defaults which is owned by Moody's and cannot publicly be accessed. Although no historical database of the same size with sovereign defaults exists, the distance to distress can be a valuable risk measure as it represents the number of standard deviation of asset return volatility that the value of the assets is away from the distress barrier.

Chapter 4

Case Study Brazil

In this chapter we perform a case study of the sovereign CCA model of Gray et al. (2007) on Brazil. We show the practicability of the sovereign CCA model by providing a general approach to adapt data available at Robeco to the key variables of the model. We compare the results of our case study with information that we gathered on the results of a study on Brazil by Gray and Malone (2008). With this comparison we can check our results and find out if we can confirm the same tight relationship between the risk measures of the model and actual CDS data as claimed by Gray et al. Moreover, the case study on Brazil provides insight in the dynamics of the sovereign CCA model and the applicability to trading strategies with CDS contracts.

As an emerging country with a large foreign debt stock, Brazil satisfies all conditions of the sovereign CCA model that we distinguished in the previous chapter. Moreover, the credit risk of Brazil is very interesting to analyze because Brazil is one of the largest emerging countries that recently went through a severe credit crisis. During this crisis of 2002-2003 the country was close to default on their debt. There were several causes that led to the crisis. One important cause was the change in the FX regime of the Brazilian Real (the name of the domestic currency) from a US Dollar pegged FX rate to a floating FX rate in 1999. This led to a devaluation of the Brazilian Real which caused difficulties for the Brazilian government in servicing the large foreign currency debt stock. In 2002, an energy rationing program had a negative effect on the economy. At the same time, Luiz Inácio da Silva, popularly known as Lula, won the electoral contest for the Brazilian presidency from the sitting conservative party on behalf of the labor party. Investors had no confidence that the socialist Lula would solve the economic crisis. However, the cheap Real gave Brazil a competitive advantage over Argentina that changed their FX regime only in 2002 from a US Dollar pegged FX rate to a floating FX rate. The subsequent growth in export led to a recovery of the Brazilian economy from 2003 which President Lula seized to improve the transparency of the local financial markets and restructure the debt by increasing the proportion of local currency debt. Currently in 2010, Brazil has one of the fastest growing economies in the world.

4.1 Data Preparation

In our case study we practically implement the sovereign CCA model on Brazil with our own data. We try to replicate the example of a practical implementation of the sovereign CCA model on Brazil by Gray and Malone (2008). We use information on the results of this example to check the results of our case study. Therefore, we use the same research period and currency unit as Gray and Malone. The research period is April 2002 to December 2005 and the currency unit is the US Dollar. Gray and Malone show that under these settings there is a tight relationship between the default probability determined by the model and the actual 5 year CDS spread. We check if we can confirm this tight relationship in our case study.

To practically implement the sovereign CCA model we have to find and prepare data that we can use for the input variables of the model. The sovereign CCA model requires data for the following input variables:

- Local Currency Liabilities (*LCL*)
  - Monetary Base
  - Market value of the Local Currency Debt
- Volatility of the Local Currency Liabilities (σ_{LCL})
- Foreign Distress Barrier (B_f)
- Risk-free interest rate (r)
- Time Horizon (T)

All values have to be measured in US Dollars and therefore another important input variable of the sovereign CCA model is the FX rate to convert all input variables to US Dollars. We have data for the following input variables directly available for our case study: the monetary base, the risk-free interest rate, and the FX rate. The time horizon is set at 5 year, equal to the maturity of the CDS contracts that we use to compare the risk measures of the sovereign CCA model with. Since the time horizon is 5 years and the unit currency is the US Dollar, the risk-free interest rate is the 5 year US government interest rate. The data for the other input variables - the local currency debt, the volatility of the local currency liabilities, and the foreign distress barrier - have to be constructed.

The main data source we use in our case study is the generic broker information from the Bloomberg Terminal which we can access within Robeco. Bloomberg is a data vendor of up-to-date business news and financial information. From Bloomberg we collect daily historical data on the 5 year US government interest rate and the FX rates. We also collect daily historical data on the 5 year CDS spread of Brazil, so that we can compare the risk measures of the sovereign CCA model for Brazil. In Bloomberg the monetary base of Brazil is only available on a monthly basis. Instead, we use daily data on the monetary base that is publicly available at the website of the Central Bank of Brazil (BCB) with a lag of one month.

The input data for the local currency debt should be in market values and is not directly available in Bloomberg. The data could be collected from public available debt reports by the Brazilian government but this has four important disadvantages: the data is not timely and can have a time lag up to a quarter of a year; the data is only available on a monthly or quarterly basis; the data collection is time consuming because data sources can differ for different periods and data have to be manually collected; and the debt is not necessarily reported in market values. Therefore, it is better to construct the local currency debt by using Brazilian government bond data that are daily and timely available from Bloomberg. This can be done by adding the market values of the total number of all active bonds that are issued in Brazilian Reais. This is a very straightforward and convenient approach to determine the current market value of the local currency debt.

However, we cannot use this approach for our case study because most market values of Brazilian bonds are not historically available. Therefore, we estimate the market values of the fixed bonds on a given date by discounting the (indexed) nominal values with the required yield as in equation (1) of Chapter 2. The applicable domestic interest rate is set as the required yield. We estimate the market values of floating bonds simply as the (indexed) nominal value. Although, it is time consuming to determine the market values of all specific types of bonds, we prefer this approach over estimating the local currency debt from reported values by the government. This is because by constructing the market value of the local currency debt with Bloomberg bond data we have the advantage of having a general approach that we can apply to other countries as well. Table 4.1 shows the fixed, floating, and inflation linked bonds issued in Reais that we distinguish in our case study on Brazil.

Table 4.1 Local currency debt of Brazil: Specification of Brazilian government bonds issued by the National Treasury of Brazil during the research period of our case study (April 2002 to December 2005). The bonds are issued in Reais, the domestic currency of Brazil, and coupons are paid semiannually. Currently in 2010, these are still the only types of Brazilian government bonds issued in Reais that are active.

Bond Name	Type	Annual Coupon	Detail
LTN	Fixed	0%	
NTN-F	Fixed	10%	
LTF	Floating	0%	Nominal value indexed to the accumulated overnight SELIC rate referenced at 1 July 2000
NTN-B	Fixed, Inflation Linked	6%	Nominal value indexed to the accumulated monthly return on the IPCA inflation index referenced at 15 July 2000
NTN-C	Fixed, Inflation Linked	6%, 12%	Nominal value indexed to the accumulated monthly return on the IGP-M inflation index referenced at 1 July 2000

Figures 4.1 to 4.3 show the market values of the total stock of fixed, floating, and inflation linked local currency debt calculated from the Bloomberg bond data compared to the reported values by the Brazilian government. In general, the calculated values are about the same or just above the reported values during the research period which gives confidence in the quality of the Bloomberg bond data and our approach. Table B.1 of Appendix B shows that we are not always able to find an appropriate interest rate that we can set as the required yield to discount the future cash flows of a specific bond issuance. This could be a reason why the calculated values of local currency debt might deviate

from the reported values. However, we do not necessarily need the exact market value of the local currency debt anyway because the output of the sovereign CCA model is less sensitive to changes in the local currency liabilities than other input variables as we explain in the model discussion section of this chapter.

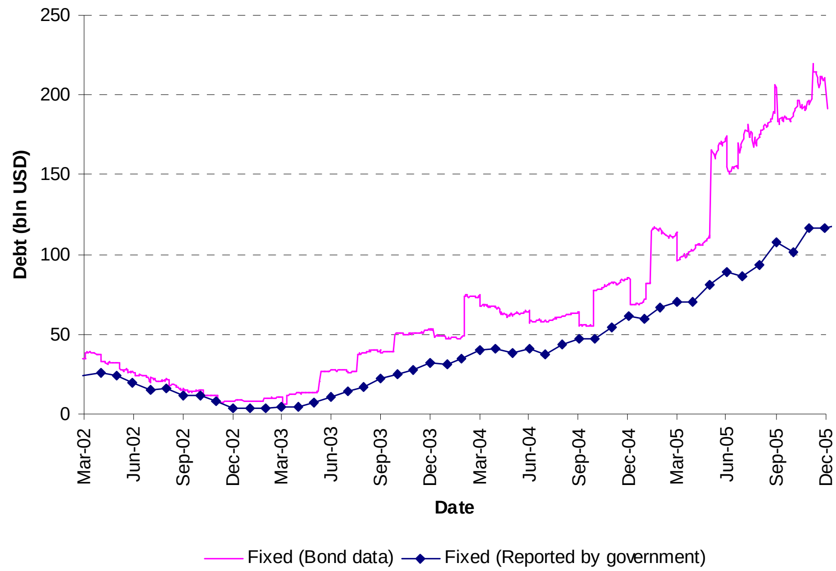


Figure 4.1 The fixed local currency debt of Brazil in the period April 2002 to December 2005. The total fixed local currency debt stock of Brazil estimated from the Bloomberg LTN and NTN-F bond data compared to the reported values by the National Treasury of Brazil.

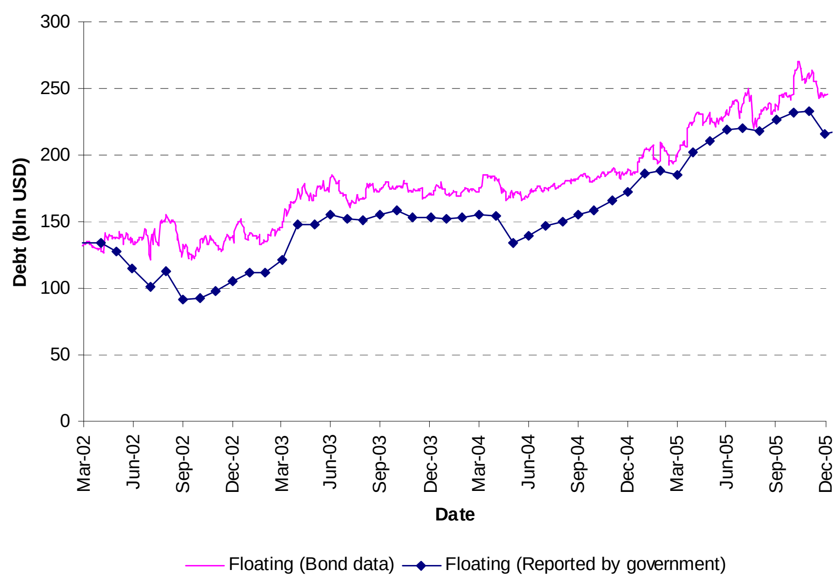


Figure 4.2 The floating local currency debt of Brazil in the period April 2002 to December 2005. The total floating local currency debt stock of Brazil estimated from the Bloomberg LTF bond data compared to the reported values by the National Treasury of Brazil.

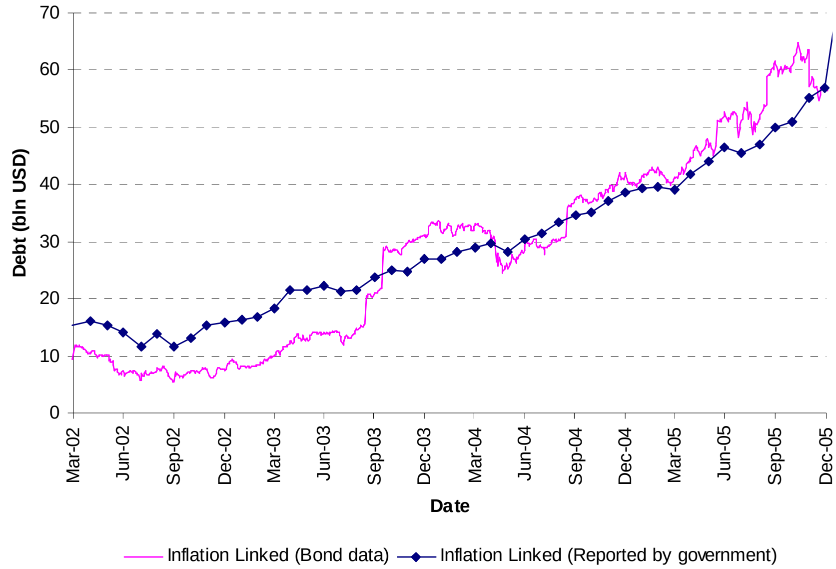


Figure 4.3 The fixed inflation linked local currency debt of Brazil in the period April 2002 to December 2005. The total fixed inflation linked local currency debt stock of Brazil estimated from the Bloomberg NTN-B and NTN-C bond data compared to the reported values by the National Treasury of Brazil.

The input data for the foreign distress barrier is not directly available in Bloomberg. The foreign distress barrier needs to be constructed from the book values of foreign currency debt with the empirical rule of equation (34): the short term debt plus the interest payments in the coming year and half of the long term debt. Like Gray and Malone (2008) we define the short term debt as all debt with a time to maturity of less than or equal to 1 year and we define the long term debt as all debt with a time to maturity of more than 1 year. We construct the foreign distress barrier with the use of Bloomberg foreign bond data. Therefore, we use Brazilian international government bonds which are not issued in Brazilian Reais but mainly in US Dollars, Euros and Japanese Yens. We also take into account Brazilian government bonds that are issued in Reais but linked to the US Dollar. Examples of Dollar-linked bonds are the national treasury's NTN-D series and the central bank's BNCB-E series that have a nominal value that is indexed to the Brazilian Real and US Dollar FX rate. Based on the time to maturity of the foreign bonds we determine if the bonds are classified as short term or long term debt and we construct the foreign distress barrier by adding the nominal values and forthcoming interest payments in US Dollars of all foreign bonds according to equation (34).

The last input variable that needs to be determined is the volatility of the local currency liabilities. We measure this input variable by calculating the historical volatility of the local currency liabilities. We find the local currency liabilities by adding the monetary base to the market value of the local currency debt which we construct out of bond data. The historical volatility of the local currency liabilities (in US Dollars) on a given date is the standard deviation of the log returns over the previous period. We want to use the highest frequency information that is possible with market data in our case study because we want to obtain timely warnings from the risk measures of the sovereign CCA model.

Therefore, we measure the volatility on a daily basis by using daily log returns. Because our time unit of the sovereign CCA model is in years, we annualize the volatility by multiplying with the square root of 252 (approximately the number of business days during a year).

An important choice in the measurement of the volatility is the length of the measurement period. Figure 4.4 shows the volatility of the local currency liabilities of Brazil with a measurement period of 1, 3, and 12 month(s). From Figure 4.4 we can clearly see that the length of the measurement period has an important influence on the volatility. If we use a short measurement period of one month the volatility responds fast to a recent change in the variability of the log returns but this also leads to a more fluctuating volatility over time. On the other hand, if we use a long measurement period of 1 year the volatility is more stable over time but reacts slowly to a recent change in the variability of the log returns. In our case study, we choose a measurement period of three months because this gives a more stable volatility over time that still has a timely reaction to changes in the variability of log returns.

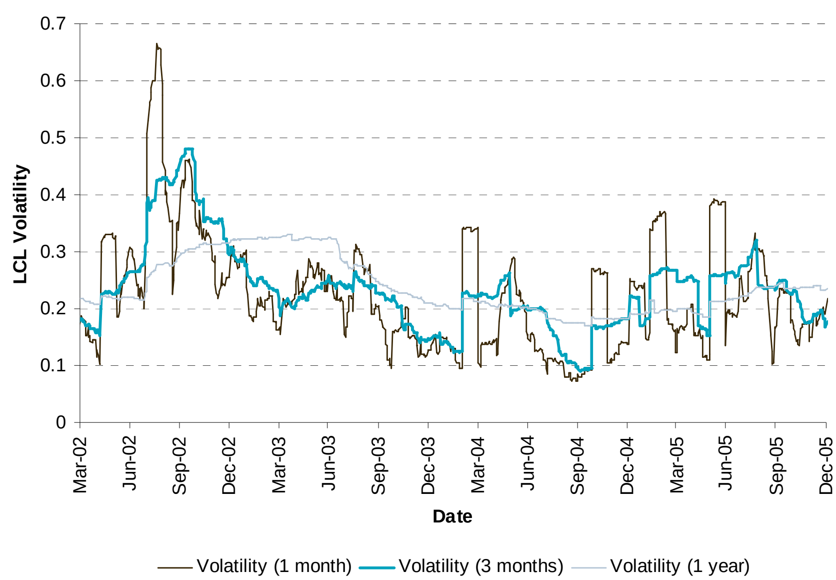


Figure 4.4 Annualized volatility of the Brazilian local currency liabilities in the period April 2002 to December 2005. The presented volatilities have a measurement period of 1, 3, or 12 months and are measured on a daily basis.

We can divide the volatility of the local currency liabilities in three components: the volatility of the monetary base in local currency terms, the volatility of the local currency debt in local currency terms, and the FX volatility (the volatility of the Brazilian Real and US Dollar FX rate). For a floating rate FX regime, as is the case for Brazil, the main driver of the volatility of the local currency liabilities is the FX volatility (Figure 4.5).

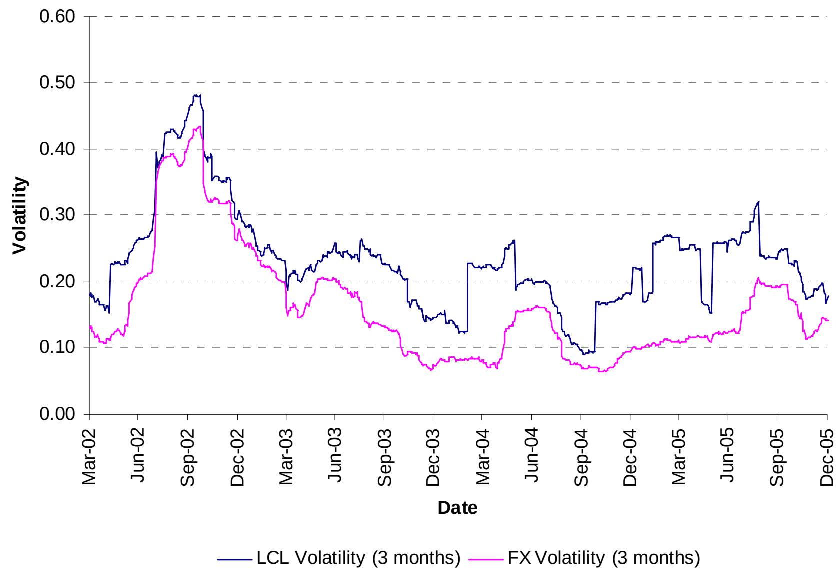


Figure 4.5 Volatility of the local currency liabilities of Brazil and the volatility of the Brazilian Real and US Dollar FX rate in the period April 2002 to December 2005. The presented volatilities have a measurement period of three months and are measured on a daily basis.

If we take a closer look at the volatility of the local currency liabilities we examine a number of sudden jumps in volatility. These jumps in the volatility of the local currency liabilities are caused by the local currency debt component of the volatility. The volatility of the local currency debt is driven by changes in the interest rate market and issuances (or redemptions) of debt. It is the discrete property of the issuance of debt that has a disproportional impact on the volatility of the local currency liabilities. Therefore, we eliminate this impact on the volatility of the local currency liabilities by excluding incidental large absolute log returns. We consider log returns larger than 125% of the maximum log return of the preceding month to be caused by incidental large debt issuances. The boundary value of 125% is arbitrary but in our case study it eliminates the jumps in volatility as required and it does not seem to affect the remaining components of the volatility of the local currency liabilities much. We can see this in Figure 4.6 where the adjusted and original volatility of the local currency liabilities are shown.

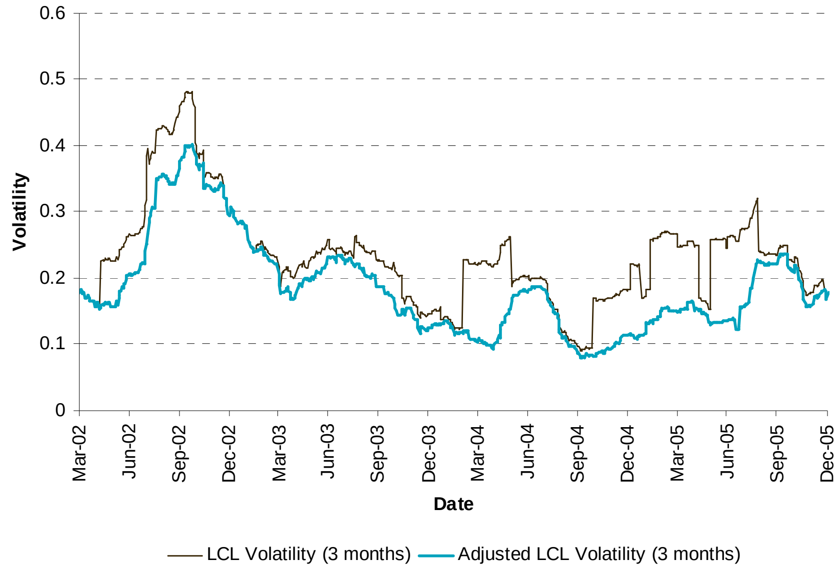


Figure 4.6 Annualized volatility and adjusted volatility of the Brazilian local currency liabilities in the period April 2002 to December 2005. The presented volatilities have a measurement period of three months and are measured on a daily basis. The adjusted volatility is the volatility where excessive log returns (more than 125% of the last month maximum log return) are eliminated.

4.2 Software Application

In the previous section we have seen that all input variables of the sovereign CCA model can be gathered or constructed on every (business) day of the research period with bond data, interest rate data, and FX rate data from Bloomberg, and data on the monetary base from the Central Bank of Brazil. First, we organize the data on three different Excel sheets that we can use to construct or access time series of the local currency liabilities, the volatility of the local currency liabilities, the foreign distress barrier, and the risk-free interest rate:

1. Bond data
2. Monetary base (time series)
3. FX rates, interest rates, and indices (time series)

The bond data contains the issue date, the maturity date, the coupon percentage, and the total amount outstanding of all specific bonds that were active from April 2002 to December 2005. The nominal value of the LFT bond types are indexed to the accumulated SELIC index which we can construct from the overnight SELIC rate available at Bloomberg. The nominal value of the NTN-B and NTN-C bond types are indexed to the IPCA and IGP-M inflation indices respectively, which are available at Bloomberg on a monthly basis. We estimate the daily levels of these indices by linearly extrapolating the index values of the last two months. The data collection from Bloomberg to Excel can easily be done with the standard Bloomberg download functions of the add-in of the Bloomberg Terminal in Excel. Table B.2 of Appendix B shows the number of missing values the interest rates data and Table C.1 of Appendix C shows the number of missing values in the FX rates data. The missing values are dealt with by calculating the average of the last known value and the next available value, which could cause a predictive error because the next available value contains forward looking information. This error would be negligible since the number of missing values of the FX rates is very small and the interest rate is only an estimate of the required yield.

Next, we construct all input variables for every date during the research period and calculate the output of the sovereign CCA model. Because we need daily information for the volatility of the local currency liabilities anyway, we calculate all our output on a daily basis which requires a large number of calculations. For this purpose, we have built a Matlab program that performs the following operations:

1. Read the bond data and the time series of the Excel sheets.
2. Constructs time series of:
    a. The local currency liabilities
    This operation requires a double for-loop construction[2] *where on every date of the research period the market values of all active local bonds are determined and accumulated to find the time series of the local currency debt. The time series of the local currency liabilities are found by adding the time series of the local currency debt and monetary base.*
    b. The foreign distress barrier
    This operation requires a double for-loop construction[3] *where on every date of the research period the rule for the distress barrier is applied to all active foreign bonds and the corresponding values are accumulated to find the time series of the foreign distress barrier.*
    c. The volatility of the local currency liabilities
3. Solve equations (35) and (36) of the sovereign CCA model iteratively for all dates to find time series of the value and volatility of the assets.
4. Calculate the model risk measures that we have described in Chapter 3:
    - spread: s
    - (risk adjusted) default probability: $N(d_2)$
    - distance to distress: d_2
5. Write the model's output and the constructed time series to an Excel file.

The output of the software application thus consists of the implied value and volatility of the assets and the risk measures of Brazil during the research period. The risk measures can be compared with the actual 5 year CDS spread of Brazil.

Since the Matlab program has to run a double for-loop construction and the calculations are done on a daily basis, the calculation time on a modern computer is quite long (≈ half

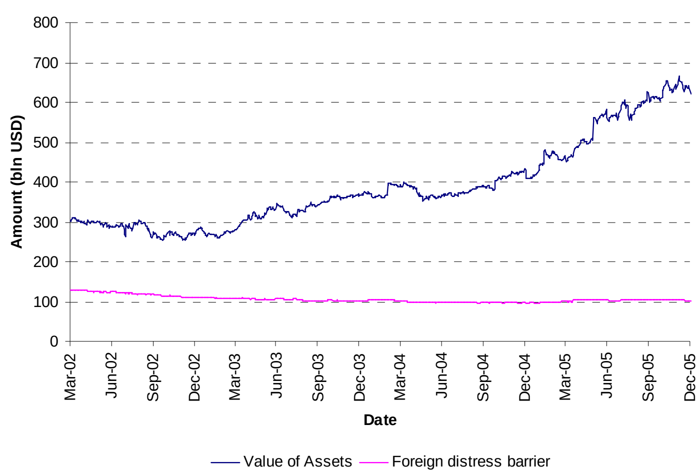
[2] We are forced to use a double for-loop construction instead of matrix operations because we have to determine the market value of each individual bond issuance by discounting the bond specific cash flows.
[3] Here, we can also use matrix operations instead of a double for-loop construction but in our case it was easier to employ a similar approach as is used for the construction of the time series of the local currency liabilities.

an hour). The Matlab program namely has to determine the market value of 142 local currency bonds and the foreign distress barrier out of 157 foreign currency bonds or Dollar-linked bonds on 980 business days. We could decrease the calculation time by a factor 21 (approximately the number of business days in a month) if we perform the calculations on a monthly basis. Therefore, we have to consider a smart method to determine the volatility of the local currency liabilities. The calculation time will improve anyhow if we build an application of the sovereign CCA model to determine risk measures of today since market values of recent bond data are available in Bloomberg and therefore we do not have to determine the present value of the bonds' future cash flows. For now we accept the calculation time.

4.3 Results

This section shows the results of the case study on Brazil that are obtained from our software application of the sovereign CCA model. Comparable results from the study of an application of the sovereign CCA model to Brazil by Gray and Malone (2008) are shown next to our results. The study of Gray and Malone is called the 'benchmark' in the next part of Chapter 4.

Figure 4.7 shows the implied asset value and the foreign distress barrier of Brazil for our case study and the benchmark. The foreign distress barrier of both our case study and the benchmark is around 100 billion US Dollar over time. The implied asset value of our case study roughly follows the same pattern as in the benchmark. However, the level of the implied asset value is in our case study around 100 billion US Dollar above the level of the implied asset value in the benchmark.



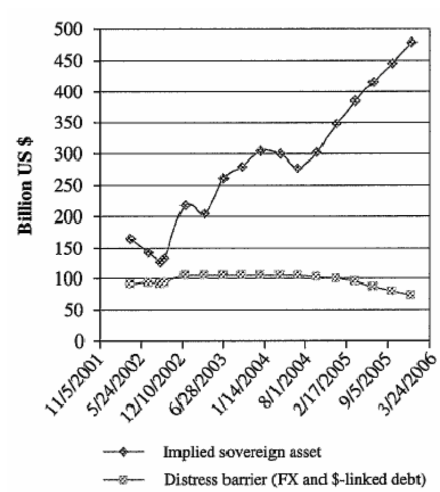


Figure 4.7 The implied sovereign asset value and the foreign distress barrier of Brazil in the period April 2002 to December 2005. The left figure shows the result of our case study. The right figure shows comparable results and is copied from Gray and Malone (2008).

Figure 4.8 shows the default probability and the 5 year CDS spread of Brazil for our case study and the benchmark. The default probability in our case study is much lower than the default probability of the benchmark. The maximum default probability is 8.54% in our case study and more than 30% in the benchmark. After March 2003 the default probability of Brazil is even constantly close to zero according to our results. The default probability is always between 5% and 10% in the benchmark for the same period. We use similar 5 year CDS data as the benchmark to evaluate the risk measures.

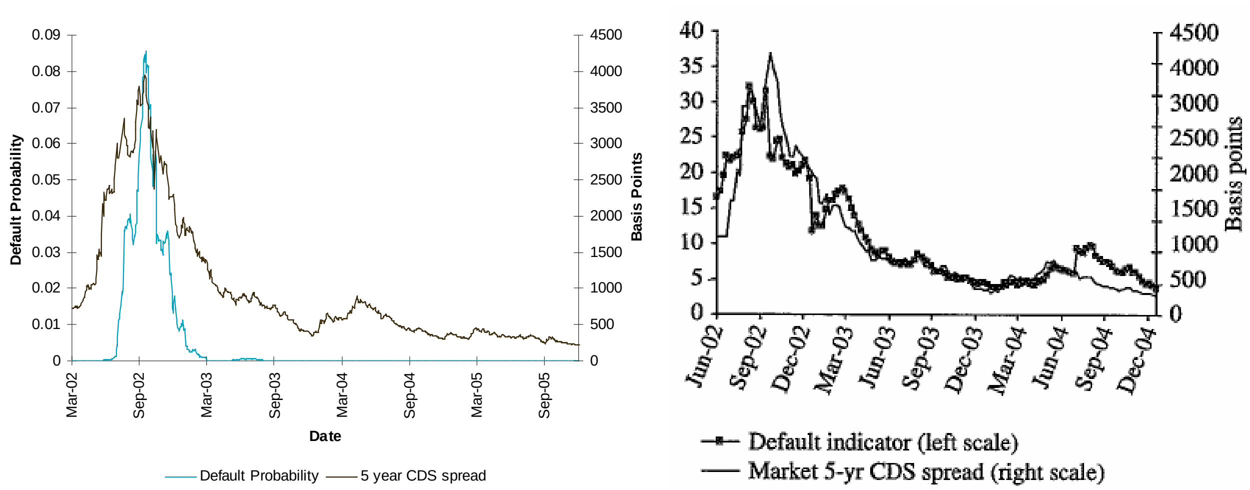


Figure 4.8 The default probability (left scale) and the actual 5 year CDS spread (right scale) of Brazil in the period April 2002 to December 2005. The left figure shows the result of our case study. The right figure shows comparable results with the default indicator being the default probability in percentages and is copied from Gray and Malone (2008).

In Figure 4.9 we can clearly see that the risk measures default probability and spread of the sovereign CCA model are very similar except for the scale of these measures. Both risk measures only show a signal in the period of June 2002 to March 2003 and are close to zero in the surrounding periods.

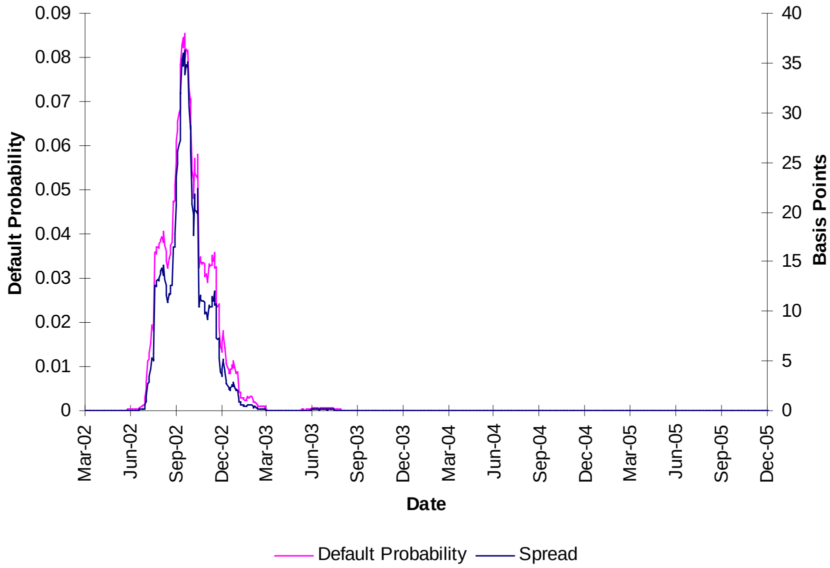


Figure 4.9 The risk measures default probability (left scale) and spread (right scale) according to the sovereign CCA model of Brazil in the period April 2002 to December 2005.

Figure 4.10 shows the distance to distress of Brazil that we find in our case study and the benchmark. The distance to distress of the benchmark is calculated only on a quarterly basis. Corresponding to the lower default probabilities, the level of the distance to distress is higher in our case study than in the benchmark. However, we see roughly the same pattern in the distance to distress of both studies. We observe that the minimum distance to distress of both studies is at October 2002. According to the higher frequency data of our case study, the upward trend in the period thereafter is actually not as stable as it appears to be in the benchmark.

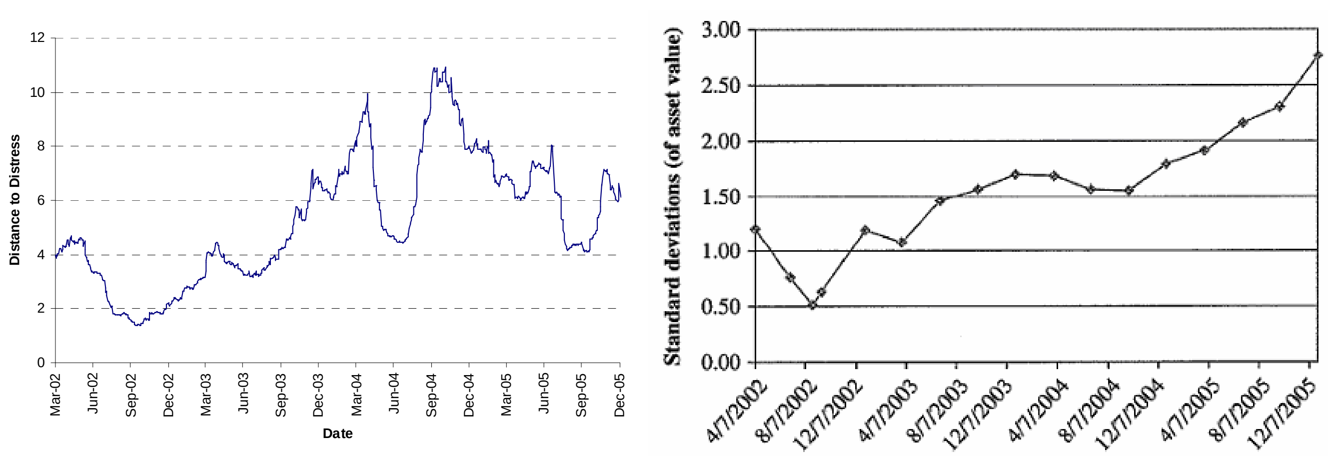


Figure 4.10 The distance to distress of Brazil in the period April 2002 to December 2005. The left figure shows the result of our case study. The right figure shows comparable results and is copied from Gray and Malone (2008).

Figure 4.11 shows the relation between the distance to distress of our case study and the actual 5 year CDS spread of Brazil. The level of distance to distress and the 5 year CDS spread are negatively correlated (-0.70).

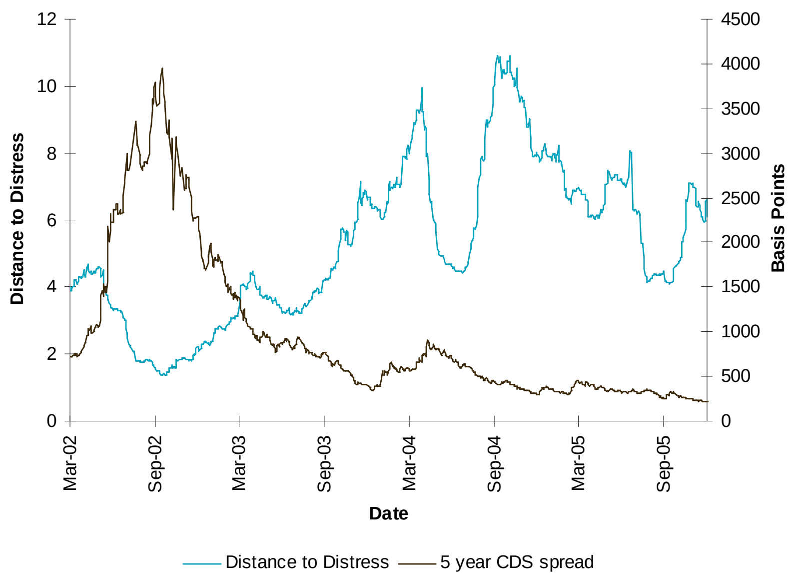


Figure 4.11 The distance to distress (left scale) and the actual 5 year CDS spread (right scale) of Brazil in the period April 2002 to December 2005.

Figure 4.12 shows that the relation between the distance and the CDS spread appears to be exponential rather than linear. The distance to distress is heteroscedastic because for small CDS spreads the distance to distress can range up to 4 standard deviations of the asset return volatility that the value of the assets is away from the foreign distress barrier, while for large CDS spreads this range is much smaller.

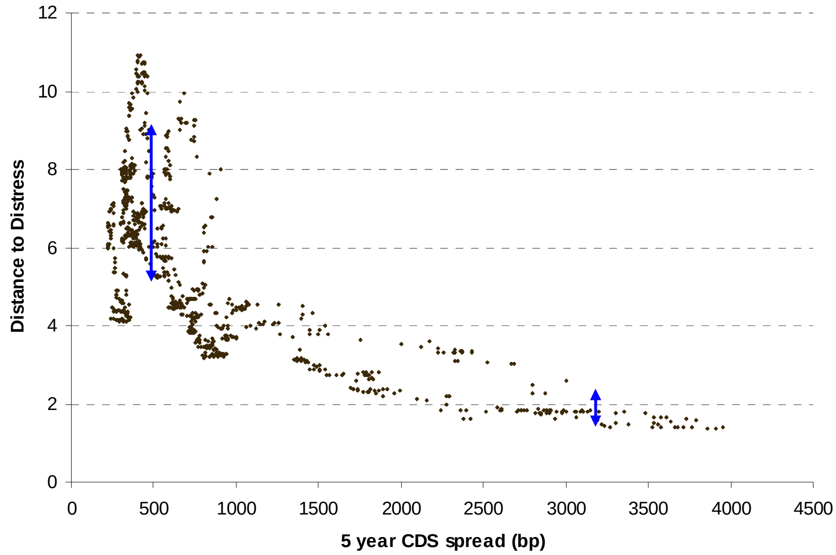


Figure 4.12 Scatter plot: The distance to distress versus the actual 5 year CDS spreads of Brazil in the period April 2002 to December 2005. The blue arrows indicate the range in the distance to distress for small and large CDS spreads.

4.4 Model Discussion

We can clearly distinguish the Brazilian crisis of 2002-2003 in our case study. At October 2002 the default probability and the spread of Brazil are at their maximum level and the distance to distress was at its minimum according to the sovereign CCA model. This is in line with the 5 year CDS spread of Brazil that was at a record height at the same time. At October 2002 the CDS spread reached 3951.5 bp (1 basis point = 0.01%), meaning that after buying a CDS an investor had to pay an annual premium of as much as 395.15 US Dollar to secure an international Brazilian government bond with a face value of 1000 US Dollar. After October 2002 the situation improves as we can see in our case study where the default probability and the spread decrease and the distance to distress increases. Again, this corresponds with actual CDS data from where we observe a declining trend after October 2002.

It may sound odd that the economic situation of Brazil improves after October 2002, while we can see from Figure 4.1 to 4.3 that the local currency debt stock is only increasing. Why does the sovereign CCA model reward governments for issuing more debt? From Figure 4.7 we can see that by issuing more local currency debt the implied assets of Brazil also increase while the foreign distress barrier remains at the same level. It is a positive sign that a country is able to raise capital for their expenses by issuing local currency debt because it shows an improvement of the liquidity of the local market through which a country can borrow money under more favorable conditions as it is no longer forced to borrow money on a foreign market. Remember that in Chapter 3 we have seen that Gray et al. (2007) state that the local currency liabilities of a sovereign country are similar to the equity of a corporation and the foreign currency debt is considered to be the risky debt of a corporation. Low leverage[4] corporations have a capital structure with relatively high equity. Such corporations are less risky and can therefore borrow at a lower spread than a similar corporation that has high leverage. The same holds for countries in the sovereign CCA model for which the equivalent to company leverage is the ratio of foreign currency debt to local currency liabilities.

The implied asset value is around 100 billion US Dollar above the implied asset value of the benchmark (Figure 4.7). Although we do not know the exact data source of the benchmark study by Gray and Malone, this difference could be caused by the volatility of the local currency liabilities which is an important factor that influences the implied asset value in the sovereign CCA model. In general, a higher volatility of the local currency liabilities leads to a decline in the implied asset value as illustrated by Figure 4.13. It is a good possibility that a significant part of the difference in the implied asset value between our case study and the benchmark is because we use a lower volatility of the local currency liabilities than the benchmark.

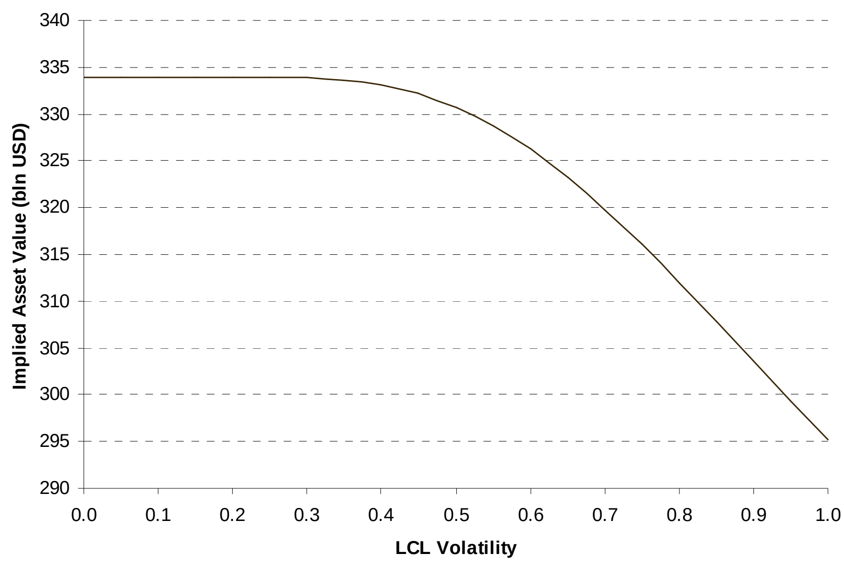


Figure 4.13 The implied asset value versus the volatility of the local currency liabilities in the sovereign CCA model with LCL = 250, B_f = 100, r = 3.5%, and T = 5 year.

We do not obtain the same tight relationship between the default probability and the actual 5 year CDS spread as the benchmark (Figure 4.8). The default probability in our case study is much lower than in the benchmark and is even close to zero in the research periods before June 2002 and after March 2003. The default probability of the benchmark is constantly above 5% in those periods. The difference in the default probability of our case study and the benchmark is mainly caused by the volatility of the local currency liabilities.

[4] Leverage is the ratio debt to equity.

We take a closer look at the date of January 2004 to underline the importance of the volatility of the local currency liabilities as input variable of the sovereign CCA model. At January 2004 the foreign distress barrier B_f is in both studies around 100 billion US Dollars, the local currency liabilities *LCL* are 270 billion US Dollar in our case study and we deduct from the implied asset value (300 billion US Dollar) that the *LCL* is at least 200 billion US Dollar in the benchmark. The time horizon is 5 years for both studies and we presume that the risk-free interest rate is 3.5%. The only unknown variable of the benchmark study is the volatility of the local currency liabilities. We derive this volatility by searching the implied level of the volatility of the local currency liabilities that gives a default probability of 5%. Figure 4.14 shows the default probability according to the sovereign CCA model versus the volatility of the local currency liabilities under different leverages. A higher leverage leads to a larger default probability but the difference in leverage between our case study and the benchmark has only a small influence on the model's default probability. From Figure 4.14 we observe that the volatility of the local currency liabilities must be 44% to get a default probability of 5%. In our case study the volatility of local currency liabilities is always below 40% even in the crisis period (Figure 4.6).

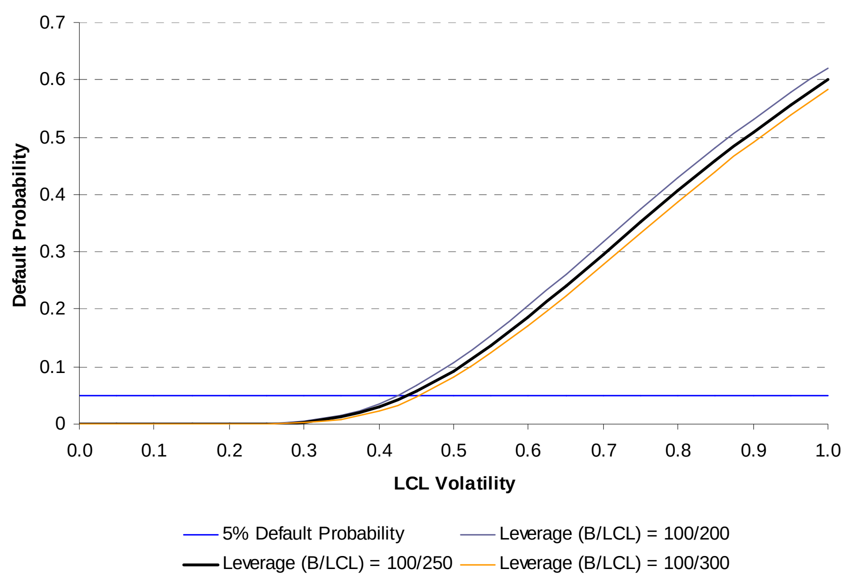


Figure 4.14 The default probability versus the volatility of the local currency liabilities in the sovereign CCA model for different leverages (r = 3.5% and T = 5 year). The leverage is the ratio risky debt (foreign distress barrier) to equity (local currency liabilities).

The volatility of the local currency liabilities is thus too low in our case study compared with the benchmark. Adjusting the measurement period does not give us volatilities that are constantly above 40% either (Figure 4.4). The method to measure the volatility of the local currency liabilities is not stated in Gray et al. (2007) or Gray and Malone (2008). Dale Gray confirmed to us in a conference call that he enlarged the volatility by adding a floor value of 30% and using artificially high estimates for the correlation between the three components of the volatility of the local currency liabilities. He argues that financial markets are not (always) normally distributed and by enlarging the volatility of the local currency liabilities he simulates a probability distribution with fat tails. If we want an unbiased quantitative value for the volatility of the local currency liabilities we cannot use the normal distribution to find an appropriate default probability. Similarly, Moody's KMV does not use the normal distribution either in the corporate CCA model to determine the default probability, as we have seen in Chapter 3. Instead, they replace the normal distribution by a historical database of corporate defaults. Such a database does not exist for sovereign defaults and if it does it would contain only a few observations.

The distance to distress of our case study roughly follows the same pattern as in the benchmark, but is logically at a higher level due to the lower volatility of the local currency liabilities (Figure 4.10). On forehand, we expected the relation between the distance to distress and the CDS spreads to be negative because a low distance to distress indicates that a country is close to default and therefore has a high credit risk. Although the relation between the distance to distress and the CDS spread appears to be exponential rather than linear (Figure 4.12), the distance to distress has a high negative linear correlation with the actual 5 year CDS spread in our case study.

It is noticeable that beyond the crisis period 2002-2003 the level of distance to distress for Brazil is high compared to the level of distance to distress of corporations. Figure 4.15 shows that the 95th percentile of the level of distance to distress of corporations (measured by a quantitative model of Robeco) is largely exceeded by the maximum level of distance to distress of Brazil (10.92) in our case study. This is not a surprising result because it is far more likely that a corporation defaults than the whole country.

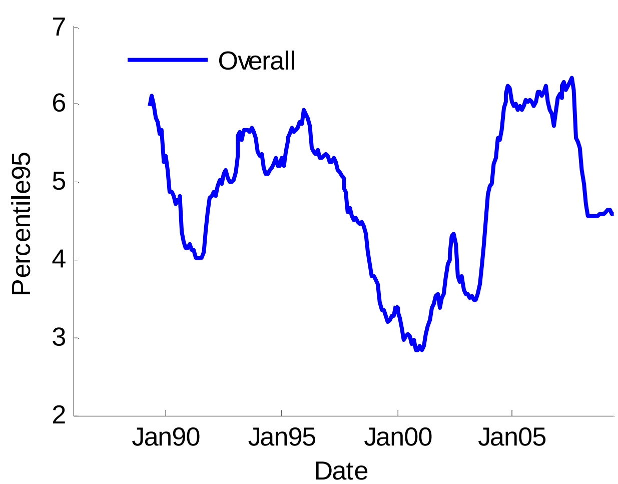


Figure 4.15 The 95th percentile of the distance to distress level for a universe of nearly 1000 corporations in the period 1990 to 2010.
Source: Robeco Quantitative Strategies.

Figure 4.16 shows the distance to distress versus the volatility of the local currency liabilities for different leverages. We distinguish a common leverage situation (*D*/*E* = 100/25) for corporations with the blue line and three leverage situations for Brazil that we observe during the research period. The main cause of the high distance to distress for Brazil compared to corporations is that the leverage of the countries in the sovereign CCA model is very low compared to the equivalent leverage of corporations in the corporate CCA model. If we concentrate on the three leverage situations of Brazil, we see that the volatility of the local currency liabilities has a large influence on the risk measure distance to distress in the sovereign CCA model. At low leverage, a change in the volatility has a larger impact on the distance to distress than a change in the leverage. Particularly when the volatility of the local currency liabilities is low, a change in the volatility causes a drastic change in the distance to distress. The FX volatility is the most important driver of the volatility of the local currency liabilities (Figure 4.6) and thus a very important input variable of the sovereign CCA model.

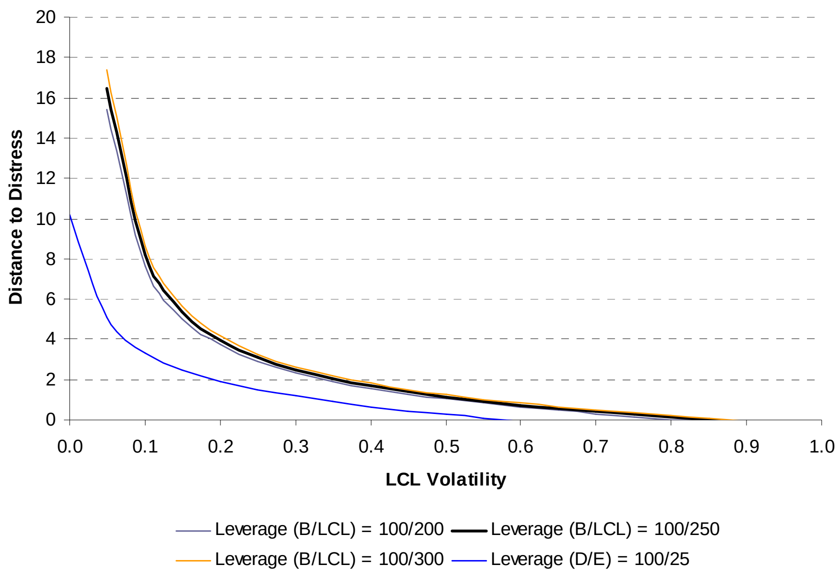


Figure 4.16 The distance to distress versus the volatility of the local currency liabilities in the sovereign CCA model for different leverages (r = 3.5% and T = 5 year). The leverage is the ratio risky debt (foreign distress barrier) to equity (local currency liabilities).

4.5 Trading Opportunities

The risk measure distance to distress of the sovereign CCA model is a promising risk measure that we can possibly use in a trading strategy with CDS contracts. In our case study, we observe a clear negative (nonlinear) relation between the distance to distress of Brazil and the actual 5 year CDS spread. Next to the distance to distress, it is interesting to analyze if the FX volatility offers trading opportunities as it is the most important input factor of the sovereign CCA model. Unfortunately, we cannot determine a quantitative default probability that we can use in a trading strategy. Since the risk measures default probability and spread are very similar and for large periods close to zero, we cannot use the spread found by the sovereign CCA model in a trading strategy with CDS contracts either. Therefore, the risk measures default probability and spread are not taken into account in the following sections of this master thesis and we concentrate on the sovereign CCA model's risk measure distance to distress (d_2) and the most important input factor FX volatility (σ_{FX}).

If we want to build a successful trading strategy with 5 year CDS contracts upon the distance to distress, there should be a relation between the *change* in the distance to distress and the *change* in the CDS spread next to the close relation between the level of the distance to distress and the CDS spread that we have already found for Brazil. Moreover, a change in the distance to distress should have predictive power on the change in the CDS spread. The same holds for the FX volatility of Brazil. Therefore, we test in this section if a change in the distance to distress and a change in the FX volatility have explanatory and predictive power on the change in the 5 year CDS spread. If we find promising results for Brazil, we may exploit this in a trading strategy with 5 year CDS contracts of Brazil and other emerging countries with a free floating currency and debt issued in both local and foreign currencies.

The explanatory power of a change in the distance to distress or a change in the FX volatility on the change in the CDS spread is tested by analyzing contemporary correlations and linear regressions. The predictive power of a change in the distance to distress or a change in the FX volatility on the change in the CDS spread is tested by analyzing lead-lag correlations and linear regressions. We use absolute changes in the distance to distress, the FX volatility and the CDS spread. Because of the heteroscedasticity of the distance to distress and the exponential high level of the distance to distress at low volatilities, we also take relative changes in the distance to distress into account. We expect for example that a deterioration of the level of distance to distress from 2 to 1 has more influence on the country's economy than a deterioration of the level of the distance to distress from 12 to 11. We set the change in the 5 year CDS spread as the dependent variable ΔY and we set the change in the distance to distress or the change in the FX volatility as the independent variable ΔX. Because the distance to distress contains heteroscedasticity, a change in the level of distance to distress does not have to lead to an immediate change in the CDS spread. The distance to distress is thus not a very fast signal in a trading strategy with CDS contracts and has to be measured over longer periods when used in a trading strategy. Therefore, we look at monthly changes and end-of-the-month values of time t during the research period of our case study.

We first test the explanatory power of ΔX and ΔY. Therefore, we look at the correlations and linear regressions of an n month change in X and the contemporary n month change in Y. We describe the contemporary changes for absolute changes of the X and Y variable with (43):

$$\begin{cases} \Delta X = X_{t+n} - X_t, \\ \Delta Y = Y_{t+n} - Y, \end{cases} \tag{43}$$

and for relative changes of the X variable with (44):

$$\begin{cases} \Delta X = \ln\left(\dfrac{X_{t+n}}{X_t}\right), \\ \Delta Y = Y_{t+n} - Y. \end{cases} \tag{44}$$

Furthermore, we test the predictive power of ΔX on ΔY. Therefore, we look at the correlations and linear regressions of an n month change in X and the subsequent one month change in Y. Thus, ΔX is the leading signal and ΔY is the lagging signal. We describe the lead-lag changes for absolute changes of the X and Y variable with (45):

$$\begin{cases} \Delta X = X_{t+n} - X_t, \\ \Delta Y = Y_{t+n+1} - Y_{t+n}, \end{cases} \tag{45}$$

and for relative changes of the X variable with (46):

$$\begin{cases} \Delta X = \ln\left(\dfrac{X_{t+n}}{X_t}\right), \\ \Delta Y = Y_{t+n+1} - Y_{t+n}. \end{cases} \tag{46}$$

The linear regression model for both contemporary and lead-lag changes is described by (47):

$$\Omega : \begin{cases} \Delta Y = \alpha + \beta * \Delta X + \varepsilon, \\ \varepsilon \sim N(0,1). \end{cases} \tag{47}$$

We want to know if ΔY significantly depends on ΔX. Therefore, we calculate the t-value of the slope coefficient β that we obtain from the linear regression model for contemporary changes to see if the distance to distress and the FX volatility are significant explanatory factors. Similarly, we calculate the t-value of the slope coefficient β that we obtain from the linear regression model for lead-lag changes to see if the distance to distress and the FX volatility are significant predictive factors. The t-value is given by formula (48):

$$t_{value} = \frac{\hat{\beta}}{SE_{\hat{\beta}}}, \qquad (48)$$

with SE_β the standard error of the least-squares estimate β.

Table 4.2 shows the contemporary correlations and t-values of ΔX with ΔY. Except for the measurement period of one month, the absolute change in the CDS spread negatively depends on the absolute change in the distance to distress with a t-value that corresponds to a significance level of at least 5%[5]. This gives confidence that we can build a successful trading strategy using the sovereign CCA risk measure distance to distress as a signal. The linear dependence of the absolute change in the CDS spread on the relative change in the distance to distress and the absolute change in the FX volatility is even larger with a t-value that corresponds to a significance level of at least 1% for all measurement periods. In general, longer measurement periods result in a higher contemporary correlation.

Table 4.2 Contemporary correlations and t-values of an *n* month absolute or relative change in *X* (the distance to distress or the FX volatility of Brazil) and an *n* month absolute change in *Y* (the 5 year CDS spread of Brazil) during the period April 2002 to December 2005.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility	
Measurement Period (*n* months)	**Contemporary Correlation**	**T-Value**	**Contemporary Correlation**	**T-Value**	**Contemporary Correlation**	**T-Value**
1	-0.23	-1.52	-0.38	-2.65	0.46	3.37
2	-0.31	-2.09	-0.54	-4.12	0.71	6.44
3	-0.35	-2.34	-0.62	-4.94	0.77	7.60
6	-0.46	-3.16	-0.73	-6.51	0.85	9.78
9	-0.31	-1.90	-0.59	-4.24	0.78	7.33
12	-0.32	-1.85	-0.57	-3.88	0.81	7.80
24	-0.76	-5.10	-0.83	-6.49	0.88	8.12

Table 4.3 shows the lead-lag correlations and t-values of ΔX with ΔY. Up to a lead of three months, the absolute change in the distance to distress has some predictive power on the next month absolute change in the CDS spread since the next month absolute change in the CDS spread negatively depends on the change in the distance to distress. However, the corresponding t-values are not significant. For relative changes of the distance to distress the predictive power on the next month absolute change in the CDS spread is improving but still not significant. Nevertheless, the change in the distance to distress could still have predictive power on the CDS spread because there might be a nonlinear relationship between the change in the distance to distress and the change in the CDS spread as we have already seen in Figure 4.12 where we look at the levels of the distance to distress and the CDS spread. The predictive power of the change in the FX volatility on the change in the CDS spread is more promising. The t-values of the first three months correspond to a significance level of at least 10%.

[5] We perform two-sided t-tests. The degrees of freedom depend on the length of the measurement period.

Table 4.3 Lead-lag correlations and t-values of a leading *n* month absolute or relative change in *X* (the distance to distress or the FX volatility of Brazil) and a lagging one month absolute change in *Y* (the 5 year CDS spread of Brazil) during the period April 2002 to December 2005.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility	
Lead (*n* months)	Lead-Lag Correlation	T-Value	Lead-Lag Correlation	T-Value	Lead-Lag Correlation	T-Value
1	-0.09	-0.61	-0.24	-1.61	0.39	2.71
2	-0.08	-0.50	-0.20	-1.33	0.35	2.37
3	-0.05	-0.32	-0.13	-0.82	0.26	1.72
6	0.36	2.35	0.43	2.91	-0.39	-2.61
9	0.23	1.40	0.24	1.43	-0.20	-1.21
12	0.15	0.83	0.08	0.42	-0.01	-0.06
24	0.23	1.01	0.16	0.73	-0.07	-0.30

Finally, we evaluate the autocorrelations of the distance to distress (absolute and relative), the FX volatility, and the CDS spread by examining the correlation and t-values of an *n* month change in these variables and the next month change of the same variable (Table 4.4). It is noticeable that the autocorrelation in the CDS spread is the highest. Up to a lead of three months, there is predictive power of the absolute change in the CDS spread on the next month absolute change in the CDS spread itself with t-values that correspond to a significance level of at least 10%. Thus, apart from trading strategies with 5 year CDS contracts based on the absolute and relative changes in the distance to distress and the absolute changes in the FX volatility, it is also worth to research trading strategies based upon the trend in the 5-year CDS spread.

Table 4.4 Autocorrelations and t-values of an *n* month absolute (or relative) change in the distance to distress, the FX volatility, and the 5 year CDS spread of Brazil and the next month absolute (or relative) change of the same signal during the period April 2002 to December 2005.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility		5 year CDS spread	
Lead (*n* months)	Auto-correlation	T-Value	Auto-correlation	T-Value	Auto-correlation	T-Value	Auto-correlation	T-Value
1	0.21	1.42	0.30	2.07	0.26	1.76	0.29	1.98
2	0.07	0.43	0.19	1.27	0.32	2.17	0.37	2.58
3	-0.22	-1.45	-0.07	-0.45	0.08	0.51	0.30	2.02
6	-0.20	-1.21	-0.20	-1.23	-0.22	-1.36	-0.21	-1.31
9	-0.15	-0.86	-0.18	-1.05	-0.09	-0.53	0.00	-0.01
12	-0.17	-0.94	-0.02	-0.10	0.01	0.07	0.16	0.91
24	-0.25	-1.13	-0.14	-0.59	-0.07	-0.30	0.15	0.65

4.6 Conclusion

The case study of the sovereign CCA model on Brazil provides us with more insight in the dynamics of the model. We can clearly distinguish the Brazilian crisis of 2002-2003 in the output of the sovereign CCA model. However, the output of our case study differs from the output of a similar study of the model on Brazil by Gray and Malone (2008). The difference is caused by the approach to measure the volatility of the local currency liabilities. We prefer the unbiased quantitative historical volatility we use in our case study over the volatility of Gray and Malone who estimate high values for the volatility amongst others by adding a floor value. Robustness checks on the sovereign CCA model with different measurement methods for volatility (e.g. changing the measurement period of three months and the log return boundary value of 125%) are not performed in this research project but would be interesting to look at in a follow up study.

The volatility of the local currency liabilities that we use in our case study leads to default probabilities and spreads that are close to zero for large periods and are therefore unsuitable for a trading strategy in those periods. The risk measure distance to distress shows more promising results because we observe a negative (nonlinear) relationship with actual 5 year CDS spreads. The most important input variable of the sovereign CCA model appears to be the volatility of the local currency liabilities and its main driver is the FX volatility.

Both the distance to distress and the FX volatility are promising signals that we can use in a trading strategy with 5 year CDS contracts. We observe a clear relation in absolute and relative changes in the distance to distress and contemporary changes in the CDS spread. We also observe a clear relation in absolute changes in the FX volatility and contemporary changes in the CDS spread. Moreover, especially the FX volatility has predictive power on the CDS spread. Finally, we observe autocorrelation in the 5 year CDS spread of Brazil so we can use a trend strategy as well. In the next chapter we test if we can use the signals in a successful trading strategy applied to multiple emerging countries.

Chapter 5

Trading Strategies

In the case study of the sovereign CCA model on Brazil of the previous chapter we discovered opportunities for trading strategies with 5 year CDS contracts. The risk measure distance to distress of the sovereign CCA model can be used in a trading strategy as well as the FX volatility which appears to be the most important input factor of the sovereign CCA model. Furthermore, there is a trend in the CDS data of Brazil that we can use in a trading strategy. In this chapter we further analyze these three trading opportunities. Therefore, we first determine the distance to distress and the FX volatility of eight emerging countries with a floating FX rate and gather the 5 year CDS data of these countries. We test for contemporary and lead-lag correlations for all countries to see if the changes in the distance to distress (absolute and relative) and the FX volatility remain explanatory and predictive variables for the change in CDS spread. Next, we propose trading strategies with 5 year CDS contracts that are based on the distance to distress, the FX volatility, or the trend in the CDS spread. The success of these strategies is shown in the results section and discussed subsequently. Finally, we end this chapter with the conclusion and follow up ideas.

5.1 Universe

The distance to distress, the FX volatility, and the trend in the 5 year CDS data have explanatory and predictive power on the 5 year CDS spread of Brazil during the period of April 2002 to December 2005. This gives confidence that we can build successful trading strategies upon these three variables. We select emerging countries for our trading strategies that have a considerable amount of foreign debt and therefore meet the requirements of the sovereign CCA model. The emerging countries must also have a floating FX rate so that we can use the FX volatility in a trading strategy. Other selection criteria of the countries are the liquidity of the local currency, the historical quality of the 5 year CDS data, and the historical size of the foreign debt market. We select the following eight emerging countries in the universe of our trading strategies:

1. Brazil
2. Hungary
3. Mexico
4. Philippines
5. Poland
6. South Africa
7. South Korea
8. Turkey

We select these countries because they have “the most liquid emerging market currencies” according to broker information of Credit Suisse. Originally, the Czech Republic is also listed to have one of the eight most liquid currencies, but we replace the Czech Republic by the Philippines because the historical quality of the 5 year CDS data of the Czech Republic that is available in Bloomberg is very poor. The historical quality of the 5 year CDS data of the Philippines is one of the best that is available in Bloomberg compared to emerging countries that are not in our universe[6]. Moreover, the Philippines have a large historical foreign debt market and currently the largest weight of all Asian countries in the J.P. Morgan Emerging Market Bond Index Global (EMBI Global). The EMBI Global tracks total returns for traded foreign currency bonds in emerging markets. Table 5.1 shows the position and the weight of the eight selected emerging countries in the EMBI Global.

Table 5.1 Position and weight of the eight selected emerging countries in the Emerging Market Bond Index Global (EMBI Global) of J.P Morgan. The EMBI Global tracks total returns for traded foreign currency bonds in up to 46 emerging markets.

	01-Apr-02		26-Feb-10	
Country	**Position**	**Weight**	**Position**	**Weight**
Brazil	1	20.9%	1	12.2%
Hungary	25	0.4%	22	1.0%
Mexico	2	19.2%	2	12.0%
Philippines	6	3.9%	5	7.4%
Poland	12	1.9%	13	2.1%
South Africa	19	1.1%	17	1.6%
South Korea	4	4.9%	-	0.0%
Turkey	8	3.5%	4	10.0%

The sample period that we use to test our trading strategies depends on the historical availability of the input data of the sovereign CCA model and the 5 year CDS data. The 5 year CDS data of the Philippines is available from April 2002, the other data input starts earlier. We set our sample period from April 2002 to February 2010 (the start of the research project). Unfortunately, this sample period is too short to perform an in-sample and out-of-sample test on the trading strategies because we cannot select different periods that contain enough representative market behavior (e.g. an actual country default situation is not yet available in the data). Therefore, we only perform an in-sample test on the trading strategies which means that we have to look critically at the stability and robustness of the results.

We use the approach described in Chapter 4 to construct time series of the local currency liabilities, the volatility of local currency liabilities, and the foreign distress barrier for the eight emerging countries as input variables of the sovereign CCA model. Like in Chapter 4, we use the 5 year US government interest rate as the risk-free interest rate, a 5 year time horizon, and the US Dollar as the numéraire currency unit as the other inputs of the model. A generalized version of the software application described in Chapter 4 is used to determine the distance to distress of each country in the sample period. In general, we

[6] The reason that we do not select Argentina and Russia (two major countries that recently defaulted on their debt) is that their CDS data is only available from 2004 which is after the default.

notice that the proportion of foreign currency debt decreases over time during the sample period. For all countries we observe that the FX volatility is the main driver of the volatility of the local currency liabilities and therefore the most input factor of the sovereign CCA model.

Table B.1 of Appendix B gives an overview of all bonds that are used to determine the distance to distress for each country and the used interest rate to discount the cash flows of the fixed rate bonds. The number of missing values of the interest rates is shown in Table B.2 of Appendix B. To check the quality of the bond data, we also construct time series of the market value of the total debt (local currency and foreign currency debt) of each country that we compare with the reported values of total debt by the government of the country, the Organization for Economic Cooperation and Development (OECD), and/or the European Commission. We cannot check the quality of the South African bond data because we do not have reported values of the total debt of South Africa. Figure B.1 to B.7 of Appendix B show the calculated market value of the total debt and the reported value of the total debt of the remaining seven countries. The calculated market values of the total debt of Brazil, Hungary, the Philippines, Poland, South Korea and Turkey are similar to the reported total debt. Only the calculated market values of the total debt of Mexico deviate from the reported total debt by the Mexican government. Although we cannot discover the main cause of this difference, we remain confident in our calculation method with the Bloomberg bond data because the results of the other countries are good.

Like the volatility of local currency liabilities, the FX volatility is historically measured on a daily basis with a measurement period of three months, and annualized. We use Bloomberg data on FX rates to construct time series of the FX volatility of each country. Table C.1 of Appendix C shows that the number of missing values of the FX rates is negligible. We also use Bloomberg to collect time series of the 5 year CDS spread of the eight emerging countries. The number of missing values in the Bloomberg 5 year CDS data of the eight countries and the start date of the data are shown in Table D.1 of Appendix D. From Figure D.1 of Appendix D we can see that the quality of the 5 year CDS data improves over time as the number of missing values declines. From 2005, the missing values in the CDS data were only due to holidays.

Figure 5.1 shows the 5 year CDS spreads of the eight emerging countries in the sample period. The CDS spread of Brazil was at extreme levels during the crisis of 2002-2003. In the same period, also Turkey went through a crisis which we can see by its high CDS spread. After this period the CDS spreads of Brazil and Turkey gradually decrease too a very low spread in the years 2006 and 2007. The CDS spreads of all countries were very low in those years, but in the global financial crisis of 2008-2009 that followed the CDS spreads of all countries were peaking. The difference in the height of the CDS spreads between periods and countries demands for a risk neutral adjustment in the trading strategies.

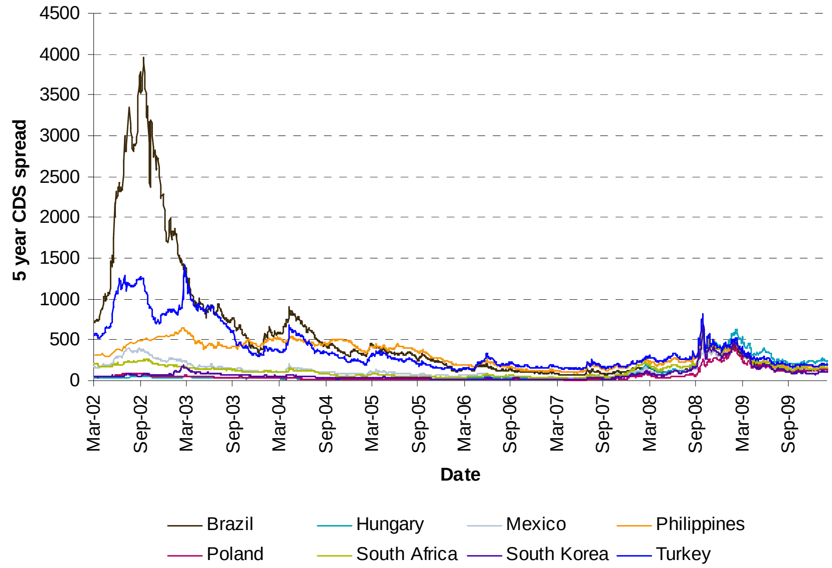


Figure 5.1 The 5 year CDS spreads of the eight selected emerging countries in the period of April 2002 to February 2020.

We test for contemporary and lead-lag correlations for all countries to see if changes in the distance to distress (absolute and relative) and the FX volatility are explanatory and predictive variables for the change in the CDS spread. We use the same approach as in Chapter 4 to perform the tests, the only difference is that we now test for eight countries instead of solely Brazil and the period is extended with more than 4 years. We use the equations (43) to (46) of Chapter 4 to describe absolute and relative contemporary changes and lead-lag changes. We use the linear regression model (47) and formula (48) of Chapter 4 to determine the t-value of the slope coefficient β which tells us if the absolute change in the distance to distress, the relative change in the distance to distress, and the absolute change in FX volatility are significant explanatory and predictive variables for the absolute change in the CDS spread.

Table 5.2 shows the average contemporary correlations and t-values of the absolute and relative change in the distance to distress, and the absolute change in the FX volatility with the absolute change in the CDS spread. Tables E.1 to E.6 of Appendix E show the elaborated data for the eight countries. The CDS spread negatively depends on the absolute change in the distance to distress. This relation is at least 10% significant[7] for all eight countries if we use a measurement period of more than two months. The CDS spread also depends negatively on the relative change in the distance to distress. With a significance of at least 2.5% for all countries if we use a measurement period of more than one month, this relation with the change in CDS spread is stronger for the relative change in the distance to distress than for the absolute change in the distance to distress. Except for the Philippines, the dependence of the CDS spreads on the absolute change in the FX volatility is at least 1% significant for all countries and measurement periods. In general, the absolute change in the distance to distress, the relative change in the distance

[7] We perform two-sided t-tests. The degrees of freedom depend on the length of the measurement period.

to distress, and the absolute change in the FX volatility have a significantly high explanatory power on the absolute change in the CDS spread.

Table 5.2 Average contemporary correlations and t-values of an *n* month absolute or relative change in *X* (the distance to distress or the FX volatility) and an *n* month absolute change in *Y* (the 5 year CDS spread). The average contemporary correlations and t-values are calculated over the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) during the period April 2002 to February 2010.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility	
Measurement Period (*n* months)	Contemporary Correlation	T-Value	Contemporary Correlation	T-Value	Contemporary Correlation	T-Value
1	-0.20	-1.98	-0.31	-3.10	0.30	3.17
2	-0.27	-2.70	-0.38	-3.95	0.39	4.20
3	-0.32	-3.27	-0.45	-4.84	0.48	5.54
6	-0.47	-5.01	-0.61	-7.78	0.65	9.78
9	-0.50	-5.51	-0.63	-8.27	0.66	10.02
12	-0.53	-5.81	-0.66	-8.77	0.68	10.68
24	-0.61	-7.00	-0.70	-9.23	0.70	9.87

Table 5.3 shows the lead-lag correlations and t-values of the absolute and relative change in the distance to distress, and the absolute change in the FX volatility with the absolute change in the CDS spread. Table F.1 to F.6 of Appendix F show the elaborated data for the eight countries. On average, we obtain the highest lead-lag correlation when we use a three month lead for the absolute change in the distance to distress, the relative change in the distance to distress, and the absolute change in the FX volatility. The absolute change in the distance to distress, the relative change in the distance to distress, and the absolute change in the FX volatility have predictive power on the change in the CDS spread with a lead up to at least three months. However, this is not significant for all countries. The absolute change in the distance to distress has the best results for Mexico, Poland, and South Africa. The relative change in the distance to distress has also good results for Hungary. The absolute change in the FX volatility has on average the highest predictive power on the change in the CDS spread because it does also well for the Philippines.

Table 5.3 Average lead-lag correlations and t-values of a leading *n* month absolute or relative change in *X* (the distance to distress or the FX volatility) and a lagging one month absolute change in *Y* (the 5 year CDS spread). The average lead-lag correlations and t-values are calculated over the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) during the period April 2002 to February 2010.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility	
Lead (*n* months)	Lead-Lag Correlation	T-Value	Lead-Lag Correlation	T-Value	Lead-Lag Correlation	T-Value
1	-0.10	-1.00	-0.10	-0.95	0.11	1.11
2	-0.10	-0.97	-0.12	-1.12	0.17	1.62
3	**-0.13**	**-1.21**	**-0.16**	**-1.50**	**0.24**	**2.31**
6	-0.05	-0.45	-0.04	-0.33	0.08	0.74
9	0.04	0.37	0.05	0.42	-0.02	-0.21
12	0.01	0.13	0.02	0.22	-0.01	-0.06
24	0.04	0.37	0.04	0.35	-0.02	-0.18

Equivalent to Chapter 4 the autocorrelations and t-values of the distance to distress (absolute and relative), the FX volatility, and the CDS spread are determined for all countries. Table 5.4 shows the average autocorrelations and t-values of the eight countries. On average, the autocorrelations of the distance to distress (absolute and relative), the FX volatility, and the CDS spread are the highest for a one month lead. The predictive power of the change in the CDS spread on the change in the CDS spread itself is not 10% significant for South Korea and the Philippines, and is even negative for Turkey. The predictive power of the change in the CDS spread on the change in the CDS spread itself is called the trend of the CDS spread. The trend of the CDS spread is the strongest for a one month lead, while we have seen that the predictive power of the change in the distance to distress (absolute and relative) and the change in the FX volatility is the strongest for a three month lead.

Table 5.4 Average autocorrelations and t-values of an *n* month absolute (or relative) change in the distance to distress, the FX volatility, and the 5 year CDS spread and the next month absolute (or relative) change of the same signal. The average autocorrelations and t-values are calculated over the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) during the period April 2002 to February 2010.

	Distance to Distress (absolute)		Distance to Distress (relative)		FX Volatility		5 year CDS spread	
Lead (*n* months)	Auto-correlation	T-Value	Auto-correlation	T-Value	Auto-correlation	T-Value	Auto-correlation	T-Value
1	**0.15**	**1.49**	**0.24**	**2.39**	**0.36**	**3.69**	**0.18**	**1.77**
2	0.10	0.93	0.16	1.54	0.22	2.14	0.12	1.19
3	-0.11	-1.04	-0.06	-0.58	0.00	0.01	0.10	0.96
6	-0.15	-1.40	-0.13	-1.22	-0.07	-0.66	-0.04	-0.40
9	-0.18	-1.66	-0.14	-1.30	-0.13	-1.21	-0.04	-0.35
12	-0.20	-1.80	-0.18	-1.70	-0.15	-1.35	0.00	0.00
24	-0.19	-1.60	-0.19	-1.57	-0.19	-1.59	-0.05	-0.44

We use the predictive power of the change in the distance to distress (absolute and relative) and the change in the FX volatility that we find in more or less extent for the eight selected emerging countries in trading strategies that take positions on expected future changes in the CDS spread of single countries. We expect to profit from the spillover of valuable information from the bond market or the currency market to the CDS market. Furthermore, we use the trend of the CDS spread in a trading strategy that takes positions on expected future changes in the CDS spread of single countries. We expect to profit from an under-reaction in the CDS market. The information-spillover and the under-reaction are effects of behavioral finance that we could exploit in quantitative trading strategies.

Since we have applied the sovereign CCA model to eight emerging countries, it is also interesting to see if we can predict the height of the 5 year CDS spread from the level of the distance to distress at any time. This could be exploited in a trading strategy that take positions on the expected relative height of the CDS spreads of the eight emerging countries. In order to successfully build such a strategy, the level of the distance to distress of the countries must be related to the height of the CDS spread of the countries. So, if the distance to distress of a country is the lowest at time *t*, than the CDS spread of the country must be the highest at the same time. However, we can see from Figure 5.2 where the distance to distress of the eight countries is plotted against the 5 year CDS spread that this probably does not work because we do not observe the same clear relationship between the distance to distress and the CDS spread as in the same plot of a single country (e.g. Brazil: Figure 4.12).

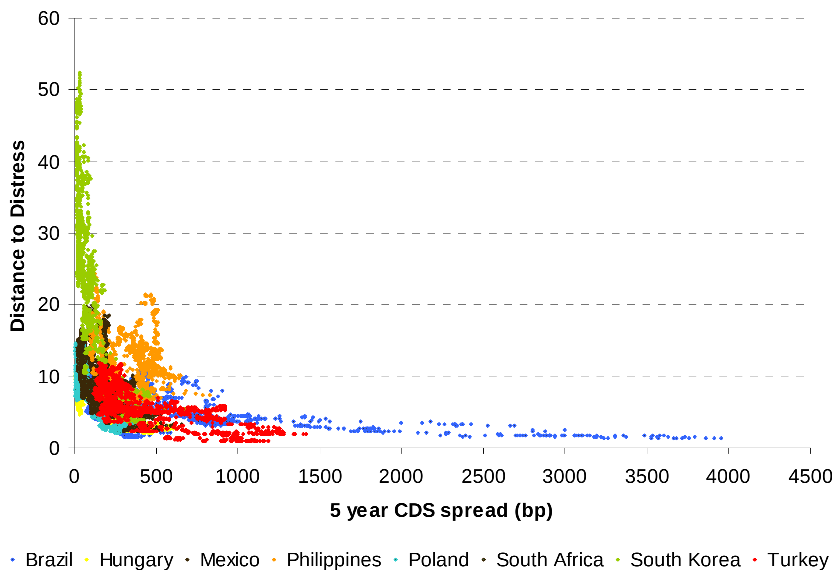


Figure 5.2 Scatter plot: The distance to distress versus the actual 5 year CDS spreads of the eight selected emerging countries in the period April 2002 to February 2010.

In addition, we rank the eight countries ascending by the distance to distress and we rank the eight countries descending by the height of the CDS spread at any time *t* during the sample period. So, the country with the lowest distance to distress is ranked 1 and the country with the highest distance to distress is ranked 8. At the same time, the country with the highest CDS spread is ranked 1 and the country with the lowest CDS spread is ranked 8. If we group the rank of the distance to distress by the rank of the CDS spread, we expect that groups with a similar distance to distress and CDS spread rank contains the most observations. However, in Table 5.5 we can clearly see that this is not the case and hence we will not build a trading strategy that takes positions on the expected future relative height of the CDS spreads of the eight emerging countries.

Table 5.5 Rank of the distance to distress (ascending) grouped by the rank of the 5 year CDS spread (descending) of the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, Turkey) in the period April 2002 to February 2010.

		Lowest distance to distress (rank)							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Highest CDS spread (rank)	**1**	34%	26%	8%	4%	5%	12%	7%	4%
	2	23%	15%	11%	16%	10%	9%	13%	3%
	3	17%	22%	10%	7%	17%	12%	11%	6%
	4	5%	5%	11%	14%	17%	18%	24%	7%
	5	5%	8%	14%	18%	11%	28%	14%	2%
	6	8%	7%	15%	10%	5%	6%	13%	36%
	7	3%	5%	9%	11%	16%	6%	15%	35%
	8	6%	12%	22%	20%	18%	9%	4%	8%

5.2 Country allocation

In the previous section we described that we can base our trading strategies with 5 year CDS contracts on the absolute change in the distance to distress, the relative change in the distance to distress (d_2), the absolute change in the FX volatility (σ_{FX}), and the absolute change in the CDS spread. These trading strategies take positions on expected future changes in the spread of the 5 year CDS contracts of a single country that is part of the universe of eight emerging countries. However, if we take a position in a single country either by buying or selling a 5 year CDS contract, the return of the position does not only depend on the change in the CDS spread. The CDS contract namely acts like an insurance against credit risk, where the buyer has to pay a premium to the seller in turn of protection of the underlying bond in case of default. The return of the position thus also largely depends on the costs or benefits that we make on the payment or the receipt of the contractually obliged premium. We want that the return of our trading strategies only depends on the change in the CDS spread and therefore we apply country allocation.

We apply country allocation by taking positions on the expected future change in the CDS spread between two countries. We take equal opposite positions in the two countries so that we have to pay the exact same amount of “insurance” premium for a CDS contract that we have bought for one country as the amount of “insurance” premium that we receive for a CDS contract that we have sold for the other country. In total, we derive 28 combinations of two countries out of the universe of the eight countries. It is possible that some country combinations are more successful in the trading strategies than others, because the two countries have for example a related distance to distress due to a comparable local and foreign debt stock or the two countries are geographically related. We do not know on forehand which country combinations are the most successful in the trading strategies and we want to analyze this in the results. This is the reason why we do not perform an out-of-sample test by selecting a subset of countries.

We propose the following four trading strategies[8] for all 28 combinations of the countries *i* and *j*:

1. $DDD2_{abs}$

   We measure the difference in the three month absolute change in the distance to distress of two countries with (49):

$$DDD2_{abs_t}^{i,j} = \left(d_{2_t}^{i} - d_{2_{t-3}}^{i}\right) - \left(d_{2_t}^{j} - d_{2_{t-3}}^{j}\right). \qquad (49)$$

   If the difference is positive, than country *i* has absolutely the largest improvement (or the smallest deterioration) of the distance to distress. We expect the financial situation of country *i* to improve compared to country *j*. Therefore, the CDS spread of country *i* is likely to decrease more than the CDS spread of country *j*. We take a long position in a 5 year CDS contract of country *i* at the current relatively high spread level by selling protection and we take an opposite short position in a 5 year CDS contract of country *j* by buying protection. We take the opposite positions when the difference is negative. The holding period of the CDS contracts is one month.

2. $DDD2_{rel}$

   We measure the difference in the three month relative change in the distance to distress of two countries with (50):

$$DDD2_{rel_t}^{i,j} = \ln\left(\frac{d_{2_t}^{i}}{d_{2_{t-3}}^{i}}\right) - \ln\left(\frac{d_{2_t}^{j}}{d_{2_{t-3}}^{j}}\right). \qquad (50)$$

   The $DDD2_{rel}$ strategy is the same as the $DDD2_{abs}$ strategy but here we look at which country has relatively the largest improvement (or the smallest deterioration) of the distance to distress.

3. *DDFX*

[8] The first 2 letters of the name of the strategies stand for "Delta Delta" as we look at the difference of the changes.

We measure the difference in the three month absolute change in the FX volatility of two countries with (51):

$$DDFX_t^{i,j} = \left(\sigma_{FX}{}_t^i - \sigma_{FX}{}_{t-3}^i\right) - \left(\sigma_{FX}{}_t^j - \sigma_{FX}{}_{t-3}^j\right). \tag{51}$$

If the difference is positive, than country *i* has absolutely the largest increase (or the smallest decrease) of the FX volatility. We expect the financial situation of country *i* to deteriorate compared to country *j*. We take a short position in a 5 year CDS contract of country *i*, and we take an opposite long position in a 5 year CDS contract of country *j*. We take the opposite positions when the difference is negative. The holding period of the CDS contracts is one month.

4. *DDCDS* (trend)

We measure the difference in the three month absolute change in the CDS spread of two countries with (52):

$$DDCDS_t^{i,j} = \left(CDS_t^i - CDS_{t-3}^i\right) - \left(CDS_t^j - CDS_{t-3}^j\right). \tag{52}$$

The *DDCDS* strategy is the same as the *DDFX* strategy but here we look at which country has absolutely the largest increase (or the smallest decrease) of the CDS spread.

The four trading strategies have the same settings for the measurement and holding period as the quantitative trading strategy by Robeco that uses the distance to distress of corporations. The measurement period of three months also matches with the best lead-lag correlations for the change in the distance to distress (absolute and relative) and the FX volatility that we found in the previous section. The trend strategy *DDCDS* may have a disadvantage because the best autocorrelations for the change in the CDS spread have a lead of one month. However, for consistency reasons and for the reason that we have to prevent data mining because we do not have an out-of-sample test, we keep the same settings as in the Robeco strategy.

We use z-scores to standardize the size of the positions that we take in the combination of two countries over time. By using z-scores we take large positions if $DDD2_{abs}$, $DDD2_{rel}$, *DDFX*, or *DDCDS* are large and we take small position if the differences are small. We are more confident that we take the correct positions when the differences are large than when the difference are small. Therefore, we prefer the z-score strategy over a simple long-short strategy where the size of the positions is equal over time. The z-scores are determined for the four trading strategies with equation (53):

$$Z_{score}{}_t^{i,j} = \frac{DDxx_t^{i,j} - \overline{DDxx^{i,j}}}{\sigma_{DDxx^{i,j}}}. \tag{53}$$

Ben Dor et al. (2007) show that the risk of CDS contract depends on the level of the spread times the duration. Ambastha, Ben Dor, and Dynkin (2007) argue that this also holds for emerging market securities. If we assume that the duration of the CDS contracts is equal for the countries over time, we can take risk neutral positions by proportioning the size of the positions in the CDS contracts of each country to 100 bp times the z-score. The value of 100 bp is just used as a start setting for the size of the positions that we can always adjust and does not affect the success measures of the trading strategies. The positions of $DDD2_{abs}$ and $DDD2_{rel}$ are described with (54):

$$\begin{cases} position_t^i = +Z_{score_t}^{i,j} * \dfrac{100}{CDS_t^i}, \\ position_t^j = -Z_{score_t}^{i,j} * \dfrac{100}{CDS_t^j}, \end{cases} \tag{54}$$

and the positions of *DDFX* and *DDCDS* are described with (55):

$$\begin{cases} position_t^i = -Z_{score_t}^{i,j} * \dfrac{100}{CDS_t^i}, \\ position_t^j = +Z_{score_t}^{i,j} * \dfrac{100}{CDS_t^j}. \end{cases} \tag{55}$$

We illustrate the choice of the positions with the following example: A negative position is called a short position, so we buy protection via a CDS contract and expect the CDS spread to increase; a positive position is called a long position, so we sell protection via a CDS contract and expect the CDS spread to decrease.

The monthly return of our trading strategies depends on the positions of the previous month. We distinguish two types of return: the carry return and the return on the change in the CDS spreads. The monthly return R is the sum of those two types of return (56):

$$R_t = R_{carry,t} + R_{spread,t} \tag{56}$$

The carry return R_{carry} is the return that is made on paying and receiving the "insurance" premiums of the CDS contracts and is described with (57):

$$R_{carry,\,t} = position_{t-1}^i * \frac{CDS_{t-1}^i}{12} + position_{t-1}^j * \frac{CDS_{t-1}^j}{12}. \tag{57}$$

Because the positions that we take in the two countries *i* and *j* are risk neutral and opposite to each other, the carry return will always be zero (58):

$$R_{carry,t} = Z_{score_{t-1}}^{i,j} * \frac{100}{CDS_{t-1}^{i}} * \frac{CDS_{t-1}^{i}}{12} - Z_{score_{t-1}}^{i,j} * \frac{100}{CDS_{t-1}^{j}} * \frac{CDS_{t-1}^{j}}{12},$$
$$R_{carry,t} = Z_{score_{t-1}}^{i,j} * \frac{100}{12} - Z_{score_{t-1}}^{i,j} * \frac{100}{12} = 0. \quad (58)$$

The only profit or loss that we can make with our trading strategies is due to the return on the change in the CDS spreads of the two countries *i* and *j*. In Chapter 2 we described that the change in the price of a bond due to a change in the required yield of the bond can linearly be estimated by multiplying the change in the required yield with minus the modified duration of the bond. This also holds for CDS contracts where we only deal with the spread component of the required yield of the underlying bond. Therefore, we can calculate the return on the change in the CDS spreads R_{spread} with (59):

$$R_{spread,t} \approx -position_{t-1}^{i} * D^{*i}_{t-1} * \left(CDS_{t}^{i} - CDS_{t-1}^{i}\right)\ldots$$
$$\ldots - position_{t-1}^{j} * D^{*j}_{t-1} * \left(CDS_{t}^{j} - CDS_{t-1}^{j}\right). \quad (59)$$

We set the modified spread duration D^* equal to the maturity of the CDS contracts at 5 years because we have no historical data on the modified spread duration available.

The success of the four trading strategies is measured with the information ratio (IR) and the t-value. We visualize the success of the trading strategies by plotting a time path of the cumulative returns during the sample period. We can use the success measures and the graphs of the cumulative returns to compare the four trading strategies.

Grinold and Kahn (1999) calculate the IR as the average of the annualized monthly returns divided by the annualized standard deviations of the monthly returns. High IRs are obtained for strategies that have high and stable returns. The IR remains the same if we change the value of 100 bp that we use to calibrate the positions because the change in return is neutralized by the change in the standard deviation of the return. The formula to calculate the IR out of monthly returns of a trading strategy is given by (60):

$$IR = \frac{\overline{R}}{\sigma_R}\sqrt{12}. \quad (60)$$

The IR can be interpreted as an annualized t-value. We can see this clearly from the formula for the t-value (61) that is used so that we can test if the returns of the strategies are significantly greater than zero:

$$t_{value} = \frac{\overline{R}}{\sigma_R}\sqrt{n}. \quad (61)$$

Finally, for all four strategies we make an overall portfolio that contains all 28 country combinations. We also make eight country portfolios for the four trading strategies that contain all seven combinations of the country with another country. The success of the portfolios of the different trading strategies is similarly measured with the IR and the t-value, but now we use the average monthly return of all country combinations in the portfolio. We expect to obtain more stable results for the portfolios of country combinations than for a single country combination because there is more risk diversification. This is the fundamental law of active management, stated by Grinold and Kahn (1999) who argue that the IR increases when a portfolio contains more independent investment instruments.

5.3 Results

In this section we first show the IR and t-values of the portfolios of the four trading strategies $DDD2_{abs}$, $DDD2_{rel}$, *DDFX*, and *DDCDS*. Moreover, we show similarities and differences between the trading strategies.

Table 5.6 shows the results of the $DDD2_{abs}$ trading strategy. The IR is low for all portfolios if we use the absolute change in the distance to distress as the base of our strategy with CDS contracts. We observe that the standard deviation of the returns decreases when we use all country combinations in the portfolio. This is the main reason that the overall portfolio has the highest IR and t-value. However, the average portfolio return of this strategy is not significantly positive[9].

Table 5.6 Average annualized return, annualized standard deviation of the monthly returns, information ratio (IR), t-value, and the number of country combinations with an average positive return of a CDS strategy based on the absolute three months change in the distance to distress for a (country) portfolio of the eight selected emerging countries in the period April 2002 to February 2010.

DDD2 abs	Portfolio	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey
Average Return (Annualized)	**0.32%**	0.42%	0.17%	0.33%	0.40%	0.26%	0.54%	0.26%	0.18%
Standard Deviation (Annualized)	**1.05%**	1.46%	1.34%	1.60%	1.64%	1.16%	1.78%	2.19%	1.65%
IR	**0.30**	0.29	0.12	0.21	0.25	0.22	0.30	0.12	0.11
T-Value	**0.84**	0.80	0.34	0.58	0.68	0.62	0.84	0.33	0.30
# Positive combinations	**20 (28)**	6 (7)	5 (7)	5 (7)	5 (7)	4 (7)	6 (7)	4 (7)	5 (7)

Table 5.7 shows the results of the $DDD2_{rel}$ trading strategy. The IR of the portfolio that contains all country combinations and the IR of the country portfolios of Brazil, the Philippines, Poland, and South Africa are reasonable. Like the trading strategy that is based on the absolute change in the distance to distress, there are 20 out of 28 country combinations that have a positive average return. The t-value is yet too low to have a portfolio return that is significantly positive on average.

[9] We perform two-sided t-tests. The degree of freedom is 91 (#observations - 1).

Table 5.7 Average annualized return, annualized standard deviation of the monthly returns, information ratio (IR), t-value, and the number of country combinations with an average positive return of a CDS strategy based on the relative three months change in the distance to distress for a (country) portfolio of the eight selected emerging countries in the period April 2002 to February 2010.

DDD2 rel	Portfolio	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey
Average Return (Annualized)	**0.41%**	0.78%	0.21%	0.19%	0.79%	0.49%	0.71%	-0.05%	0.16%
Standard Deviation (Annualized)	**1.02%**	1.77%	1.30%	1.54%	1.76%	1.28%	1.63%	2.04%	1.58%
IR	**0.40**	0.44	0.16	0.12	0.45	0.38	0.44	-0.02	0.10
T-Value	**1.11**	1.22	0.44	0.34	1.24	1.06	1.21	-0.06	0.27
# Positive combinations	**20 (28)**	6 (7)	4 (7)	5 (7)	7 (7)	6 (7)	5 (7)	3 (7)	4 (7)

Table 5.8 shows the results of the *DDFX* trading strategy. The IR of the portfolio of all country combination is reasonably good. Although the standard deviation is the highest, the high average return on the country portfolio of the Philippines provides a high IR. Also, the IR of the country portfolios Brazil, Mexico, South Africa and Turkey are good. The strategy does not work well for Hungary and South Korea. With 22 out of 28 country combinations having a positive average return, the strategy based on the change in the FX volatility scores better than the strategies that are based on the change in the distance to distress. The average return of the portfolio of all country combinations is significantly positive at a level of at least 10%.

Table 5.8 Average annualized return, annualized standard deviation of the monthly returns, information ratio (IR), t-value, and the number of country combinations with an average positive return of a CDS strategy based on the three months change in the FX volatility for a (country) portfolio of the eight selected emerging countries in the period April 2002 to February 2010.

DDFX	Portfolio	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey
Average Return (Annualized)	**0.79%**	1.27%	0.01%	0.55%	2.25%	0.56%	0.99%	-0.10%	0.82%
Standard Deviation (Annualized)	**1.15%**	2.54%	2.01%	1.08%	2.91%	1.59%	1.80%	2.13%	1.88%
IR	**0.69**	0.50	0.01	0.51	0.77	0.35	0.55	-0.05	0.44
T-Value	**1.91**	1.38	0.02	1.41	2.14	0.98	1.52	-0.13	1.21
# Positive combinations	**22 (28)**	7 (7)	4 (7)	6 (7)	7 (7)	5 (7)	6 (7)	3 (7)	6 (7)

Table 5.9 shows that the results of the trend strategy *DDCDS* are poor. Only Brazil and the Philippines have a moderate IR. The IR and t-value of the portfolio that contains all country combination is even negative because the average portfolio return is negative. Therefore, we exclude this strategy in the remaining of this chapter.

Table 5.9 Average annualized return, annualized standard deviation of the monthly returns, information ratio (IR), t-value, and the number of country combinations with an average positive return of a CDS strategy based on the absolute three months change in the 5-year CDS spread of the eight selected emerging countries in the period April 2002 to February 2010.

DDCDS	Portfolio	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey
Average Return (Annualized)	**-0.16%**	0.83%	-0.54%	-0.63%	0.70%	-0.95%	-0.35%	-0.66%	0.29%
Standard Deviation (Annualized)	**1.73%**	2.89%	2.22%	1.61%	1.57%	2.44%	1.85%	2.97%	1.82%
IR	**-0.09**	0.29	-0.24	-0.39	0.45	-0.39	-0.19	-0.22	0.16
T-Value	**-0.26**	0.80	-0.67	-1.08	1.24	-1.08	-0.53	-0.61	0.44
# Positive combinations	**17 (28)**	6 (7)	2 (7)	3 (7)	7 (7)	4 (7)	3 (7)	4 (7)	5 (7)

The time path of the cumulative returns of the trading strategies *$DDD2_{abs}$*, *$DDD2_{rel}$*, and *DDFX* during the sample period is shown in Figure 5.3. In the first periods of the sample period until end 2003, the *DDFX* strategy has a nice return while the *$DDD2_{abs}$* and *$DDD2_{rel}$* strategy struggle. The returns look similar after this period and increase for all strategies from mid 2007. In the period from end 2003 to mid 2007 the average return is around zero.

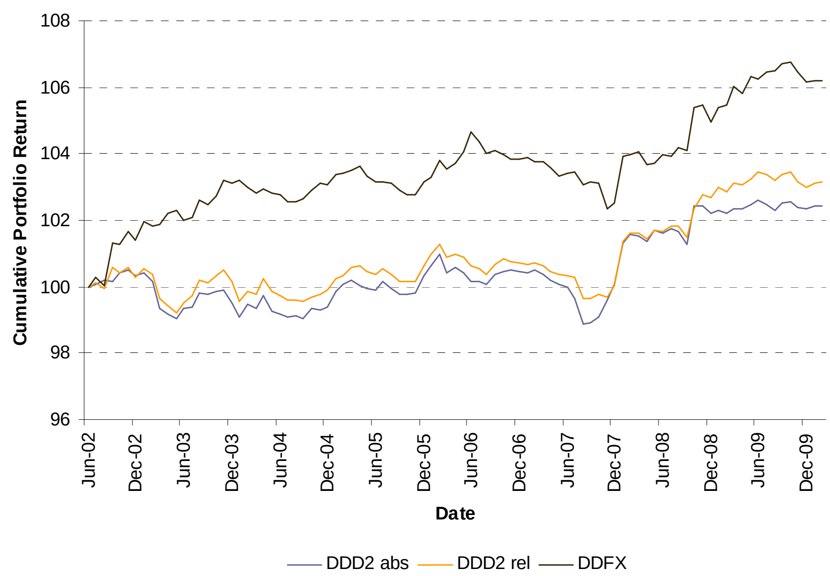


Figure 5.3 Cumulative return on the portfolio of the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) of the CDS trading strategies based on the absolute three month change in the distance to distress (DDD2 abs), the relative three month change in the distance to distress (DDD2 rel), and the three month change in the FX volatility (DDFX) in the period April 2002 to February 2010.

Table 5.10 shows the correlation of the monthly returns on the portfolios of all country combinations for the trading strategies *DDD2*$_{abs}$, *DDD2*$_{rel}$, and *DDFX*. The correlation of the trading strategies *DDD2*$_{abs}$ and *DDD2*$_{rel}$ and the correlation of the trading strategies *DDD2*$_{rel}$ and *DDFX* are high.

Table 5.10 Correlation of the monthly returns on the portfolio of the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) between the CDS trading strategies based on the absolute three month change in the distance to distress (DDD2 abs), the relative three month change in the distance to distress (DDD2 rel), and the three month change in the FX volatility (DDFX) in the period April 2002 to February 2010.

	DDD2 abs	DDD2 rel	DDFX
DDD2 abs	-		
DDD2 rel	0.87	-	
DDFX	0.47	0.66	-

Table 5.11 shows the correlation of the direction of the positions of the 28 country combinations. This correlation is high for all strategies and very high for the *DDD2*$_{abs}$ and *DDD2*$_{rel}$ strategies in particular. The percentage of positions that yields a positive monthly return is 50% for the *DDD2*$_{abs}$ strategy, 52% for the *DDD2*$_{rel}$ strategy, and 53% for the *DDFX* strategy.

Table 5.11 Correlation of the direction of the positions (long or short) of the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) between the CDS trading strategies based on the absolute three month change in the distance to distress (DDD2 abs), the relative three month change in the distance to distress (DDD2 rel), and the three month change in the FX volatility (DDFX) in the period April 2002 to February 2010.

	DDD2 abs	DDD2 rel	DDFX
DDD2 abs	-		
DDD2 rel	0.80	-	
DDFX	0.46	0.56	-

Figure 5.4 shows the accumulated z-scores and positions that we take with the *DDD2*$_{abs}$ strategy in Brazil. The accumulated z-scores indicate the amount of money that is invested in Brazilian CDS contracts. Remember that over all countries the amount of “insurance” premium that is paid is equal to the amount of “insurance” premium that we receive because the strategy is risk neutral. The accumulated positions show the risk exposure in Brazil of the trading strategy. It represents the fraction of CDS contracts that is in our possession. If the CDS spread is low, the positions could be large like in the period from 2006 to 2007. In case of a default (which never happens in our sample period) the seller of a CDS contract is obliged to pay the face value of the underlying bond. The difference in the accumulated z-scores and positions is caused by the factor that we use to proportion the height of the CDS spread to 100 bp.

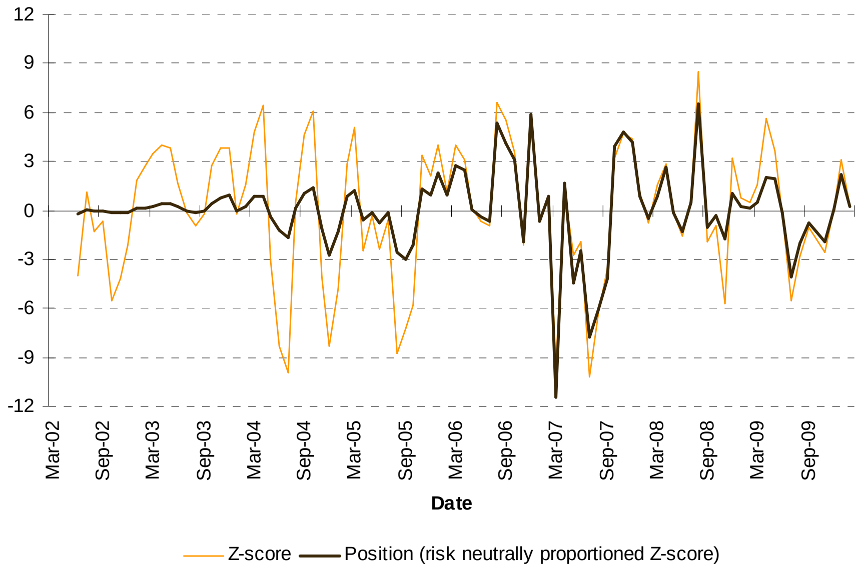


Figure 5.4 Z-scores and positions in the country portfolio of Brazil of the CDS trading strategies based on the absolute three month change in distance to distress (DDD2 abs) in the period April 2002 to February 2010.

The stability of the accumulated z-scores of a portfolio over time is measured with the standard deviations of the accumulated z-scores. A high standard deviation could indicate that the portfolio is taking aggressive positions which involve higher transaction costs. Table 5.12 shows the standard deviation of the country portfolios for the trading strategies $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX*. The standard deviation of the accumulated z-scores is the highest for the *DDFX* strategy.

Table 5.12 Standard deviation of the accumulated Z-scores of the portfolios of the eight selected emerging countries (and their average) of the CDS trading strategies based on the absolute three month change in the distance to distress (DDD2 abs), the relative three month change in the distance to distress (DDD2 rel), and the three month change in the FX volatility (DDFX) in the period April 2002 to February 2010.

	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
DDD2 abs	4.07	2.93	2.24	1.71	2.34	3.22	4.68	4.27	3.18
DDD2 rel	5.41	3.72	2.55	2.19	2.51	3.33	4.41	5.45	3.70
DDFX	6.88	4.38	2.68	2.23	3.20	3.88	6.29	5.88	4.43

Figure 5.5 shows the accumulated z-scores for the $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy in Brazil. The patterns of the accumulated z-scores are very similar for the three strategies. The *DDFX* strategy takes more aggressive positions in the crisis period of Brazil and Turkey in 2002-2003 and the financial crisis of 2008-2009. The graph of Brazil is representative because we observe the same results for the other country portfolios.

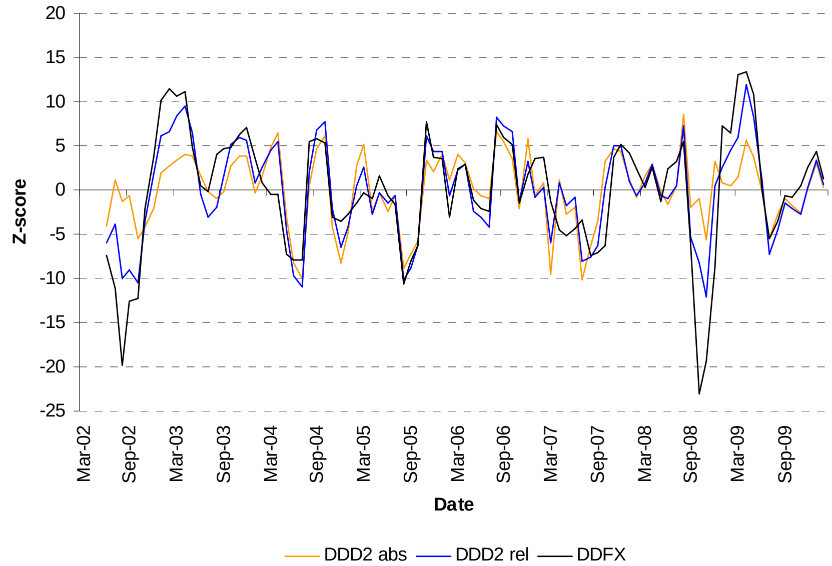


Figure 5.5 Z-scores in the country portfolio of Brazil of the CDS trading strategies based on the absolute three month change in distance to distress (DDD2 abs), the relative three month change in distance to distress (DDD2 rel), and the three month change in FX volatility (DDFX) in the period April 2002 to February 2010. (In order to make a fair comparison between the Z-scores, the Z-scores of the DDFX strategy are multiplied with -1).

Finally, we look at which z-scores contribute to the most successful positions in the three trading strategies $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX*. Therefore, we divide the monthly z-scores into buckets of 5 absolute z-score ranges. The IR of every country combination is calculated separately for the buckets. The IR of the z-score buckets of the overall portfolio are calculated by taking the average IR of the z-score buckets of every country combination. Note that by doing so the IRs will be lower than the IR of the overall portfolio because we loose the additional value that we gain by diversification. The ranges of the z-score buckets are chosen so that every bucket represents approximately 20% of the data.

Figure 5.6 shows the IR of the z-score buckets for the $DDD2_{abs}$ strategy. The strategy works best for high absolute z-scores (≥0.8).

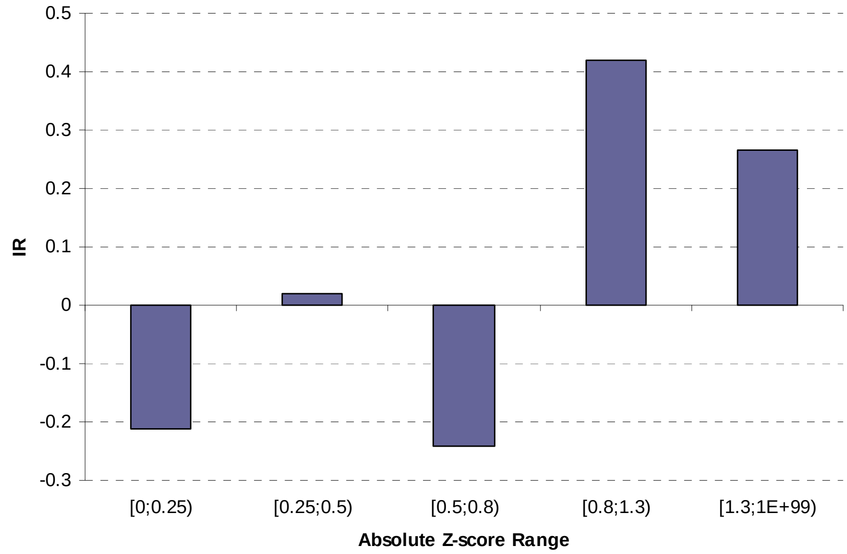


Figure 5.6 Information Ratio (IR) per absolute z-score bucket of the CDS trading strategy based on the absolute three month change in the distance to distress for the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) in the period April 2002 to February 2010.

Figure 5.7 shows the IR of the z-score buckets for the $DDD2_{rel}$ strategy. The strategy works best for moderate and high absolute z-scores (≥0.5).

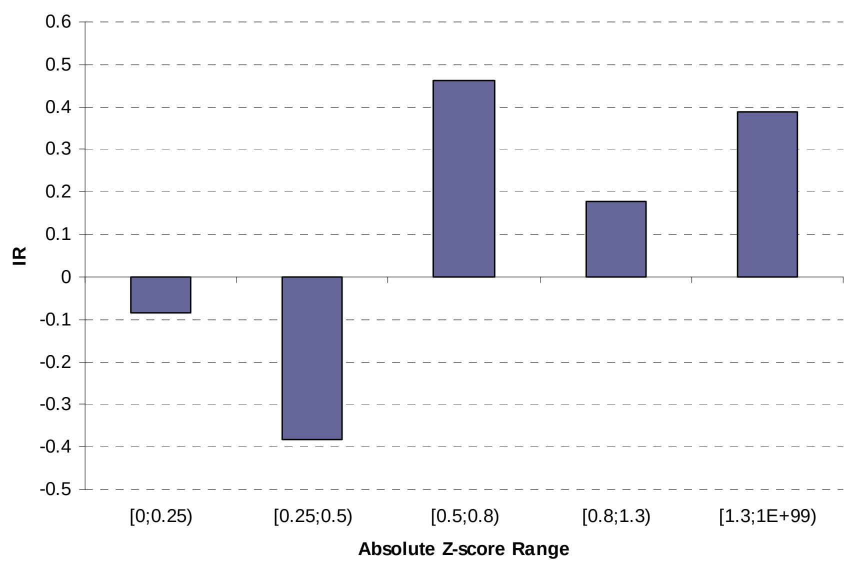


Figure 5.7 Information Ratio (IR) per absolute z-score bucket of the CDS trading strategy based on the relative three month change in the distance to distress for the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) in the period April 2002 to February 2010.

Figure 5.8 shows the IR of the z-score buckets for the *DDFX* strategy. The strategy has a positive IR for all z-score buckets.

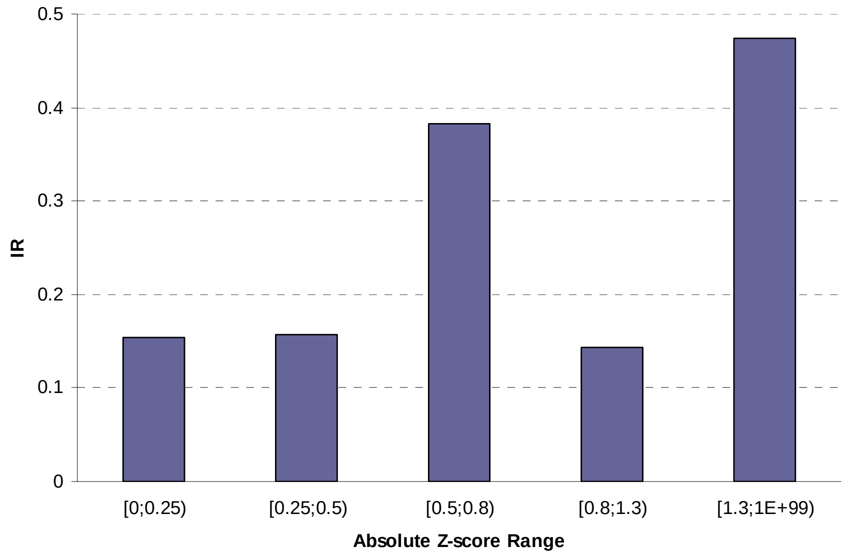


Figure 5.8 Information Ratio (IR) per absolute z-score bucket of the CDS trading strategy based on the three month change in the FX volatility for the eight selected emerging countries (Brazil, Hungary, Mexico, Philippines, Poland, South Africa, South Korea, and Turkey) in the period April 2002 to February 2010.

5.4 Discussion

The best results are obtained with the *DDFX* strategy as it has the highest IR for the overall portfolio and 5 out of 8 country portfolios. The *DDFX* strategy is the only strategy that has a significant positive average return. The $DDD2_{rel}$ strategy is the second best with slightly better results than the $DDD2_{abs}$ strategy. We have already mentioned the heteroscedasticity of the distance to distress and the high levels of the distance to distress as the main reasons to prefer the relative change in the distance to distress used in the $DDD2_{rel}$ strategy over the absolute change in the distance to distress used in the $DDD2_{abs}$ strategy. The results of the *DDCDS* strategy are unsatisfactory.

The cumulative returns of the $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy look very similar from 2004 to the end of the sample period (Figure 5.3). The *DDFX* strategy works well in the period of 2002-2003 when both the FX volatility and the CDS spread were high for Brazil and Turkey. The $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy all work well in the financial crisis period of 2008-2009 when both the FX volatility and the CDS spread were high for all the eight selected emerging countries. So, the best periods for the strategies seem to be crisis periods when the CDS spreads of the emerging countries peak to high levels. We see the similarities between the trading strategies back in the high correlations between the strategies of the monthly overall portfolio returns (Table 5.10) and the direction of the positions (Table 5.11). This implies that the size of the positions, which can only deviate between the strategies due to different z-scores, is an important factor that makes the *DDFX* strategy more successful than the other strategies.

The *DDFX* strategy has the highest standard deviations of the accumulated z-scores (Table 5.12). However, the accumulated z-scores are very similar over time for the three strategies except for the crisis periods of 2002-2003 and 2008-2009 (Figure 5.5). The *DDFX* strategy is apparently better capable to enlarge its positions in crisis periods compared to the $DDD2_{abs}$ and $DDD2_{rel}$ strategy. The intuition behind this observation could be that the FX volatility is a more stable variable than the distance to distress. In calm periods, the volatility of the local currency liabilities is low and the level of the distance to distress is high. But it is exactly in that situation that a small change in the volatility of the local currency liabilities can cause a large change in the level of the distance to distress as discussed in Chapter 4. These large changes in the distance to distress result in a high z-score in calm periods and a z-score that is relatively too low in crisis periods. This effect is even not completely eliminated if we use the relative change in the distance to distress.

To see the contribution of low and high z-scores to the IR of the $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy we look at the z-score buckets that are presented in Figures 5.6 to 5.8. The *DDFX* strategy has a positive IR for all z-score buckets. The *DDFX* strategy obtains the highest IR for the z-score bucket with the highest absolute z-scores (≥1.3). The $DDD2_{abs}$ and $DDD2_{rel}$ strategies do not have a positive IR for all z-score buckets. Only the z-score buckets of absolute z-scores that are greater or equal to 0.8 and 0.5 for the $DDD2_{abs}$ and $DDD2_{rel}$ strategies respectively, have positive IRs. This indicates that we could improve the performance of the $DDD2_{abs}$ and $DDD2_{rel}$ strategies when we introduce a floor value for the z-scores. The floor value forces the strategy to only take a position when the z-score is sufficiently large enough.

We conclude this discussion section with some technical points concerning the country allocation in the overall portfolio, the risk exposure at a low CDS spread, the duration, and the ghost effect. These are technical points that can influence the results of the $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy but are not analyzed in this research project. Therefore, it is recommended to pay attention to these technical points in a follow up study. Another important issue that we have not researched in this research project is the transaction costs that are involved by taking positions in the CDS contracts. It would be interesting to calculate the net IR of the strategies by deducting the transaction costs from the monthly returns in a follow up study to analyze if the strategies are still profitable.

Figure 5.9 shows the absolute long-short overall portfolio position in eight countries that we can observe every month for our trading strategies if we did not use risk neutral z-scores. This is an exaggerated view of the country allocation in the overall portfolio, but it indicates that we can easily construct a portfolio that takes long positions in the top two countries and short positions in the bottom two countries. This strategy is applied in a quantitative country allocation model by Robeco for developed bond markets. Such a strategy would be very similar to the strategy that we use in our overall portfolio. The advantage of this “long top two and short bottom two” strategy is that the transaction costs decrease because fewer positions are taken in the CDS contracts. Moreover, we can minimize the transaction costs even further if we develop a more sophisticated strategy that tries to avoid rebalancing the portfolios positions every month.

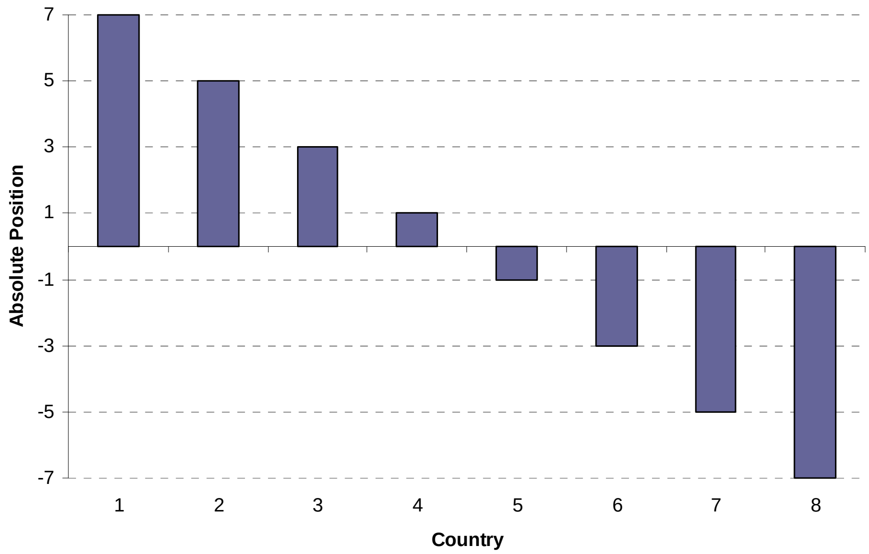


Figure 5.9 Graphical overview of the absolute long-short portfolio position per country (without adjusting for risk neutral z-scores).

The positions that we take with our strategies are large when the CDS spread is low. This because we proportion the positions to a CDS spread of 100 bp. The research of Ben Dor et al. (2007) show that the positions that we use in our strategies are risk neutral and therefore the risk exposure of our strategy only depends on the z-scores, but the large positions due to a low CDS spread go together with a large value at risk. If we sell a large number CDS contracts for a single country, we are obliged to pay the face value of the underlying bond for each of the contracts in case of a default. Although, the chance that this would happen is very small, the maximum loss could be enormous because it depends on the presumably low recovery of the face value of the bonds that are in now our position. The strategies do not have a good performance anyway in the periods when the CDS spread is low, so this applies for a cap value to control the size of the positions.

Figure 5.10 shows the estimated modified spread duration that belongs to different 5 year CDS spreads. We estimate the modified spread duration of the CDS spreads by determining the modified duration of an equivalent 5 year bond with the annual coupon and the required yield equal to the 5 year CDS spread. We can clearly see that the modified spread duration decreases as the CDS spread increases. However, we set the modified spread duration that we use to calculate the monthly return in our strategies at 5 year. Although this is thus not entirely correct, this is does not affect the IR of the trading strategies much as long as the CDS spreads of all countries are close to each other. We can change the positions of our trading strategies anyway if we adjust the value of 100 bp to which we proportion the CDS spread. Only in the period from 2002 to end 2003 the CDS spreads of the countries heavily differ which causes an error in the monthly return for that period in the sample.

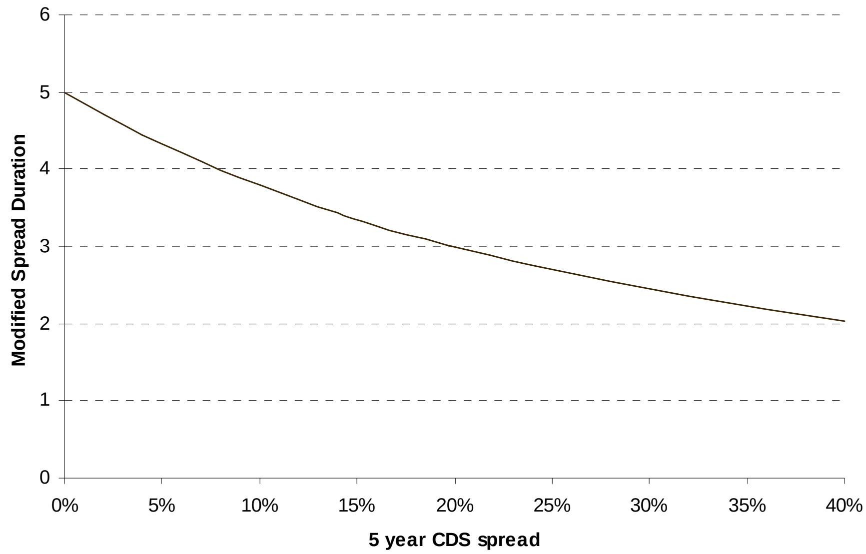


Figure 5.10 Estimated modified spread duration of 5 year CDS spreads. The modified spread duration is estimated by determining the modified duration of an equivalent 5 year bond with the annual coupon and the required yield equal to the 5 year CDS spread.

In our trading strategies, a ghost effect can appear meaning that the strategies miss valuable inside information because we use a measurement period of three months. For example if the FX volatility at the start of the measurement period is about the same as the FX volatility at the end of the measurement period, this could be because the FX volatility hardly changed in the mean time. But this could also be because the FX volatility first dramatically decreased and then dramatically increased with the same quantity. In the latter case we possibly miss an opportunity to immediately profit from this information. We can analyze if the strategies can be enhanced by adapting the measurement method.

5.5 Conclusion

In this chapter trading strategies with 5 year CDS contracts for eight emerging countries with a floating FX rate and a considerable foreign debt stock are tested. The sample period of the test is from April 2002 to February 2010.

The change in the distance to distress has explanatory and predictive power on the change in the CDS spread. The predictive power of the distance to distress is significant for the most countries when we use relative changes of the distance to distress instead of absolute changes. The explanatory and predictive power of the change in the FX volatility on the change in the CDS spread is even larger for the eight countries. The most predictive power on the next month change in the CDS spread is obtained when the change in the distance to distress and the FX volatility has a lead of three months. The autocorrelation of the change in the distance to distress, the change in the FX volatility, and the change in the CDS spread is on average the highest when we use a measurement period of one month.

There is no relation between the relative level of the distance to distress of the eight countries and the relative height of the CDS spread. Therefore, we use the predictive power of the change in the distance to distress, the change in the FX volatility, and the trend in the CDS spread on the change in the CDS spread of a single country in our trading strategies. We distinguish four trading strategies where we take risk neutral positions between two countries that are determined by z-scores:

1. $DDD2_{abs}$
2. *DDD2rel*
3. *DDFX*
4. *DDCDS*

The trading strategies $DDD2_{abs}$ and $DDD2_{rel}$ are based on the three month absolute or relative change in the distance to distress. The *DDFX* strategy is based on the three month absolute change in the FX volatility. The $DDD2_{abs}$, $DDD2_{rel}$, and *DDFX* strategy should profit from the spillover of information from the markets that we use to construct the distance to distress (the bond market and the currency market) and the FX volatility (the currency market). This information-spillover effect is an example of behavioral finance and could exist because valuable country information is earlier available in the bond market or the FX market than in the CDS market. The *DDCDS* strategy is a three month trend strategy that should profit from under-reaction in the CDS market and is tested because we observe autocorrelation in the CDS spread.

The *DDFX* strategy is the most successful trading strategy and outperforms the $DDD2_{abs}$ and $DDD2_{rel}$ strategies. The *DDFX* is the only strategy with a significant average positive return. We conclude that it is better to use the FX volatility than the distance to distress as input variable in a trading strategy with CDS contracts for emerging countries with a floating FX rate and a considerable foreign debt stock. In addition, the FX volatility of a country is much easier to construct than the distance to distress. The *DDCDS* strategy is not a successful trading strategy from which we conclude that a three month trend strategy of the CDS spread does not work.

The *DDFX* strategy works best for crisis periods when the CDS spreads as well as the FX volatilities of the countries are high. The *DDFX* strategy could not yet be tested with an in-sample and an out-of-sample test because there is not enough historical CDS data available. Therefore, we have to look critically at the stability and robustness of the results. The promising results of the *DDFX* strategy tempt to enhance the stability and robustness of the strategy in a follow up study that concentrates on caps for the size of the positions when the CDS spread is low, the monthly return when the correct spread duration is used, and a measurement method that deals with the ghost effect. The *DDFX* strategy needs to be critically analyzed in a follow up study on the influence of the transaction costs on the net IR of the strategy and the sensitivity to a delay in implementation of the positions. We can also think of ways to reduce transaction costs for example by constructing a simple “long top two and short bottom two” portfolio and developing a sophisticated method to avoid rebalancing the portfolios positions every month.

Chapter 6

Conclusions

The main purpose of our research project is to investigate the new sovereign CCA model by Gray et al. (2007) more specifically to analyze whether a profitable trading strategy is possible that would benefit active asset managers like Robeco. In this chapter we present the final conclusions of the project and the answers to the following three research questions:

1. To what extent is the model applicable to developed countries?
2. How can we implement the model and confirm the tight relationship with actual CDS data?
3. How can we develop a successful trading strategy based on the model?

The first research question is treated in Chapter 3 where we describe the sovereign CCA model in detail. From this description it becomes clear that the model is best suited for emerging countries with a considerable amount of debt denominated in a hard foreign currency like the US Dollar and the Euro. The sovereign CCA model is unsuitable for developed countries because these countries do not comply with two important features of the model.

First, an important feature of the model is the foreign distress barrier that is constructed from the book values of the foreign currency debt of a country. Developed countries have a foreign distress barrier that is close to zero because they have direct access to large and liquid international markets to issue debt in their domestic currency and therefore have no or only a small amount of foreign currency debt.

Second, an important feature of the model is the analogy between the local currency liabilities of a country and the equity of corporations. After the financial crisis of 2008-2009, sovereign credit risk especially applied to developed countries like Greece, Ireland, Portugal, and Spain. For these developed countries the analogy between local currency liabilities and equity does not hold, because countries from the EMU have very limited control over the money supply by the ECB.

It is not possible to adapt these features of the sovereign CCA model to make it applicable to developed countries without changing the economic sense of the model. Therefore, we focus on emerging countries for our second and third research question.

With the case study of Chapter 4 we answered the second research question. In the case study we implement the sovereign CCA model for Brazil in the period April 2002 to December 2005. We propose a method to construct the input variables of the model with Bloomberg as main data source. The monetary base, the risk-free interest rate, and the time horizon are input variables of the model which are easy to access. The local currency debt (market value) and foreign distress barrier are input variables of the model which we can construct with data on bonds and interest rates. The volatility of the local currency liabilities is an input variable that we measure based on the daily log returns of the local currency liabilities (the sum of the local currency debt and the monetary base). This approach to construct the input variables has the advantage of being a general, up-to-date, quantitative approach with a daily frequency.

Indeed, we find a tight relationship between the sovereign CCA model's risk measure distance to distress and the actual CDS spread of Brazil. We can clearly distinguish the Brazilian crisis of 2002-2003 in the output of the sovereign CCA model. However, the output of the sovereign CCA model of our case study on Brazil differs from the benchmark study by Gray and Malone (2008). The difference is caused by the method to measure the volatility of the local currency liabilities. We prefer the unbiased quantitative historical volatility we use in our case study over the volatility of Gray and Malone who estimate high values for the volatility by adding a floor value and using artificially high estimates for the correlation between the different components of the volatility of the local currency liabilities to force a relationship with the actual CDS data.

The volatility of the local currency liabilities is a very important input variable of the model. The volatility of the local currency liabilities that we use in our case study is low. Combined with the low leverage (ratio foreign currency debt to local currency liabilities) this leads to high levels of the risk measure distance to distress and low levels of the estimated default probability and the estimated spread. The default probability and spread are even close to zero for large periods of the case study. The FX volatility is the most important driver of the volatility of the local currency liabilities and therefore an important input factor of the model.

The third research question is dealt with in Chapter 4 and elaborated with the proposed trading strategies of Chapter 5. From the analysis of the sovereign CCA model in our case study we select the distance to distress and the FX volatility as promising variables for a trading strategy with CDS contracts. In order to use the variables in a trading strategy they have to contain predictive power on the CDS spread. This could indicate that there is a valuable information spillover from the bond market or the currency market to the CDS market. We test the contemporary and lead-lag correlations of changes in the variables with changes in the CDS spread. In Chapter 4, we observed that the variables have explanatory power on the CDS spread of Brazil. Moreover, especially the FX volatility has predictive power on the CDS spread of Brazil.

In Chapter 5 we extended the universe of the research to eight emerging countries with a considerable amount of foreign currency debt and a free floating currency (Brazil, Hungary, Mexico, the Philippines, Poland, South Africa, South Korea, and Turkey). The research period is extended to a sample period of April 2002 to February 2010. There is no relation between the relative level of the distance to distress of the eight countries and the relative height of the CDS spread. But when we look at the changes in the distance to distress and the FX volatility, we see that the explanatory and predictive power of these variables on the CDS spread improve on average compared to the Brazilian results. We use the predictive power in a trading strategy with 5 year CDS contracts. We distinguish four trading strategies where we take risk neutral positions between two countries:

5. $DDD2_{abs}$
6. *DDD2rel*
7. *DDFX*
8. *DDCDS*

The trading strategies $DDD2_{abs}$ and $DDD2_{rel}$ are based on the three month absolute or relative change in the distance to distress. The *DDFX* strategy is based on the three month absolute change in the FX volatility. The *DDCDS* strategy is a three month trend strategy of the CDS spread that we also analyze because we observe some autocorrelation in the CDS data of the eight countries.

The *DDCDS* strategy is not a successful trading strategy from which we conclude that a three month trend strategy of the CDS spread does not work. Apparently, there is no under-reaction in the CDS market in this three month time period. The $DDD2_{abs}$ and $DDD2_{rel}$ strategies perform better because both strategies have a positive average return. The *DDFX* strategy is the most successful trading strategy and outperforms the $DDD2_{abs}$ and $DDD2_{rel}$ strategies. The *DDFX* strategy is the only strategy with a statistical significant positive average return. The *DDFX* strategy works best for crisis periods when the CDS spreads as well as the FX volatilities of the countries are high.

The thorough analysis of the model in this research project provides us with promising trading strategies. We have not found a trading strategy using the sovereign CCA model that has a statistical positive average return. The most important input factor of the model does provide us with a successful trading strategy. This strategy is based on the FX volatility and profits from the spillover of information from the currency market to the CDS market. It is only disturbing to incorporate the debt structure of the countries with the sovereign CCA model in a trading strategy because the additional value of information spillover from the bond market to the CDS market is not visible in our research. We conclude that it is better to use the FX volatility than the distance to distress in a trading strategy with CDS contracts for emerging countries with a floating FX rate and a considerable foreign debt stock.

The intuitive economic sense of the predictive power of the FX volatility on the CDS spread is for a large part described with the sovereign CCA model, where we have seen the importance of the FX rate in the structure and output of the model. Finally, the FX volatility is very easy to determine in comparison with the distance to distress. In our study we used the standard deviation of daily FX returns but we can even directly use the implied volatility from FX options. The FX volatility has thus the advantage that it is very easy to determine for multiple emerging countries in follow up studies on this subject.

Chapter 7

Follow Up

In this chapter we present a brief overview of the ideas on follow up research that we gathered during the research project.

One of the conclusions of this research project is that it is not possible to adapt the sovereign CCA model to make it applicable to developed countries without changing the economic sense of the model. We need a different model to analyze the sovereign credit risk of developed countries like the Southern European countries that are currently subject to a much higher sovereign credit risk. The problems of these countries are related to the shorter term debt that is close to maturity and the corresponding refinancing risk. Also the budget deficit of these countries is an important input factor for sovereign credit risk. A follow up study for sovereign credit risk of developed countries should be on models that take these issues into account.

Further research could be done on enhancing the trading strategies that are based on the distance to distress. Robustness checks on the sovereign CCA model with different measurement methods for volatility (e.g. changing the measurement period of three months and the log return boundary value of 125%) are not performed in this research project but would be interesting to look at in a follow up study. In addition, robustness analyses of the other parameters in the model have not been done yet in this study and may deliver valuable new insights and potentially good results. We have also observed that the strategies based on the distance to distress are the most successful when the z-scores are relatively high. It is therefore interesting to investigate if the trading strategies can be enhanced by using a floor value for the z-scores.

In this study we have focused on the basic sovereign CCA model, but several more complicated extensions are possible. For example guarantees to financial institutions could be modeled as put options on the asset side of a sovereign. A follow up study can enhance the basic model with such extensions.

Our study has revealed a predictive power of the FX volatility on the CDS spread, but did not show predictive power of the bond market (volatility) on the CDS spread. However, this may be caused by the use of the sovereign CCA model, a direct analysis of a spillover effect from the bond market in the CDS market will help to ascertain the limited predictive power of bond volatility.

We recommend though to focus further research on the trading strategy that is based on the promising FX volatility variable. The strategy could be enhanced with caps for the size of the positions when the CDS spread is low and a measurement method that deals with the so called ghost effect. The strategy needs to be critically analyzed on the influence of the transaction costs on the information ratio of the strategy and the sensitivity to a delay of the implementation. We can also think of ways to reduce transaction costs for example by constructing a simple “long top two countries and short bottom two countries” portfolio and developing a sophisticated method to avoid rebalancing the portfolio every month. Finally, an out-of-sample test is possible on the strategy by extending the number of emerging countries with a liquid floating FX rate and a liquid CDS market. In addition it would be interesting to compare the realized FX volatility to the implied volatility from FX options.

Literature

Ambastha, Ben Dor, Dynkin (2007), *DTS (Duration Times Spread) for Emerging Market Securities, A Measure of Spread Exposure*, Lehman Brothers, Global Family of Indices, not published.

Ben Dor, Dynkin, Hyman, Houweling, Van Leeuwen, and Penninga (2007), *DTS (Duration Times Spread), A New Measure of Spread Exposure in Credit Portfolios*, The Journal of Portfolio Management, Winter (2007), pp. 77-100.

Black and Scholes (1973), *The Pricing of Options and Corporate Liabilities*, The Journal of Political Economy, Vol. 81, No. 3 (May - Jun, 1973), pp. 637-654.

Crosbie and Bohn (2003), *Modeling Default Risk*, Moody's KMV, not published.

Duffie and Singleton (1999), *Modeling the Term Structure of Defaultable Bonds*, Review of Financial Studies, 12 (1999), pp. 687-720.

Fabozzi (2007), *Bond Markets, Analysis, and Strategies*, Sixth edition, Pearson Prentice Hall, New Jersey, United States.

Gapen, Gray, Lim, and Xiao (2004), *The Contingent Claims Approach to Corporate Vulnerability Analysis: Estimating Default Risk and Economy-Wide Risk Transfer*, Working Paper, IMF, International Capital Markets Department.

Gray and Malone (2008), *Macrofinancial Risk Analysis*, John Wiley & Sons Ltd, Chichester, England.

Gray, Merton, and Bodie (2007), *Contingent Claims Approach to Measuring and Managing Sovereign Credit Risk*, Journal Of Investment Management, Vol. 5, No. 4 (2007), pp. 5–28.

Grinold and Kahn (1999), *Active Portfolio Management, A Quantitative Approach for Providing Superior Returns and Controlling Risk*, Second Edition, McGraw Hill, New York, United States.

Hull and White (2010), *The Risk of Tranches Created from Residential Mortgages*, Working Paper, University of Toronto.

Itô (1951), *On Stochastic Differential Equations*, Memoris of the American Mathematical Society, No. 4 (1951).

Jarrow and Turnbull (1995), *Pricing Derivatives on Financial Securities Subject to Default Risk*, Journal of Finance, 50 (1995), pp. 53-86.

Merton (1974), *On the Pricing of Corporate Debt: the Risk Structure of Interest Rates,* Journal of Finance, 29 (May, 1974), pp. 449–470.

Moody's (2008), *Rating Methodology, Sovereign Bond Ratings*, Moody's Investors Service, not published.

Saunders and Cornett (2008), *Financial Institutions Management,* McGraw Hill, New York, United States.

Sims (1999), *Domestic Currency Denominated Government Debt as Equity in the Primary Surplus*, paper presented at the Latin American meetings of the Econometric Society (August, 1999), Cancun, Mexico.

Sturzenegger and Zettelmeyer (2007), *Debt Defaults and Lessons from a Decade of Crises*, The MIT Press, Cambridge, United States.

Wilmott, Howison, Dewynne (2007), *The Mathematics of Financial Derivatives, A Student Introduction*, 15th printing, Cambridge University Press, New York, United States.

Appendix A

Abbreviations

AIG	American International Group
BAC	Bank Advisory Committee
BCB	Banco Central do Brasil (Central Bank of Brazil)
CCA	Contingent Claims Analysis
CDO	Collateralized Debt Obligation
CDS	Credit Default Swap
CFB	Corporation of Foreign Bondholders
ECB	European Central Bank
EMBI	Emerging Market Bond Index
EMU	Economic and Monetary Union of the European Union
FI	Financial Institution
FX	Foreign Exchange
GDP	Gross Domestic Product
IMF	International Monetary Fund
IR	Information Ratio
KMV	Kealhofer, McQuown and Vasicek
OECD	Organization for Economic Cooperation and Development

Appendix B

Bond Data

Table B.1 Used bond data from Bloomberg per country, average time to maturity (TTM), and used interest rate to determine the market value of debt.
Abbreviations: ZC = Zero Coupon; CHF = Swiss Franc, EUR = Euro, GBP = British Pound, JPY = Japanese Yen, and USD = US Dollar; I/L = Inflation linked.

Country	Bond Name	Type	Comment	Active	Average TTM (yrs)	Used discount rate
Brazil	LTN	Fixed (ZC)		start-end	0.8	Brazil 1 yr
Brazil	NTN-F	Fixed		2003-end	4.3	Brazil 2 yr
Brazil	LFT	Floating (SELIC linked)	Referenced at SELIC rate of 1 Jul 2000	start-end	2.2	none
Brazil	NTN-B	Fixed (Inflation linked)	Referenced at IPCA of 15 Jul 2000	2001-end	17.0	Brazil 2 yr
Brazil	NTN-C	Fixed (Inflation linked)	Referenced at IGP-M rate of 1 Jul 2000	start-end	14.6	Brazil 2 yr
Brazil	NTN-D	Fixed (Dollar linked)	Referenced at BRLUSD <= 1 Jul 2000	start-2008	1.3	Brazil 1 yr
Brazil	BNBC-E	Fixed (Dollar linked)	Referenced at BRLUSD <= 1 Jul 2000	start-2006	1.2	Brazil 1 yr
Brazil	International	Fixed, Floating	USD, EUR, JPY	start-end	11.5	Brazil USD 10 yr
Hungary	T-Bill	Fixed (ZC)		start-end	0.4	Hungary 3 m
Hungary	Interest bearing T-Bill	Fixed		2005-end	0.5	Hungary 3 m
Hungary	Government	Fixed, Floating		start-end	4.9	Hungary 5 yr
Hungary	International	Fixed, Floating	EUR, USD, JPY, GBP	start-end	5.7	Hungary 5 yr
Hungary	Central Bank T-Bill	Fixed (ZC)		start-2002, 2007-end	0.1	Hungary 3 m
Hungary	Central Bank International	Fixed, Floating	EUR, JPY, USD, CHF	start-end	3.2	Hungary 5 yr
Mexico	CETES	Fixed (ZC)		start-end	0.3	Mexico 3 m
Mexico	Udibonos	Fixed		start-end	8.9	Mexico 10 yr
Mexico	Banobras	Fixed, Floating		start-end	12.6	Mexico 10 yr
Mexico	BREMS	Floating		start-end	1.4	none
Mexico	Bondes	Floating		start-end	1.7	none
Mexico	Bondes D	Floating		2006-end	2.5	none
Mexico	BPA	Floating		start-end	2.6	none
Mexico	International	Fixed, Floating	USD, EUR, GBP, JPY	start-end	12.0	Mexico 10 yr
Philippines	T-Bill	Fixed (ZC)		start-end	0.4	Philippines 3 m
Philippines	Government	Fixed, Floating		start-end	5.2	Philippines 5 yr
Philippines	International	Fixed, Floating	USD, EUR, JPY	start-end	10.4	Philippines 10 yr
Philippines	Special Series T-Bill	Fixed (ZC)		start-end	0.3	Philippines 3 m
Philippines	Central Bank International	Fixed, Floating	USD	start-end	18.4	Philippines 10 yr
Poland	T-Bill	Fixed (ZC)		start-end	0.5	Poland 1 yr
Poland	Government	Fixed, Floating	Some I/L	start-end	5.1	Poland 5 yr
Poland	International	Fixed, Floating	EUR, USD, JPY, GBP, CHF	start-end	9.8	Poland 10 yr

Country	Bond Name	Type	Comment	Active	Average TTM (yrs)	Used discount rate
South Africa	T-Bill	Fixed (ZC)		start-end	0.3	South Africa 2 yr
South Africa	Government	Fixed, Floating	Some I/L	start-end	9.2	South Africa 10 yr
South Africa	International	Fixed	USD, EUR, JPY, GBP	start-end	6.4	South Africa 5 yr
South Korea	T-Bill	Fixed (ZC)		2003-2006	0.1	South Korea 3 m
South Korea	Government	Fixed	Some I/L	start-end	4.3	South Korea 5 yr
South Korea	International	Fixed	USD, EUR	start-end	5.8	South Korea 5 yr
South Korea	Stabilization	Fixed		start-2008	1.9	South Korea 2 yr
South Korea	Housing	Fixed		start-end	3.5	South Korea 3 yr
South Korea	Jobless	Fixed		start-2004	0.9	South Korea 1 yr
South Korea	Grain	Fixed		start-2004	1.3	South Korea 1 yr
Turkey	T-Bill	Fixed (ZC)		start-end	0.3	Turkey T-Bill yields
Turkey	Government	Fixed, Floating	Some in USD, EUR; Some I/L	start-end	2.5	Turkey USD 3 yr
Turkey	International	Fixed	USD, EUR, JPY	start-end	7.7	Turkey USD 8 yr

Table B.2 Quality of Bloomberg data on the interest rates of the eight selected emerging countries and the chosen risk-free interest rate (the 5 year US government interest rate).

Country	Term	Start date	End date	#Values	#Missing Values	Missing Values (%)
Brazil	1 year	1-1-2002	26-2-2010	2198	118	5.37%
Brazil	2 year	1-1-2002	26-2-2010	2198	116	5.28%
Brazil	10 year (USD)	15-5-2002	26-2-2010	2102	175	8.33%
Hungary	3 months	1-1-2002	26-2-2010	2198	115	5.23%
Hungary	5 year	1-1-2002	26-2-2010	2198	107	4.87%
Mexico	3 months	1-1-2002	26-2-2010	2198	89	4.05%
Mexico	10 year	1-1-2002	26-2-2010	2198	449	20.43%
Philippines	3 months	1-1-2002	26-2-2010	2198	125	5.69%
Philippines	5 year	1-1-2002	26-2-2010	2198	125	5.69%
Philippines	10 year	1-1-2002	26-2-2010	2198	126	5.73%
Poland	1 year	1-1-2002	26-2-2010	2198	22	1.00%
Poland	5 year	1-1-2002	26-2-2010	2198	6	0.27%
Poland	10 year	25-11-2002	26-2-2010	1964	4	0.20%
South Africa	2 year	19-3-2003	26-2-2010	1882	397	21.09%
South Africa	5 year	1-1-2002	26-2-2010	2198	953	43.36%
South Africa	10 year	1-1-2002	26-2-2010	2198	0	0.00%
South Korea	3 months	1-1-2002	26-2-2010	2198	127	5.78%
South Korea	1 year	1-1-2002	26-2-2010	2198	124	5.64%
South Korea	2 year	1-1-2002	26-2-2010	2198	101	4.60%
South Korea	3 year	1-1-2002	26-2-2010	2198	106	4.82%
South Korea	5 year	1-1-2002	26-2-2010	2198	115	5.23%
Turkey	T-Bill yields	1-1-2002	26-2-2010	2198	1585	72.11%
Turkey	3 year (USD)	1-1-2002	26-2-2010	2198	10	0.45%
Turkey	8 year (USD)	1-1-2002	26-2-2010	2198	385	17.52%
United States	5 year	1-1-2002	26-2-2010	2198	0	0.00%

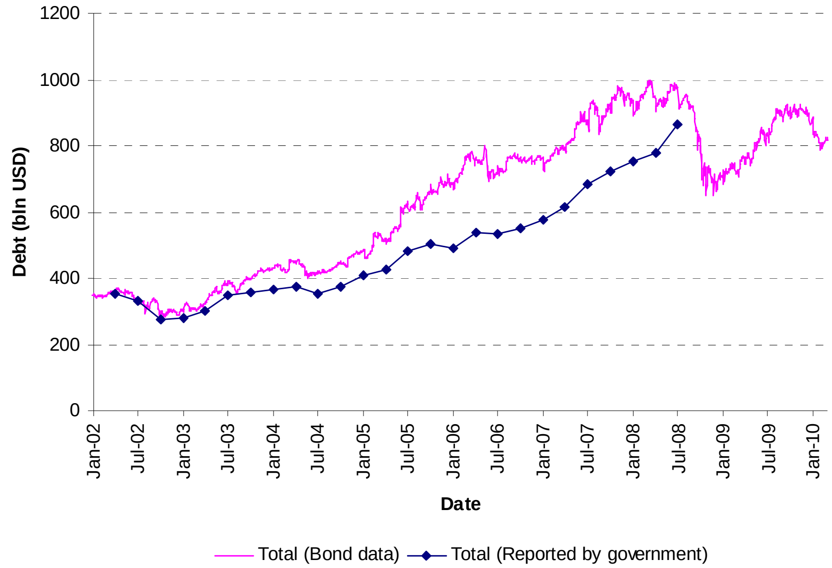


Figure B.1 Calculated market values of total debt and reported values of total debt of Brazil in the period April 2002 to February 2010.

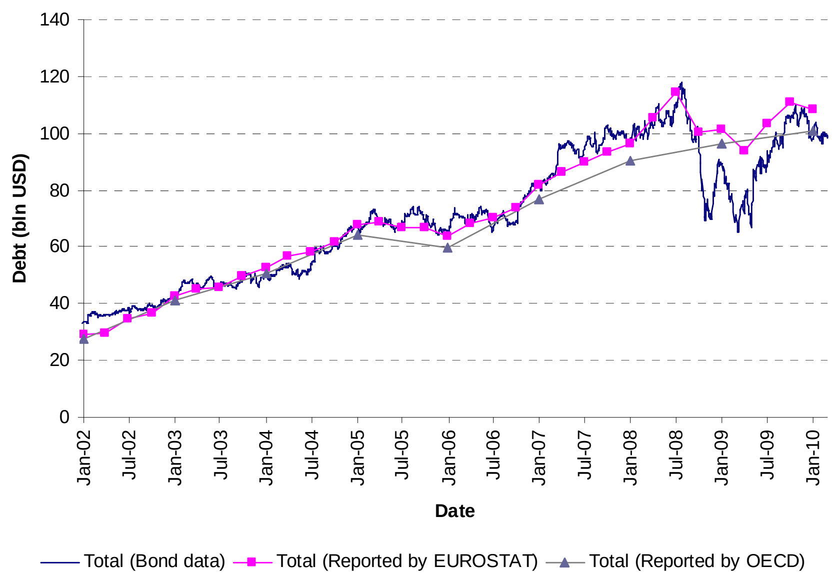


Figure B.2 Calculated market values of total debt and reported values of total debt of Hungary in the period April 2002 to February 2010.

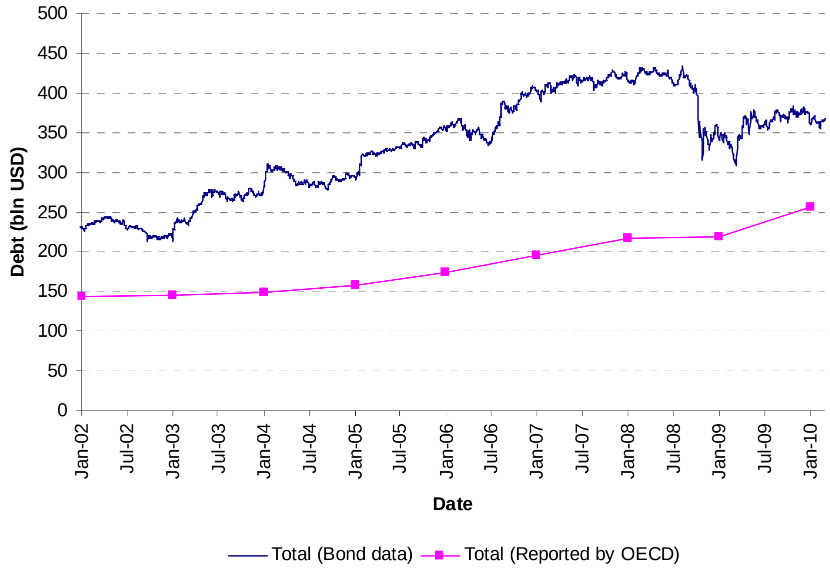


Figure B.3 Calculated market values of total debt and reported values of total debt of Mexico in the period April 2002 to February 2010.

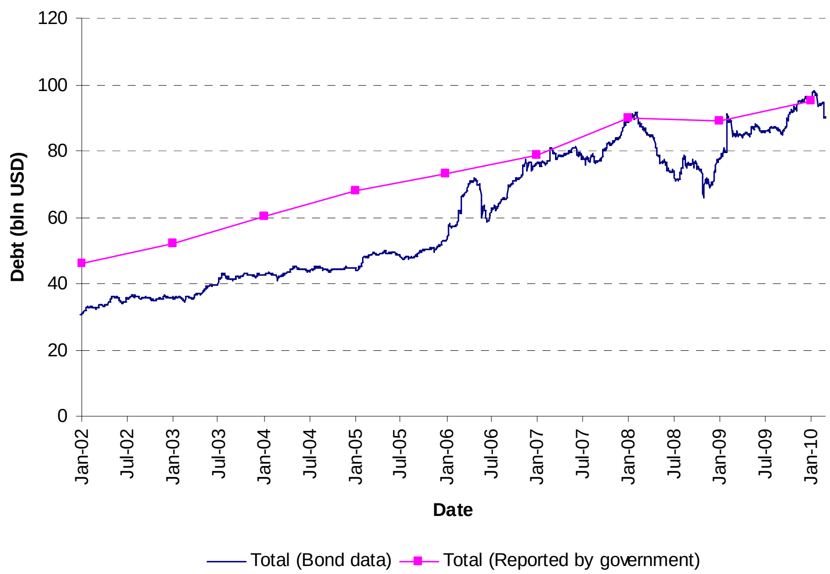


Figure B.4 Calculated market values of total debt and reported values of total debt of the Philippines in the period April 2002 to February 2010.

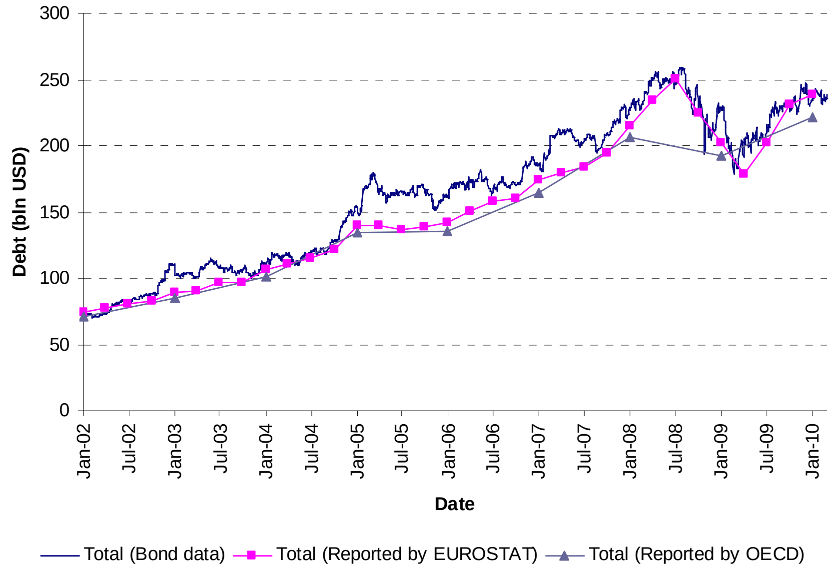


Figure B.5 Calculated market values of total debt and reported values of total debt of Poland in the period April 2002 to February 2010.

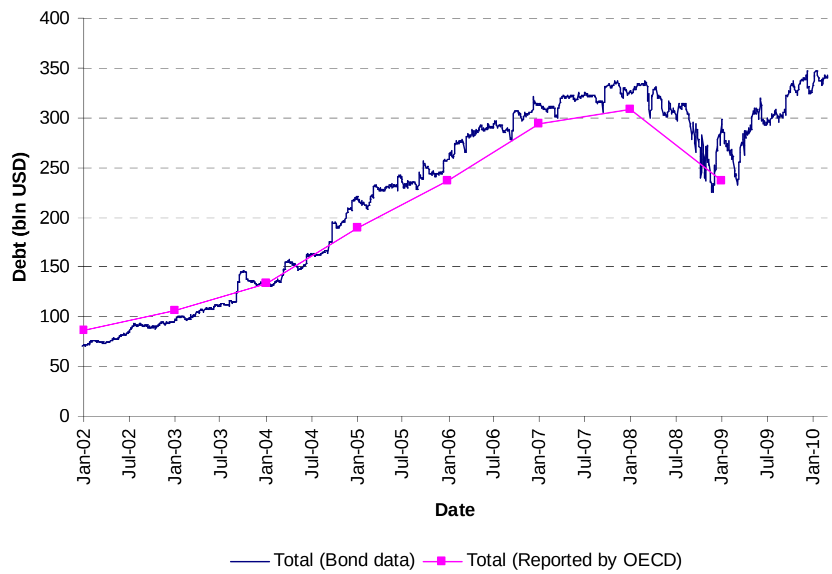


Figure B.6 Calculated market values of total debt and reported values of total debt of South Korea in the period April 2002 to February 2010.

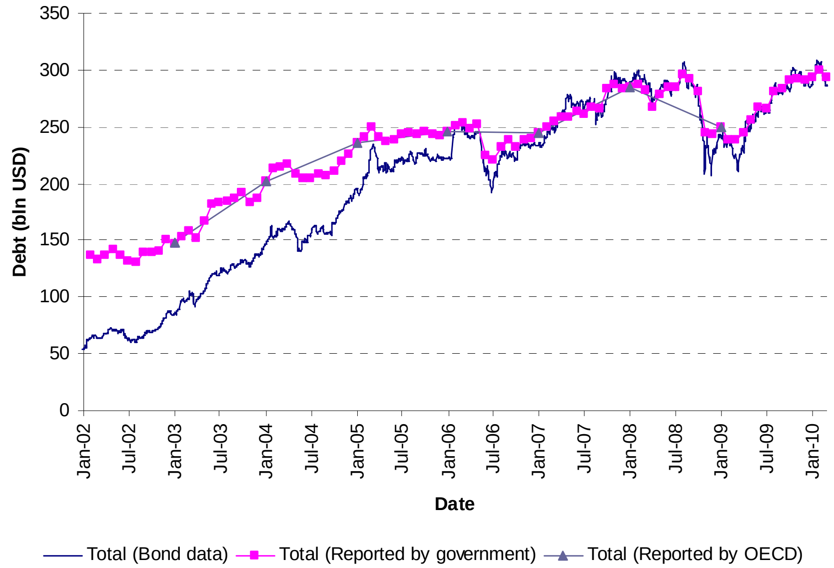


Figure B.7 Calculated market values of total debt and reported values of total debt of Turkey in the period April 2002 to February 2010.

Appendix C

FX Data

Table C.1 Quality of Bloomberg data on the local currency and the US Dollar FX rate of the eight selected emerging countries.

Country	Currency	Start date	End date	#Values	#Missing Values	Missing Values (%)
Brazil	Real (BRL)	1-1-2002	26-2-2010	2129	11	0.52%
Hungary	Florint (HUF)	1-1-2002	26-2-2010	2129	0	0.00%
Mexico	Peso (MXN)	1-1-2002	26-2-2010	2129	0	0.00%
Philippines	Peso (PHP)	1-1-2002	26-2-2010	2129	2	0.09%
Poland	Zloty (PLN)	1-1-2002	26-2-2010	2129	1	0.05%
South Africa	Rand (ZAR)	1-1-2002	26-2-2010	2129	0	0.00%
South Korea	Wong (KRW)	1-1-2002	26-2-2010	2129	1	0.05%
Turkey	Lira (TRY)	1-1-2002	26-2-2010	2129	1	0.05%

Appendix D

CDS Data

Table D.1 Quality of Bloomberg data on the 5 year CDS spreads of the eight selected emerging countries.

Country	Start date	End date	#Values	#Missing Values	Missing Values (%)
Brazil	12-10-2001	26-02-2010	2186	112	5.12
Hungary	15-03-2002	26-02-2010	2076	118	5.68
Mexico	12-10-2001	26-02-2010	2186	107	4.89
Philippines	**04-04-2002**	26-02-2010	2062	185	**8.97**
Poland	20-10-2000	26-02-2010	2441	72	2.95
South Africa	**06-10-2000**	26-02-2010	2451	70	2.86
South Korea	28-02-2002	26-02-2010	2087	51	**2.44**
Turkey	12-10-2000	26-02-2010	2447	64	2.62

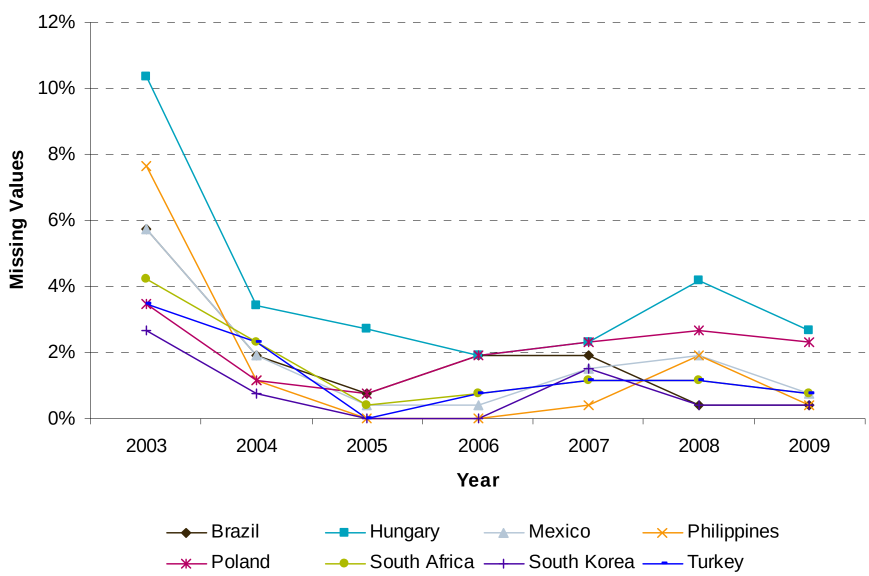


Figure D.1 Percentage missing values of Bloomberg data on the 5 year CDS spreads of the eight selected emerging countries.

Appendix E

Contemporary Correlations and T-Values

Table E.1 Contemporary correlations of an *n* month absolute change in the distance to distress and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-0.16	-0.24	-0.21	-0.08	-0.20	-0.29	-0.15	-0.27	-0.20
2	-0.22	-0.34	-0.28	-0.17	-0.28	-0.37	-0.21	-0.30	-0.27
3	-0.24	-0.38	-0.31	-0.19	-0.35	-0.44	-0.29	-0.37	-0.32
6	-0.29	-0.52	-0.48	-0.31	-0.58	-0.55	-0.52	-0.47	-0.47
9	-0.25	-0.59	-0.57	-0.42	-0.67	-0.54	-0.57	-0.38	-0.50
12	-0.29	-0.60	-0.53	-0.37	-0.66	-0.62	-0.66	-0.47	-0.53
24	-0.58	-0.86	-0.57	-0.36	-0.59	-0.67	-0.71	-0.53	-0.61

Table E.2 Contemporary t-values of an *n* month absolute change in the distance to distress and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-1.50	-2.42	-2.09	-0.81	-1.92	-2.94	-1.50	-2.64	-1.98
2	-2.19	-3.40	-2.75	-1.60	-2.76	-3.83	-2.09	-3.01	-2.70
3	-2.39	-3.94	-3.05	-1.82	-3.55	-4.66	-2.91	-3.84	-3.27
6	-2.86	-5.65	-5.16	-3.02	-6.61	-6.17	-5.72	-4.90	-5.01
9	-2.36	-6.76	-6.34	-4.24	-8.36	-5.91	-6.29	-3.78	-5.51
12	-2.76	-6.81	-5.64	-3.54	-7.83	-7.10	-7.97	-4.84	-5.81
24	-5.97	-13.77	-5.79	-3.18	-6.13	-7.56	-8.33	-5.22	-7.00

Table E.3 Contemporary correlations of an *n* month relative change in the distance to distress and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-0.26	-0.36	-0.29	-0.14	-0.31	-0.38	-0.33	-0.37	-0.31
2	-0.37	-0.47	-0.31	-0.24	-0.37	-0.47	-0.39	-0.41	-0.38
3	-0.41	-0.53	-0.35	-0.26	-0.47	-0.56	-0.49	-0.51	-0.45
6	-0.47	-0.71	-0.57	-0.38	-0.75	-0.69	-0.79	-0.57	-0.61
9	-0.42	-0.78	-0.64	-0.48	-0.82	-0.68	-0.77	-0.49	-0.63
12	-0.45	-0.77	-0.64	-0.43	-0.79	-0.75	-0.85	-0.60	-0.66
24	-0.69	-0.89	-0.69	-0.36	-0.72	-0.76	-0.84	-0.65	-0.70

Table E.4 Contemporary t-values of an *n* month relative change in the distance to distress and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-2.62	-3.67	-2.88	-1.31	-3.18	-3.99	-3.34	-3.82	-3.10
2	-3.78	-5.03	-3.13	-2.33	-3.85	-5.04	-4.10	-4.34	-3.95
3	-4.29	-5.91	-3.51	-2.53	-5.05	-6.35	-5.40	-5.69	-4.84
6	-4.92	-9.36	-6.48	-3.87	-10.52	-8.82	-11.90	-6.41	-7.78
9	-4.19	-11.50	-7.54	-4.97	-13.05	-8.49	-11.24	-5.20	-8.27
12	-4.54	-10.88	-7.48	-4.27	-11.79	-10.07	-14.43	-6.72	-8.77
24	-7.98	-16.28	-7.82	-3.24	-8.70	-9.63	-13.06	-7.09	-9.23

Table E.5 Contemporary correlations of an *n* month absolute change in the FX volatility and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	0.29	0.44	0.31	-0.03	0.33	0.33	0.50	0.28	0.30
2	0.41	0.58	0.32	0.07	0.42	0.41	0.57	0.31	0.39
3	0.44	0.68	0.40	0.11	0.58	0.52	0.69	0.39	0.48
6	0.50	0.83	0.69	0.32	0.84	0.67	0.90	0.45	0.65
9	0.47	0.88	0.66	0.39	0.88	0.65	0.89	0.43	0.66
12	0.52	0.88	0.69	0.36	0.86	0.71	0.92	0.50	0.68
24	0.68	0.89	0.76	0.35	0.83	0.72	0.89	0.49	0.70

Table E.6 Contemporary t-values of an *n* month absolute change in the FX volatility and an *n* month absolute change in the 5 year CDS spread of the eight selected emerging countries during the period April 2002 to February 2010.

Contemporary (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	2.90	4.68	3.10	-0.28	3.30	3.33	5.55	2.79	3.17
2	4.26	6.88	3.27	0.63	4.48	4.31	6.65	3.16	4.20
3	4.69	8.78	4.17	1.01	6.72	5.83	9.07	4.06	5.54
6	5.40	14.08	8.96	3.14	14.20	8.48	19.20	4.76	9.78
9	4.86	16.78	8.08	3.93	16.66	7.79	17.72	4.35	10.02
12	5.53	16.56	8.49	3.49	15.18	9.14	21.90	5.15	10.68
24	7.62	16.46	9.69	3.11	12.24	8.65	16.53	4.68	9.87

Appendix F

Lead - Lag Correlations and T-Values

Table F.1 Lead-lag correlations of an *n* month absolute change in the distance to distress (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-0.07	-0.15	-0.15	-0.13	-0.15	-0.19	-0.06	0.07	-0.10
2	-0.05	-0.13	-0.14	-0.08	-0.21	-0.17	-0.06	0.03	-0.10
3	-0.04	-0.15	-0.22	-0.10	-0.21	-0.20	-0.06	-0.03	**-0.13**
6	0.12	-0.12	-0.15	-0.07	-0.16	-0.03	-0.03	0.05	-0.05
9	0.09	-0.02	0.05	0.02	0.04	0.10	-0.02	0.06	0.04
12	0.08	-0.03	0.09	0.04	-0.07	-0.07	-0.04	0.11	0.01
24	-0.01	0.05	0.11	-0.03	0.01	0.05	0.15	0.03	0.04

Table F.2 Lead-lag t-values of an *n* month absolute change in the distance to distress (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-0.70	-1.48	-1.41	-1.24	-1.49	-1.83	-0.58	0.72	-1.00
2	-0.49	-1.25	-1.31	-0.75	-2.01	-1.64	-0.60	0.31	-0.97
3	-0.35	-1.39	-2.08	-0.97	-2.02	-1.96	-0.60	-0.30	**-1.21**
6	1.16	-1.09	-1.43	-0.65	-1.55	-0.23	-0.31	0.49	-0.45
9	0.79	-0.19	0.48	0.16	0.40	0.91	-0.16	0.55	0.37
12	0.70	-0.24	0.78	0.35	-0.60	-0.61	-0.34	0.98	0.13
24	-0.12	0.44	0.90	-0.22	0.12	0.40	1.22	0.22	0.37

Table F.3 Lead-lag correlations of an *n* month relative change in the distance to distress (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-0.16	-0.20	-0.05	-0.12	-0.13	-0.19	-0.04	0.09	-0.10
2	-0.13	-0.18	-0.08	-0.05	-0.26	-0.21	-0.05	0.03	-0.12
3	-0.10	-0.21	-0.18	-0.08	-0.30	-0.27	-0.08	-0.02	**-0.16**
6	0.16	-0.13	-0.14	-0.02	-0.17	-0.03	-0.02	0.07	-0.04
9	0.07	-0.01	0.05	0.05	0.03	0.09	0.02	0.06	0.05
12	0.03	0.01	0.06	0.09	-0.03	-0.06	0.03	0.07	0.02
24	-0.06	0.06	0.11	0.00	0.01	0.06	0.15	-0.01	0.04

Table F.4 Lead-lag t-values of an *n* month relative change in the distance to distress (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	-1.53	-1.96	-0.44	-1.15	-1.25	-1.80	-0.34	0.88	-0.95
2	-1.24	-1.73	-0.72	-0.51	-2.55	-2.01	-0.48	0.28	-1.12
3	-0.91	-2.03	-1.76	-0.78	-2.97	-2.63	-0.72	-0.22	**-1.50**
6	1.47	-1.22	-1.32	-0.21	-1.59	-0.27	-0.17	0.68	-0.33
9	0.63	-0.05	0.44	0.47	0.26	0.82	0.22	0.56	0.42
12	0.26	0.06	0.51	0.83	-0.26	-0.50	0.24	0.63	0.22
24	-0.49	0.53	0.91	0.01	0.11	0.53	1.29	-0.12	0.35

Table F.5 Lead-lag correlations of an *n* month absolute change in the FX volatility (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	0.21	0.26	-0.05	0.16	0.15	0.15	0.02	0.03	0.11
2	0.18	0.26	0.05	0.15	0.30	0.22	0.08	0.08	0.17
3	0.16	0.33	0.21	0.21	0.37	0.32	0.16	0.12	**0.24**
6	-0.13	0.17	0.17	0.14	0.14	0.07	0.11	-0.05	0.08
9	-0.06	0.03	-0.02	0.00	-0.02	-0.05	-0.01	-0.06	-0.02
12	0.00	0.01	-0.02	0.04	0.01	0.04	-0.07	-0.06	-0.01
24	0.07	-0.04	-0.08	0.15	-0.03	-0.04	-0.14	-0.06	-0.02

Table F.6 Lead-lag t-values of an *n* month absolute change in the FX volatility (leading) and a one month absolute change in the 5 year CDS spread (lagging) of the eight selected emerging countries during the period April 2002 to February 2010.

Lead - Lag (#months)	Brazil	Hungary	Mexico	Philippines	Poland	South Africa	South Korea	Turkey	Average
1	2.06	2.52	-0.46	1.50	1.41	1.42	0.18	0.25	1.11
2	1.78	2.51	0.46	1.42	2.97	2.18	0.80	0.80	1.62
3	1.53	3.27	1.98	2.06	3.82	3.16	1.51	1.18	**2.31**
6	-1.17	1.63	1.63	1.31	1.27	0.67	1.03	-0.46	0.74
9	-0.51	0.31	-0.18	0.01	-0.18	-0.50	-0.08	-0.54	-0.21
12	0.00	0.12	-0.20	0.36	0.08	0.34	-0.66	-0.54	-0.06
24	0.54	-0.34	-0.70	1.24	-0.28	-0.32	-1.13	-0.48	-0.18