Summer 8-13-2010

Essays in Sovereign Credit Risk

Thomas J. Plank
University of Pennsylvania, tplank@wharton.upenn.edu

Essays in Sovereign Credit Risk

Abstract
This dissertation investigates aspects of sovereign credit risk in advanced and emerging economies. It consists of two chapters.

Chapter 1 studies the determinants of sovereign credit default swap (CDS) spreads for 16 advanced economies during the recent financial crisis. We document that the state of the world financial system, and since the beginning of the crisis, the state of a country's domestic financial system, have strong explanatory power for the behavior of CDS spreads. Furthermore, the magnitude of this effect depends on the relative importance of a country's financial system pre-crisis. Our results suggest the presence of a private-to-public risk transfer through which market participants incorporate their expectations about the potential burden of government intervention.

Chapter 2 studies the extent to which macro-economic variables govern the dynamics of emerging market sovereign CDS spreads. In this chapter, I propose a structural model of sovereign credit risk based on a country's access to international capital flows through exports, imports and international reserves. The joint dynamics of the sovereign's repayment capacity and the amount of outstanding debt determine the level of default risk and thus the sovereign CDS spread. I implement the model for a sample of six emerging economies for a period covering the recent financial crisis. A calibrated version of the model captures the widening of sovereign spreads during the crisis and provides a good fit for their time-series dynamics. Lastly, I find that the market-implied level of country liabilities is on average 13% larger than the reported level of debt.

Degree Type
Dissertation

Degree Name
Doctor of Philosophy (PhD)

Graduate Group
Finance

First Advisor
Urban J. Jermann

Second Advisor
Karen K. Lewis

Third Advisor
Stephan Dieckmann

Keywords
sovereign credit risk, sovereign cds, credit default swaps

Subject Categories
Finance

ESSAYS IN SOVEREIGN CREDIT RISK

Thomas J. Plank

A DISSERTATION

in

Finance

For the Graduate Group in Managerial Science and Applied Economics

Presented to the Faculties of the University of Pennsylvania

in

Partial Fulfillment of the Requirements for the

Degree of Doctor of Philosophy

2010

Supervisor of Dissertation

Signature ______________________________

Urban J. Jermann, Safra Professor of International Finance and Capital Markets

Graduate Group Chairperson

Signature ______________________________

Eric Bradlow, Professor of Marketing, Statistics, and Education

Dissertation Committee

Urban J. Jermann, Safra Professor of International Finance and Capital Markets

Karen K. Lewis, Sondheimer Professor in International Economics and Finance

Stephan Dieckmann, Visiting Assistant Professor of Finance

Essays in Sovereign Credit Risk

ABSTRACT

ESSAYS IN SOVEREIGN CREDIT RISK

Thomas J. Plank

Urban J. Jermann

This dissertation investigates aspects of sovereign credit risk in advanced and emerging economies. It consists of two chapters.

Chapter 1 studies the determinants of sovereign credit default swap (CDS) spreads for 16 advanced economies during the recent financial crisis. We document that the state of the world financial system, and since the beginning of the crisis, the state of a country's domestic financial system, have strong explanatory power for the behavior of CDS spreads. Furthermore, the magnitude of this effect depends on the relative importance of a country's financial system pre-crisis. We also find that CDS spreads behaved differently for countries in the Economic and Monetary Union of the European Union (EMU). Although the level of spreads is lower for member countries, their sensitivities to the health of the financial system are higher compared to non-EMU members. Our results suggest the presence of a private-to-public risk transfer through which market participants incorporate their expectations about financial industry bailouts and the potential burden of government intervention.

Chapter 2 studies the extent to which macro-economic variables govern the dynamics of emerging market sovereign CDS spreads. In this chapter, I propose a structural model of sovereign credit risk based on a country's access to international capital flows through exports, imports and international reserves. Using these macro-fundamentals, I define a sovereign's ability to pay as the maximum amount of foreign currency available for repayment of external debt. The joint dynamics of the ability to pay and the amount of outstanding debt determine the level of default risk and thus the sovereign CDS spread.

I implement the model for a sample of six emerging economies for a period covering the recent financial crisis. A calibrated version of the model captures the widening of sovereign spreads during the crisis and provides a good fit for their time-series dynamics. Lastly, I use the model to measure the market-implied level of country liabilities. On average, the value of implied external debt is 13% larger than the reported level of debt.

Contents

List of Tables

List of Figures

Chapter 1

Default Risk of Advanced Economies: An Empirical Analysis of Credit Default Swaps during the Financial Crisis

Joint with Stephan Dieckmann

1.1 Introduction

The collapse of US and global real estate prices in 2007 initiated an international financial crisis which subsequently spread to the real economy. Established financial institutions in the US and Europe suffered large losses, driven by write-downs related to sub-prime mortgages, a decline in the availability of credit and damaged investor confidence. While central banks expanded monetary policy and engaged in quantitative easing in an effort to stabilize the economy, governments provided unprecedented levels of public financial assistance to ailing institutions. As fiscal concerns following government-funded stabilization programs come to the fore, the sovereign credit default swap (CDS) market for advanced economies has become less obscure and increasingly liquid. Out of the ten largest single name CDS exposures by net notional, seven are now European advanced economies.[1] Furthermore, since September 2009 investors can trade index products on a basket of Western European sovereign CDS in addition to the long-standing emerging markets and corporate CDS indices.

While CDS on emerging market debt have received much attention in the literature, research on the credit risk of more advanced economies has been sparse. Our analysis builds on the work of Boehmer and Megginson (1990) and Edwards (1984), who focus on the determinants of the yield spreads of emerging market debt, as well as Longstaff, Pan, Pedersen and Singleton (2009), who examine the sources of commonality in emerging market CDS spreads. In contrast to the emerging markets literature, we study the determinants of the price of insurance against default of developed nations, using a new data set containing CDS spreads of 16 advanced economies.

The cross-section of these sovereign CDS spreads exhibits a strong degree of commonality. The first principal component of spread changes explains roughly 74% of variation, whereas the first three principal components cumulatively account for 89%. We document that, above and beyond the factors of commonality suggested by Longstaff et al. (2009), the state of the world financial system, and since the beginning of the recent financial crisis also the state of a country's domestic financial system, have strong explanatory power for the behavior of CDS spreads. This finding suggests a private-to-public risk transfer through which market participants incorporate their expectations about financial industry bailouts and the potential burden of government intervention. Our interpretation is motivated by Burnside, Eichenbaum and Rebelo (2001), who argue that the principal cause of the 1997 Asian currency crisis was the future deficits associated with implicit bailout guarantees to the failing domestic financial system. Similarly, European countries extended significant

[1] As of 1/30/2009. Source: HSBC.

amounts of loans to local banks in order to prevent large bank failures, partially recapitalized financial institutions by taking equity stakes and outright nationalized firms which posed a systemic risk to the economy. These actions may have led market participants to assume government guarantees on the liabilities of the financial sector, and in many cases these liabilities were large. Ireland's aggregate bank assets between 2003 and 2006, for example, were on average almost five times as large as its GDP. Such explicit assistance to failing banks, large-scale support programs as well as implicit government guarantees may have led to a repricing of advanced economies' sovereign CDS.

Our analysis relies on the empirically observed correlation patterns between sovereign CDS spreads and the stock market performance of the local and global financial services industry.[2] We formulate and test four hypotheses related to a potential private-to-public risk transfer.

First, we show that the magnitude of this economic channel depends on the relative importance of a countrys financial system pre-crisis. CDS spreads of countries whose domestic economies relied heavily on the financial services industry pre-crisis show a stronger co-movement with the health of the domestic and international financial system. This result is consistent with popular belief about governments absorbing risks of private sectors during the recent crisis and may not seem surprising. However, to our knowledge, we are the first to quantify this economic channel.

Secondly, we analyze two sources of country heterogeneity: whether a country is a member of the Monetary and Economic Union of the European Union (EMU) and how exposed a country's financial system was to the sub-prime mortgage sector. The level of CDS spreads is, on average, 50-70bps lower for countries in the EMU, which is consistent with

[2]Even though one could, in principle, investigate the joint evolution of sovereign and financial sector CDS spreads, we choose to examine financial system stock market returns. This does not change the correlation patterns due to the strong negative relation between CDS spread and stock price.

results based on government yields as in Lund (1999). But we also show EMU countries' sensitivities to shocks to the global and local financial system are higher compared to non-EMU members, suggesting the private-to-public risk transfer was larger for countries operating under a supra-national monetary authority. Specifically, the sensitivities of EMU member countries are twice as large compared to non-EMU members – possibly a reflection of those countries' inability to individually control Euro money supply. The second source of country heterogeneity we study is a country's exposure to the sub-prime mortgage sector. Since we do not observe bank-level holding data on sub-prime mortgage securities, we estimate countries' exposure to this sector through a correlation study of domestic financial firms' returns and the ABX.HE index – a popular index tracking the price performance of sub-prime securities. We find that a country's exposure to the US sub-prime mortgage sector does not significantly alter the magnitude of the private-to-public risk transfer. This seems surprising given the widely-held belief that the roots of the current crisis and much of the associated losses can be traced to the sub-prime sector. However, we acknowledge that this finding could also be due to an imprecise measure of sub-prime risk exposure.

Lastly, the importance of the financial sector should also be reflected in CDS spread levels, not only in changes, and investigating levels has the advantage that we can control for a country's indebtedness. A deterioration of the financial system might lead to lower levels of output, or additional debt issuance may be needed to finance government deficits associated with a risk transfer, thus increasing leverage. For example, high budget deficits and an ailing economy in Greece led to a significant widening of CDS spreads since December 2009, fueling the discussion about a potential credit event. We find that a country's pre-crisis exposure to the financial system explains on average 39bps, above and beyond its debt to GDP ratio explaining 26bps. While such a difference appears large, it is of course an ex-ante perspective – government guarantees that were triggered should be reflected in country-specific fundamentals ex-post. We employ a battery of explanatory variables that market participants might use in assessing the distance to a country's default barrier. For example, a countries' stock market volatility matters, which is consistent with predictions that arise from an ability-to-repay model as in Claessens and Pennacchi (1996). In addition, the impact of stock market volatility has increased substantially in magnitude during the financial crisis.

The remainder of this paper is organized as follows: Section 1.2 describes the data and discusses the mechanics of the Western European sovereign CDS market. Section 1.3 studies the co-movement between the performance of the financial system and sovereign CDS spreads, in the time series and the cross section as well as in changes and in levels. Section 1.4 concludes.

1.2 Data Description

The raw data in this study consists of sovereign CDS spread levels at the 10 year maturity mark. For the empirical analysis we use both weekly spread levels, denoted CDS_{it}, as well as changes, denoted ΔCDS_{it}. We first discuss the mechanics of the sovereign CDS market and then proceed to characterize the dataset. For an in-depth discussion of the pricing and modeling of CDS contracts see, for example, Duffie and Singleton (2003) or Hull and White (2000).

1.2.1 Mechanics of the Sovereign CDS Market

A sovereign CDS is a bilateral over-the-counter agreement between two parties to exchange cash-flows based on future contingencies. The CDS seller provides insurance to the buyer in case a credit event occurs in an obligation issued by the reference entity. In exchange for credit protection, the CDS buyer pays an amount equal to the spread times the notional to the protectional seller on a semi-annual basis for the maturity of the contract or the occurrence of a credit event, whichever is sooner. In case a credit event occurs, the CDS buyer pays the accrued coupon for the period and delivers the defaulted obligation to the seller for a payment of par value (physical settlement), or receives the difference between par value and the market price (cash settlement). Important for our case, the International Swaps and Derivatives Association (ISDA) defines a credit event for a sovereign issuer as obligation acceleration, failure to pay, restructuring or repudiation/moratorium.

For a bond to qualify as the reference obligation, it should be a deliverable obligation as defined by ISDA. In the case of emerging markets sovereign CDS, only bonds issued non-domestically in a standard specified currency (USD, Euro, Yen, Canadian dollar, Franc, and Pound) are considered admissible[3]. This is similar in the case of Western European sovereign CDS – if a country has outstanding foreign currency debt issued in a standard specified currency, these bonds are considered to be deliverable obligations. However, if a sovereign does not have any outstanding foreign currency debt, the deliverable obligation is the domestic local-currency debt. Lastly, in the case of Eurozone sovereigns, EUR denominated debt is considered a deliverable obligation, alongside any other foreign currency debt in one of the standard currencies. In the case of a credit event, the post-event market price of the underlying is determined through an auction process. It is generally not possible to physically deliver outside the auction process. Instead, protection buyers can deliver into the auction or cash settle off the auction price. Likewise, protection sellers can take delivery from the auction or cash settle off the auction price.

In order to mitigate counterparty risk, parties can be asked to post cash-equivalent collateral. However, the possibility remains that a credit event on an advanced industrial country would coincide with a severe market disruption, rendering one or both of the counterparties unable to fulfil their contractual obligations. We acknowledge that such jump

[3]See Pan and Singleton (2008)

to default risk exists and point to two mitigating factors with respect to our study: First, banks will generally not trade the CDS contract on their domestic sovereign due to correlation risk. Second, a negative shock to the financial system should decrease the conditional expected payoff of a CDS contract solely from the perspective of counterparty risk. However, we find that the empirical correlation between sovereign CDS spreads and the state of the financial sector is robustly negative. Thus, even if counterparty risk were priced in, it only would serve to strengthen our results.

1.2.2 The Dataset

We utilize proprietary data from the credit trading desk of a large US bank, containing end-of-day 10-year sovereign CDS mid-quotes for 16 countries from January 2003 to September 2009.[4] All quotes are based on the USD-denominated CDS contract. The countries covered are the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Netherlands, Portugal, Slovenia, Spain, Sweden and the UK. All countries are classified as advanced economies by the IMF, with the exception of Hungary. Out of the 16 countries, 10 are members of the European Economic and Monetary Union (EMU) and thus share the EURO as their common currency. Of the remaining six countries, five are members of the European Union. The spread data is recorded at a daily frequency and indicates whether a trade has taken place in the instrument during that day. We only use observations for our analysis if the CDS contract was indeed traded.

We use both weekly spread levels as well as changes which yields a total of 1,901 country-week observations for levels and 1,523 country-week observations for non-overlapping changes. Table 1.1 shows summary statistics in basis points.

Of the countries in our sample, 12 traded in single digit spreads at the beginning of the

[4] Anecdotal evidence from conversations with traders suggests that the 10 year maturity contract is the most liquid on the Western European sovereign CDS term structure. However, our results are robust to using 5 year CDS spreads.

Table 1.1: **Sovereign CDS Spreads**.
This table reports descriptive statistics for weekly CDS spread levels and changes. The spreads are recorded as mid-point quotes between bid and offer at the end of each trading day in basis points.

	Levels (bps, weekly)							Changes (bps, weekly)						
Country	**Mean**	**SD**	**Min**	**Max**	**Start**	**End**	**N**	**Mean**	**SD**	**Min**	**Max**	**Start**	**End**	**N**
Czech Republic	67.4	73.4	8.7	346.0	Mar-03	Sep-09	150	0.90	16.15	-61.00	60.00	Apr-03	Sep-09	110
Denmark	56.2	43.3	3.4	140.2	Mar-03	Sep-09	61	0.38	9.96	-25.33	26.50	Dec-03	Sep-09	49
Finland	38.1	21.7	2.8	93.7	Feb-04	Sep-09	64	0.09	6.08	-18.47	18.33	Jan-08	Sep-09	59
France	25.6	23.3	3.0	94.2	Jan-03	Sep-09	115	0.04	5.08	-15.77	13.51	Apr-03	Sep-09	75
Germany	20.8	20.7	2.9	91.3	Apr-03	Sep-09	125	-0.03	4.77	-18.67	16.74	Jan-04	Sep-09	93
Greece	70.6	74.5	11.8	296.3	Mar-03	Sep-09	161	0.60	12.78	-39.39	40.88	Jul-03	Sep-09	123
Hungary	116.5	135.3	19.3	585.7	Apr-03	Sep-09	289	0.70	24.31	-195.67	148.58	May-03	Sep-09	278
Ireland	141.1	101.4	3.5	369.3	Mar-03	Sep-09	70	1.50	29.41	-59.50	104.98	Feb-05	Sep-09	55
Israel	90.6	61.4	28.6	287.5	Apr-03	Sep-09	170	-0.26	11.96	-81.47	46.74	Apr-04	Sep-09	144
Italy	51.5	50.8	11.0	193.1	Mar-03	Sep-09	183	0.33	9.16	-27.37	36.73	Jul-03	Sep-09	139
Netherlands	50.8	34.9	3.3	124.3	Mar-03	Sep-09	69	-0.21	8.33	-22.86	27.93	Jan-08	Sep-09	56
Portugal	44.7	38.0	7.3	157.5	Apr-03	Sep-09	140	0.22	8.84	-22.91	37.26	Apr-03	Sep-09	102
Slovenia	84.1	55.8	6.5	231.0	Apr-03	Sep-09	53	1.52	17.73	-37.50	41.00	Apr-06	Sep-09	35
Spain	49.5	43.0	3.4	165.3	Mar-03	Sep-09	133	0.38	9.67	-23.94	41.25	Dec-03	Sep-09	104
Sweden	66.9	39.4	3.4	155.7	Mar-03	Sep-09	51	-1.14	12.70	-31.00	28.75	Jan-08	Sep-09	44
United Kingdom	71.4	42.8	4.2	164.3	Mar-03	Sep-09	67	0.09	11.17	-30.52	39.45	Mar-07	Sep-09	57

sample period, whereas all 16 countries traded in double or triple digit spreads at the end of the sample. Furthermore, there is a wide dispersion of average premia within the sample: average spreads are as low as 20.8bps in the case of Germany or as high as 141.1bps in the case of Ireland. The standard deviation of spread changes highlights further differences: France exhibits a weekly volatility in spread changes of 4.8bps versus Ireland's 29.4bps. Although countries in the sample are geographically clustered (with the exception of Israel), we can observe a high degree of cross-sectional variation, both in levels and changes, which may partially be a reflection of differing degrees of credit quality across countries.[5]

It is also instructive to graphically examine the time series properties of CDS spreads. Figure 1.1 plots the level of spreads from January 2007 to September 2009. Prior to the bankruptcy of Lehman Brothers on the 15^{th} September 2008, CDS spreads for most countries are relatively stable and exhibit low correlation cross-sectionally. Since the bankruptcy, however, sovereign CDS strongly move together and rise to unprecedented levels. Most sovereign spreads peak at the beginning of March 2009, shortly after AIG announced a fourth quarter loss of $61.7bn, the largest quarterly loss in corporate history at the time. Ireland's credit swap spread, for example, peaked at 369bps, a more than hundredfold increase over its pre-crisis lows. Even Germany experienced a CDS spread more than 30 times the magnitude of its 2006 levels.

1.2.3 Principal Component Analysis

Figure 1.1 suggests there existed strong co-movement in CDS spreads across countries during the financial crisis. To further quantify the degree of such commonality, we conduct a principal component analysis in the spirit of Longstaff et al. (2009). The results of this

[5] In our sample, seven countries hold AAA Standard & Poor's (S&P) credit ratings, three countries are rated AA and the remaining six countries are rated A and below. The country with the lowest S&P credit rating is Hungary, which ranks at BBB- at the end of the sample. Nine countries experienced ratings downgrades in the time covered by the sample, five of which occurred during the first half of 2009.

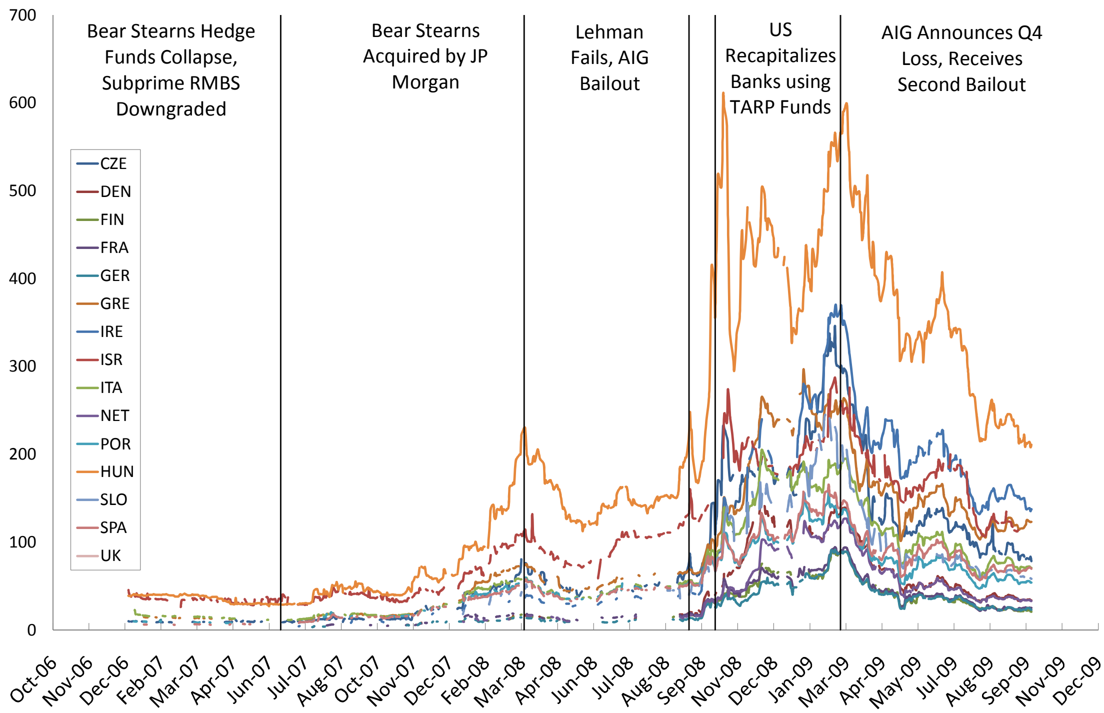


Figure 1.1: **CDS Spreads for Advanced Economies**: 10Y Maturity mid in bps

analysis are listed in Table 1.2. Panel A lists the cumulative percentage of explained variation in CDS spread changes by the first five principal components. To assess the economic significance of the explained variation, we also conduct a principal component analysis of the weekly domestic stock market returns of the sovereigns, respectively.[6]

The first principal component alone explains 74% of sample variation, whereas the first five principal components explain 94%. For domestic stock market returns the first principal

[6] As a proxy for local stock market performance, we utilize the Dow Jones Total Market Indices. These are float-adjusted market capitalization weighted country-specific indices aiming to represent the domestic common stock universe. Also included are securities with the characteristics of common equities, such as REITs. Our empirical results are robust to using alternative country-specific indices. All indices are USD-denominated.

Table 1.2: **Principal Components Analysis**.
This table reports results of a principal components analysis of weekly CDS spread changes. Panel A reports the cumulative percentage of explained variation in CDS spread changes as well as of country-specific equity index returns. Panel B reports the results of a time-series regression of the first principal component on several factors. Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

Panel A

PC	Delta CDS	Stock Returns
1	74.35%	66.05%
2	83.49%	71.63%
3	87.80%	76.64%
4	91.61%	80.77%
5	94.22%	84.06%

Panel B

	(1)	(2)
Stoxx 50	−0.46***	−0.16
	(−4.62)	(−1.61)
Vix	−0.04	−0.14
	(−0.46)	(−1.46)
High Yield	0.09**	0.08**
	(2.24)	(2.15)
GSCI	−0.11*	−0.16**
	(−1.79)	(−2.42)
Carry Trade	−0.18***	−0.10
	(−2.73)	(−1.48)
World Financials		−0.47***
		(−3.53)
N	289	289
R^2 (%)	38	44

component explains 66% of sample variation, and the first five principal components explain 84%. Although both equity returns and spread changes exhibit a large degree of commonality, CDS spreads appear to display stronger cross-sectional correlation. This echoes the results in Longstaff et al. (2009), who argue that diversification benefits for sovereign credit portfolios are lower than for international equity portfolios.

To explore what economically meaningful factors might underlie such commonality, we extract the first principal component and regress it on several factors commonly used in credit risk modeling. The factors are the return of a European equity index, the Stoxx 50, changes in the VIX index, changes in a European high yield index (BB European Corporates - BBB European Corporates), the return to the Goldman Sachs Commodity Index, the return to a carry trade portfolio and the return to an index measuring the performance of financials in developed countries (MSCI Financials Index). Panel B in 1.1 shows the results.

The equity market factor and the carry trade factor are significantly negatively related to the first principal component, such that a one standard deviation change in the Stoxx 50 leads to a negative 0.46 standard deviation change in the first principal component. Contrary to the findings of Pan and Singleton (2008) and Longstaff et al. (2009), the VIX appear to be unrelated to the first principal component. In specification (2), we add the return of a world financials index to the regression. This inclusion adds to the explanatory power of the regression showing a 6% increase in the R^2 value. Furthermore, the coefficient estimate is large and highly significant, and the world financials factor drives out entirely the equity market factor – suggesting that the first principal component is strongly correlated with the state of the world financial system, a finding that we explore further in the next section.

1.3 Empirical Analysis

The starting point for our empirical analysis is Longstaff et al. (2009), who specify a set of factors that proxy for underlying sources of commonality in sovereign emerging market CDS spreads.[7] In particular, the proposed sources of co-movement affect the expected recovery rates, the default probabilities and any risk premia associated with liquidity, and thus impact the market pricing of these contracts. We adopt these factors for our empirical analysis. However, since all of the countries in our sample are more advanced economies and in geographical proximity to Europe, we construct the European equivalent factors.

1.3.1 Explanatory Variables

We sort the covariates into three groups - local, global, and risk premium variables.

Local Variables. We consider three local variables which capture the state of the domestic macroeconomy: (i) the weekly return of the USD-denominated Dow Jones Total Market country index, (ii) the weekly return of the exchange rate relative to the USD, (iii) the weekly change in the USD-value of exchange rate reserves, in billions.[8]

Global Variables. We use four global variables to proxy for the state of the global macroeconomy: (i) the weekly return of the USD-denominated Euro Stoxx 50 Index[9], (ii) the weekly percentage change in the yield to the 10 year German Bund, (iii) the weekly change in the spread between BBB European Corporates and AA European Corporates

[7]For detailed explanations of the construction of the factors see Longstaff et al. (2009).

[8]The dollar value of exchange rate reserves is provided at a monthly frequency. We linearly interpolate monthly observations to arrive at weekly data. As a robustness check, we also conduct our analysis using only the monthly observations. The results are qualitatively and quantitatively similar.

[9]There are many other European market indices that could potentially be used in the analysis. The reason we chose the Euro Stoxx 50 is twofold: First, it is a very visible European equity index. Second, it is highly correlated with other cross-European indices such as the FTSE Eurotop 100 and the S&P Europe 350.

(investment grade spread), (iv) the weekly change in the spread between BB European Corporates and BBB European Corporates (high yield spread). Furthermore, we use two variables to proxy for global investment flows (both series are in USD billions): (i) the weekly change in total net inflows to long-term US equity mutual funds, (ii) the weekly change in total net inflows to long-term US bond mutual funds.[10]

Risk Premium Variables. We use two variables to proxy for risk premia: (i) weekly changes in the price to earnings ratio for the Euro Stoxx 50 (equity premium proxy), (ii) weekly changes in the spread between the V2X volatility implied index (implied volatility of the Euro Stoxx 50) and the weekly realized volatility as measured by the Garman and Klass (1980) volatility estimator.

1.3.2 Preliminary Analysis

We now employ the above factors to analyze the time-series and cross-sectional dynamics of observed sovereign CDS spreads.

1.3.2.1 Country by Country Regressions

To identify which of the covariates have explanatory power for CDS spread changes, we specify a regression given by

$$\Delta CDS_{it} = X_{it}^T \beta_i + \epsilon_{it}, \tag{1.1}$$

where X_{it} is the matrix of factor observations and β_i is a vector of standardized regression coefficients[11]. The coefficients are scaled by the ratio of the standard deviation of the

[10] These dataseries cover US mutual funds from the Investment Company Institute. Unfortunately, to our knowledge there is no publicly available European equivalent. Nevertheless, we believe that these variables are relevant proxies for global capital flows.

[11] Instead of the regression specified in Equation 1.1, we could also assess the significance of different factors by regressing relative CDS spreads on relative factors, where the differences are taken with respect to a base country. However, we specify the regressions in absolute terms so that the reported coefficients are numeraire invariant.

independent variable relative to the standard deviation of the dependent variable. Hence, a regression coefficient of -0.5 implies that a one standard deviation move in the independent variable results in a -0.5 standard deviation move in the dependent variable. Furthermore, all independent variables are demeaned.

The results of the country-by-country regression in Equation 1.1 are displayed in Table 1.3. A casual inspection reveals that the commonality in CDS spreads apparent in Figure 1.1 does not appear to be captured by any of the covariates.

The market factor is only significant at the 5% level in 6 of the 16 countries in the sample. No other covariate is significant in more than 6 countries, and many variables are only significant in one or two countries. Confirming the results is Longstaff et al. (2009), we also find that local factors generally perform poorly relative to their global counterparts. The local market index is only significant at the 5% level in 4 of the countries and carries considerably smaller loadings than the market factor in those cases. Furthermore, for most countries, we find that the regression coefficients have a sign in line with economic intuition. For the local and the global market factors, we expect negative coefficients since an increase in local and global index returns may proxy for an improvement in the domestic and international macroeconomic climate, thus reducing the sovereign credit risk and CDS spread.

We find different results compared to Longstaff et al. (2009) and Pan and Singleton (2008) for the volatility risk premium factor. Even though our sample covers an episode of crisis and market turmoil, the volatility risk premium is statistically insignificant in all of the countries in our sample, which also echoes the results found in the principal component analysis in Table 1.2. To ensure that these results are not driven by mismeasurement of realized volatility, or the definition of the V2X index, we repeat the analysis using weekly changes in the CBOE VIX index as the volatility factor. This confirms our earlier results:

Table 1.3: **Sources of Commonality in Sovereign CDS Spreads**.
This table reports the results of the regression $\Delta CDS_{it} = X_{it}^T \beta_i + \epsilon_{it}$ at a weekly frequency. The regressors in X_{it} are analogous to the factors used in Longstaff et al. (2009) but computed using European data. Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	CZE	**DEN**	**FIN**	**FRA**	**GER**	**GRE**	**HUN**	**IRE**	**ISR**	**ITA**	**NET**	**POR**	**SLO**	**SPA**	**SWE**	**UK**
Local Index	−0.27***	0.05	−0.10	0.04	−0.03	−0.19**	−0.31***	0.04	−0.03	−0.20**	0.01	−0.16	−0.16	−0.19*	0.07	0.32*
	(−2.67)	(0.39)	(−0.95)	(0.34)	(−0.27)	(−2.29)	(−3.45)	(0.24)	(−0.35)	(−2.23)	(0.10)	(−1.63)	(−0.90)	(−1.84)	(0.50)	(1.91)
FX	−0.06	−0.08	0.05	−0.04	−0.02	0.08	−0.01	−0.07	0.03	0.15	−0.07	0.15	0.08	0.18	0.35*	0.13
	(−0.52)	(−0.39)	(0.23)	(−0.20)	(−0.08)	(0.70)	(−0.08)	(−0.32)	(0.26)	(1.41)	(−0.42)	(0.91)	(0.33)	(1.64)	(1.94)	(0.62)
FX Reserves	−0.14	−0.22*	0.07	−0.02	0.03	0.03	−0.15**	−0.08	−0.32***	−0.07	0.04	−0.06	−0.17	−0.04	0.12**	−0.00
	(−1.47)	(−1.93)	(1.33)	(−0.17)	(0.23)	(0.41)	(−1.98)	(−0.84)	(−3.08)	(−1.05)	(0.89)	(−0.84)	(−1.47)	(−0.58)	(2.42)	(−0.03)
Stoxx 50	−0.69***	−0.46	−0.35	−0.62**	−0.32	−0.31	−0.55***	−0.62***	−0.46***	−0.32*	−0.30	−0.33	0.13	−0.32	−0.47**	−0.16
	(−4.60)	(−1.41)	(−1.01)	(−2.24)	(−0.85)	(−1.62)	(−6.22)	(−2.77)	(−3.36)	(−1.97)	(−0.98)	(−1.43)	(0.30)	(−1.64)	(−2.69)	(−0.66)
10Y Bund	−0.08	−0.40	−0.21	−0.17	−0.27	−0.30**	−0.04	−0.30	0.10	−0.28**	−0.33*	−0.27**	−0.06	−0.31**	−0.11	−0.46*
	(−0.66)	(−1.46)	(−1.20)	(−1.13)	(−1.57)	(−2.07)	(−0.45)	(−1.38)	(0.92)	(−2.18)	(−1.90)	(−2.04)	(−0.19)	(−2.20)	(−0.61)	(−1.97)
IG Spread	−0.08	0.18	0.17	0.15	0.10	0.04	0.04	−0.00	−0.02	0.13*	0.34	0.05	0.20	0.01	−0.19	0.25*
	(−0.73)	(0.92)	(1.12)	(1.22)	(0.79)	(0.42)	(0.62)	(−0.01)	(−0.28)	(1.71)	(1.37)	(0.57)	(1.07)	(0.16)	(−1.46)	(1.78)
HY Spread	0.03	−0.07	−0.07	−0.08	−0.11	−0.01	0.02	0.04	0.15**	−0.06	−0.04	0.00	0.25	−0.06	−0.24	0.09
	(0.44)	(−0.47)	(−0.66)	(−0.88)	(−1.08)	(−0.19)	(0.36)	(0.37)	(1.99)	(−0.97)	(−0.29)	(0.03)	(1.17)	(−0.76)	(−1.37)	(0.75)
P/E Ratio	−0.07	−0.03	−0.08	−0.12**	−0.08	−0.07	−0.06	−0.04	−0.06	−0.07	−0.01	−0.09**	−0.39***	−0.11**	−0.11	−0.07
	(−0.98)	(−0.38)	(−0.85)	(−2.36)	(−0.88)	(−1.21)	(−1.52)	(−0.82)	(−0.66)	(−1.33)	(−0.11)	(−2.10)	(−3.39)	(−2.40)	(−1.24)	(−0.73)
Vol. Premium	−0.10	−0.16	−0.07	−0.13	−0.12	−0.01	−0.03	0.02	0.06	−0.04	−0.11	0.01	−0.12	−0.07	−0.16	0.13
	(−0.93)	(−0.55)	(−0.70)	(−0.96)	(−0.92)	(−0.07)	(−0.38)	(0.10)	(0.56)	(−0.36)	(−0.73)	(0.09)	(−0.32)	(−0.53)	(−1.02)	(0.67)
Equity Flow	0.27	0.09	0.14	0.06	0.06	0.02	0.04	0.11	0.11	0.12*	0.20	0.05	−0.88***	0.06	0.25	0.12
	(1.62)	(0.45)	(1.30)	(0.52)	(0.43)	(0.25)	(0.83)	(0.93)	(1.21)	(1.83)	(1.41)	(0.59)	(−3.27)	(0.88)	(1.49)	(0.69)
Bond Flow	−0.17	0.06	−0.01	−0.06	−0.07	−0.12	0.05	−0.25	0.19	−0.12*	−0.20	−0.04	1.01***	−0.10	−0.16	−0.09
	(−1.50)	(0.30)	(−0.15)	(−0.65)	(−0.57)	(−1.24)	(0.60)	(−1.62)	(1.43)	(−1.78)	(−1.07)	(−0.73)	(2.89)	(−1.55)	(−1.02)	(−0.48)
N	94	48	59	72	89	117	204	55	135	132	56	98	35	102	44	57
R^2 (%)	51	50	38	49	26	40	53	48	48	45	33	46	47	46	56	44

changes in the VIX index are insignificant for all countries in the sample. Contrary to popularly held belief, it appears that Wall Street's "fear gauge" was not the primary channel explaining the considerable inflation in sovereign CDS spreads during the financial crisis.

1.3.2.2 Local and Global Financials

As seen in Section 1.2.3, the time series of the first principal component of CDS spread changes is significantly correlated with the global performance of financial services firms. Motivated by this, we include two new covariates in the regression setup: (i) the weekly return of an index of domestic financial services firms and (ii) the weekly return of a global index of financial services firms.

To capture the state of local financials, we use the Dow Jones Total Market (DJTM) Financials index, a float adjusted market capitalization weighted sector index denominated in USD and available for all countries in our sample. This index aims to represent the investable universe of financial services firms in each country. As for the return to global financials, we again use the MSCI World Financials index. However, returns to the MSCI index tend to be strongly correlated with returns to the Euro Stoxx 50 index, potentially leading to the issue of collinearity. While collinearity per se is not a problem in judging the overall fit of the model, it interferes with our ability to sensibly interpret the coefficients. Hence, we first orthogonalize the world financials return by regressing it on the market return, and assume the sum of the estimated residual and intercept to be our return to world financials. We let R_t^{WF} denote the orthogonalized return to world financials.

Similarly, we orthogonalize the return to domestic financial firms. We are interested in creating a variable measuring the performance of local financial firms independent of market returns and global financials returns. Hence, we regress returns of the local financials on returns to the market index and returns to global financials. As before, we take the sum of the estimated residuals and intercept to be our orthogonalized return to local financials, denoted R_t^{LF}.

We modify the regression specification in Equation 1.1 such that

$$\Delta CDS_{it} = X_{it}^T \beta_i + \gamma_i R_t^{WF} + \delta_i R_{it}^{LF} + \epsilon_{it}. \tag{1.2}$$

The point estimates of γ_i, shown in Table 1.4, are highly significant and large in absolute magnitudes in 10 of the 16 countries, suggesting that the performance of the world financial system may be an important source of commonality in the dynamics of CDS spreads over the sample.

Interestingly, the estimates of δ_i are significant in 4 countries, all of which also have significant estimates for γ_i. In these countries, the performance of the local financial system had an impact above and beyond the health of the global financial system. The fit of the model also seems considerably improved relative to Equation 1.1: the minimum R^2 is 34% relative to 26% in Table 1.3 whereas the maximum R^2 rises to 64% in the case of Ireland, relative to 56% for Sweden before.

1.3.2.3 Panel Regressions

To further assess the significance of the financials factors, we construct a panel from the country-by-country observations. Since trading in advanced economies sovereign CDS was relatively sparse pre-2007, the pooled sample also allows us to conduct statistical tests that differentiate between the pre and post crisis periods. Furthermore, a panel setup enables us to concisely verify and extend the results from the country-by-country regressions. We specify the country fixed-effects panel regression as

$$\Delta CDS_{it} = X_{it}^T \beta + \gamma R_t^{WF} + \delta R_{it}^{LF} + \alpha_i + \epsilon_{it}. \tag{1.3}$$

The first specification does not differentiate between pre and post crisis period. We then interact R_t^{WF} and R_{it}^{LF} with an indicator function $\mathbb{I}_{t>\tau}$, which takes a value of 0 before the bankruptcy of Lehman Brothers (9/15/2008) and a value of 1 afterwards.

Table 1.4: **Sovereign CDS Spreads and the Local and Global Financial System**.
This table reports the results of the regression $\Delta CDS_{it} = X_{it}^T \beta_i + \gamma_i R_t^{WF} + \delta_i R_{it}^{LF} + \epsilon_{it}$ at a weekly frequency. The regressors in X_{it} are analogous to the factors used in Longstaff et al. (2009) but computed using European data. In addition, R_t^{WF} denotes the orthogonalized returns on a world financials index and R_{it}^{LF} denotes the orthogonalized returns to local financials indices. Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	CZE	DEN	FIN	FRA	GER	GRE	HUN	IRE	ISR	ITA	NET	POR	SLO	SPA	SWE	UK
Local Index	−0.17	0.45**	0.02	0.06	−0.08	0.54**	−0.22*	0.33**	0.03	0.07	0.14	−0.06	0.04	0.19	−0.18	0.59***
	(−1.23)	(2.42)	(0.16)	(0.53)	(−0.68)	(2.16)	(−1.76)	(2.43)	(0.34)	(0.49)	(0.80)	(−0.46)	(0.12)	(0.94)	(−0.62)	(3.33)
FX	−0.02	0.11	0.21	0.17	0.19	0.47***	0.06	0.21	0.01	0.36***	0.02	0.42**	0.20	0.47***	0.38**	0.18
	(−0.19)	(0.45)	(0.71)	(0.68)	(0.84)	(3.39)	(0.53)	(1.03)	(0.11)	(3.42)	(0.10)	(2.39)	(0.56)	(4.06)	(2.08)	(0.90)
FX Reserves	−0.13	−0.10	0.05	−0.02	−0.04	0.01	−0.17**	−0.12	−0.33***	−0.04	0.02	−0.06	−0.12	−0.00	0.14*	0.01
	(−1.41)	(−0.82)	(1.07)	(−0.14)	(−0.36)	(0.15)	(−2.17)	(−1.37)	(−3.11)	(−0.65)	(0.36)	(−0.76)	(−0.77)	(−0.08)	(2.03)	(0.08)
Local Financials	−0.14	−0.37**	−0.14	−0.01	0.06	−0.69**	−0.08	−0.41***	−0.10	−0.25	−0.19	−0.06	−0.33	−0.36**	0.28	−0.23
	(−0.87)	(−2.18)	(−0.88)	(−0.10)	(0.57)	(−2.56)	(−0.64)	(−4.70)	(−0.88)	(−1.57)	(−0.90)	(−0.51)	(−1.11)	(−2.15)	(1.04)	(−1.44)
Stoxx 50	−0.65***	−0.18	−0.26	−0.43	−0.19	0.06	−0.51***	−0.27	−0.45***	−0.12	−0.18	−0.09	0.32	−0.08	−0.50**	−0.05
	(−4.37)	(−0.56)	(−0.66)	(−1.33)	(−0.50)	(0.32)	(−5.61)	(−1.57)	(−3.52)	(−0.80)	(−0.69)	(−0.45)	(0.73)	(−0.49)	(−2.52)	(−0.21)
World Financials	−0.08	−0.32**	−0.29	−0.29**	−0.36**	−0.45***	−0.20**	−0.37***	−0.10	−0.30***	−0.07	−0.35***	−0.28	−0.37***	−0.03	−0.31***
	(−0.80)	(−2.16)	(−1.58)	(−2.44)	(−2.52)	(−3.56)	(−2.51)	(−3.09)	(−1.39)	(−3.81)	(−0.46)	(−3.23)	(−1.39)	(−2.82)	(−0.21)	(−4.18)
10Y Bund	−0.07	−0.33	−0.08	−0.09	−0.17	−0.27*	0.01	−0.15	0.13	−0.24*	−0.34*	−0.20	0.12	−0.23*	−0.06	−0.40
	(−0.52)	(−1.32)	(−0.47)	(−0.62)	(−1.09)	(−1.88)	(0.19)	(−0.74)	(1.20)	(−1.95)	(−1.83)	(−1.51)	(0.33)	(−1.85)	(−0.33)	(−1.66)
IG Spread	−0.07	0.18	0.15	0.15	0.08	0.07	0.03	−0.08	−0.02	0.16**	0.38	0.06	0.15	0.08	−0.19	0.30**
	(−0.67)	(1.08)	(0.90)	(1.12)	(0.66)	(0.88)	(0.46)	(−0.70)	(−0.20)	(2.19)	(1.42)	(0.68)	(0.80)	(1.08)	(−1.45)	(2.23)
HY Spread	0.03	0.01	−0.04	−0.06	−0.10	0.11	0.03	0.17	0.16**	−0.03	−0.07	0.03	0.33	−0.06	−0.23	0.12
	(0.38)	(0.05)	(−0.30)	(−0.63)	(−0.87)	(1.60)	(0.63)	(1.54)	(2.02)	(−0.43)	(−0.43)	(0.47)	(1.00)	(−0.78)	(−1.21)	(0.99)
P/E Ratio	−0.07	0.01	−0.03	−0.12**	−0.05	−0.08	−0.05	−0.10*	−0.03	−0.07	−0.02	−0.08**	−0.36**	−0.09*	−0.10	−0.06
	(−0.98)	(0.16)	(−0.28)	(−2.61)	(−0.47)	(−1.50)	(−1.52)	(−1.78)	(−0.30)	(−1.43)	(−0.18)	(−2.12)	(−2.55)	(−1.95)	(−1.07)	(−0.62)
Vol. Premium	−0.08	−0.10	−0.04	−0.11	−0.05	0.11	−0.02	0.12	0.07	−0.02	−0.12	0.04	0.04	−0.06	−0.13	0.11
	(−0.78)	(−0.37)	(−0.41)	(−0.93)	(−0.45)	(0.85)	(−0.30)	(0.59)	(0.73)	(−0.17)	(−0.78)	(0.33)	(0.08)	(−0.51)	(−0.80)	(0.52)
Equity Flow	0.27	0.02	0.18	0.08	0.04	0.05	0.05	−0.05	0.12	0.12*	0.21	0.06	−0.81*	0.11*	0.24	0.03
	(1.62)	(0.10)	(1.66)	(0.60)	(0.35)	(0.85)	(1.03)	(−0.47)	(1.34)	(1.68)	(1.42)	(0.77)	(−1.91)	(1.67)	(1.45)	(0.20)
Bond Flow	−0.17	−0.03	−0.00	−0.03	−0.00	−0.07	0.07	−0.07	0.21	−0.05	−0.19	0.01	1.04**	−0.03	−0.13	0.09
	(−1.46)	(−0.15)	(−0.05)	(−0.32)	(−0.02)	(−0.96)	(0.90)	(−0.54)	(1.59)	(−0.69)	(−1.03)	(0.19)	(2.40)	(−0.58)	(−0.83)	(0.60)
N	94	48	59	72	89	117	204	55	135	132	56	98	31	102	44	57
R^2 (%)	53	61	44	55	34	51	57	64	49	53	35	55	57	57	58	54

Table 1.5: **Effects of the Financial System on Sovereign CDS Spreads Pre/Post Crisis Breakpoint**.

Specification (1) reports the results of the fixed-effects panel regression $\Delta CDS_{it} = X_{it}^T\beta + \gamma R_t^{WF} + \delta R_{it}^{LF} + \alpha_i + \epsilon_{it}$ at a weekly frequency. Country fixed-effects are captured by α_i. Specification (2) interacts R_t^{WF} and R_{it}^{LF} with the indicator function $\mathbb{1}_{t>\tau}$, which takes a value of 0 before the bankruptcy of Lehman Brothers (9/15/2008) and a value of 1 afterwards. Reported t-statistics (in parentheses) are adjusted for heteroskedasticity at the country-level. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	(1)	(2)
Local Index	−40.25	−47.76
	(−1.25)	(−1.40)
FX	121.86***	124.63***
	(2.77)	(2.86)
FX Reserves	−1.07*	−1.08*
	(−1.86)	(−1.89)
Local Financials	−39.21***	8.01
	(−3.22)	(0.39)
Dummy * Local Financials		−50.84**
		(−2.34)
Stoxx 50	−84.77***	−81.76***
	(−4.27)	(−4.18)
World Financials	−103.41***	−62.49***
	(−5.61)	(−3.41)
Dummy * World Financials		−58.45**
		(−2.19)
10Y Bund Yield	−31.84*	−28.50*
	(−1.94)	(−1.73)
IG Spread	10.40	10.09
	(1.41)	(1.34)
HY Spread	4.37	4.46
	(1.31)	(1.40)
Eq. Premium	−0.49***	−0.46***
	(−3.04)	(−2.99)
Vol Premium	−0.58	−1.14
	(−0.08)	(−0.15)
Eq. Flow	0.08**	0.09**
	(2.16)	(2.22)
Bond Flow	−0.03	−0.02
	(−0.17)	(−0.15)
Intercept	0.42	0.63
	(1.16)	(1.62)
Dummy		−0.35
		(−0.33)
N	1393	1393

Although several observers may argue that the financial crisis began in 2007 with the demise of Bear Stearns, we believe that only after the collapse of Lehman Brothers did the pass-through effects of the market turmoil significantly affect sovereign credit risk. Indeed, Figure 1.1 shows that most of the widening in spreads happened in the immediate aftermath of Lehman's bankruptcy. Hence, we choose 9/15/2008 as our pre-post crisis breakpoint[12].

The estimates of specification (1) in Table 1.5 generally confirm our findings of the country-by-country regressions.[13] The return to local and global financials exhibit negative coefficients significant at the 0.1% level. Furthermore, the coefficients are also economically large: a one standard deviation increase in the return to the global financials, for example, entails a 0.2 standard deviation decrease in the CDS spread. In terms of absolute magnitude, this coefficient estimate is only second to the market factor, whose standardized loading is 0.27. Specification (2) accounts for pre and post crisis differences. As expected, much of the covariation between financials and sovereign CDS spreads is an artefact of the post-Lehman time period. In fact, the impact of the return to the local financial system is insignificant pre-Lehman. Note that impact of world financials almost doubles in the aftermath of the Lehman bankruptcy.

1.3.3 Private-to-Public Risk Transfer

Our results thus far indicate that the Lehman bankruptcy event and the ensuing government interventions led market participants to price in a transfer of risk from private institutions to the public sector, which considerably affected the dynamics of sovereign CDS market prices, a channel that will now be explored in more depth.

[12] Our results are robust to changing the cut-off point within the two weeks encompassing the bankruptcy of Lehman Brothers. Since the sovereign CDS market for advanced economies did not trade liquidly prior to 2007, breakpoints surrounding the demise of Bear Stearns suffer from an inadequate number of observations pre-crisis.

[13] All return variables are expressed in decimal form. Hence, a 0.01 unit increase in a return-based regressor corresponds to a 1% increase. The units of all other explanatory variables are outlined in Section .

1.3.3.1 Measuring Exposure to the Financial System

If sovereign credit risk embedded in CDS spreads truly covaries with the health of the financial system, we expect this effect to be stronger in countries with higher exposure to the financial system. Countries in which the financial sector plays a larger role may need to take larger ownership stakes, extend more support programs and assume more bank liabilities to stabilize their economy, thus increasing their credit risk. The channel through which a sovereign's default probability and expected recovery is affected can manifest in different ways. Government support programs for ailing financial firms, for example, may require the sovereign to issue more domestic or non-domestic debt, thus increasing the leverage ratio. In the long run, the desire to monetize some of the domestic debt outstanding may also stoke inflation, which could affect the sovereign's ability to repay its external debt. Another channel may be the implicit or explicit assumption of financial sector liabilities, thus creating a private-to-public transfer of credit risk. Finally, a worsening domestic and global financial sector may decrease economic growth and therefore affect a country's fundamentals, making it more difficult to service outstanding debt.

There exist several measures that may capture the exposure of a country to its financial system. We focus on two measures, a stock-based measure and a flow-based measure, and both are evaluated on a country basis.

The first metric, θ_i, proxying for the relative size of the financial system, is a ratio of two market capitalizations. It is computed as the average (1/1/2003-6/1/2007) of the ratio of the market capitalization of financial firms over total market capitalization for each country. To compute the market capitalization of financial firms, we simply use the market capitalization of the DJTM Financials Index. Similarly, to compute the total market capitalization of each country, we use the DJTM Country index. As mentioned before, both indices are value-weighted and float-adjusted. Hence, θ_i may not quantitatively equal the true size of the financial sector. However, robustness tests show that it correlates positively with other, similar measures, such as the ratio of aggregate bank assets to GDP.

The second metric, ΔBA_i, proxies for the growth in the financial sector pre-2007. It is defined as the average percentage change in domestic bank assets (1/1/2003 - 12/31/2006). This measure identifies countries for which the financial sector grew quicker in the years leading up to the financial crisis. Hence, a high ΔBA_i may indicate that banks may have taken on additional risks for higher returns and accelerated growth. Such fast-growing financial sectors could be particularly susceptible to collapse in the wake of financial turmoil, thus prompting government bail-outs and increased sovereign CDS spread sensitivity.

Table 1.6: **Measuring Exposure to the Financial Sector**. This table reports the results of sorting countries in the sample by two metrics: θ_i and ΔBA_i. θ_i is computed as the average (1/1/2003 - 6/1/2007) of the ratio of the market capitalization of financial firms over total market capitalization for each country. ΔBA_i is the average (1/1/2003 - 12/31/2006) annual growth rate in total bank assets for each country.

θ_i		ΔBA_i	
Country	Ratio	Country	Ratio
SLO	0.01	GER	0.02
FIN	0.05	POR	0.05
CZE	0.18	CZE	0.05
ISR	0.18	ITA	0.09
FRA	0.21	FRA	0.11
GER	0.24	DEN	0.11
DEN	0.26	SWE	0.12
UK	0.27	FIN	0.12
SWE	0.28	GRE	0.14
NET	0.38	UNI	0.15
SPA	0.41	NET	0.15
HUN	0.42	SPA	0.17
ITA	0.47	HUN	0.20
GRE	0.54	IRE	0.23
IRE	0.54	ISR	N/A
POR	0.56	SLO	N/A

Table 1.6 reports the country ranking by θ_i and ΔBA_i. Both metrics are positively correlated, with a Spearman rank order correlation of 0.32[14]. Ireland and Hungary rank in the top third using either metric. Anecdotally, this seems consistent with the pattern observed during the crisis. Ireland, for example, nationalized Anglo Irish Bank in January 2009 after it was determined that a government recapitalization scheme would not be sufficient to prevent the bank's failure. Furthermore, the nation's two largest banks, Allied Irish Bank and Bank of Ireland, both received EUR3.5bn in government assistance.

1.3.3.2 Explaining CDS Spread Changes

Under the assumption that the two metrics discussed above, θ_i and ΔBA_i, are reasonable proxies for a sovereign's exposure to its financial system, we formulate hypotheses about how the private-to-public risk transfer differs across countries along this dimension. The first hypothesis concerns the time-series dynamics of countries with high values of θ_i or ΔBA_i relative to countries with low values.

Hypothesis 1. *If a change in the condition of the financial system matters for the price of sovereign CDS, then we expect this effect to be stronger in high θ_i (ΔBA_i) versus low θ_i (ΔBA_i) countries.*

To see whether this is indeed the case, we stratify the sample by θ_i.[15] All 16 countries are sorted by the magnitude of θ_i and ranked from 1 to 16. Each country is then placed in one of two bins. The low-θ bin contains the bottom eight countries, whereas the high bin contains the top eight. We then estimate the regression

$$\Delta CDS_{it} = X_{it}^T \beta_j + \gamma_j R_t^{WF} + \delta_j R_{it}^{LF} + \epsilon_{it} \tag{1.4}$$

[14] Portugal ranks highly on the θ_i measure but low on the ΔBA_i measure. As a robustness check, we exclude Portugal from the empirical analysis. The results are qualitatively similar in the specifications for CDS spread changes as well as levels.

[15] We also conduct this analysis using ΔBA_i to stratify the sample. The results are qualitatively similar.

for each of the two bins j={low,high}. If Hypothesis 1 is correct, we expect that $|\gamma_{high}| - |\gamma_{low}| > 0$, $|\delta_{high}| - |\delta_{low}| > 0$ and both differences are statistically significant.

The results of this regression are presented in Table 1.7 under the single sorts tab. The loadings on world and local financials for the high-θ bin are larger in absolute magnitude than the corresponding loadings for the low-θ bin. Furthermore, the difference $|\gamma_{high}| - |\gamma_{low}|$ is statistically significant at the 1% level, whereas the difference $|\delta_{high}| - |\delta_{low}|$ is significant at the 5% level. This finding suggests that countries with a large exposure to the domestic financial sector pre-crisis were indeed more strongly affected by the health of the global and local financial system. In particular, credit risk the for low-θ countries was not significantly affected by the health of the local financial system. However, market participants appeared to be concerned about the systemic risk posed by a deterioration in the world financial sector. This is evidenced by the statistically significant point estimate for δ_{low}. In high-θ countries, however, CDS spreads co-vary strongly with both the idiosyncratic and systematic risk of the financial sector. In such countries, market participants priced in increased credit risk due to local financial distress as well as the negative feedback effects of a world financial crisis. The double sorts tab in Table 1.7 will be discussed below in the context of country heterogeneity.

So far we have tested the risk transfer in a time-series setting, but we should also expect this effect to be present in a cross-sectional test. Furthermore, a cross-sectional analysis can shed light on the economic significance of any effects imparted by changes in the condition of the financial system. To that end we specify a cross-sectional panel regression model with time fixed effects. Since we are interested in empirical regularities across countries, we include as explanatory variables the subset of factors that are country-specific: (i) the weekly percentage return of the USD-denominated Dow Jones Total Market country index, (ii) the weekly percentage return of the exchange rate relative to the USD, (iii) the weekly

Table 1.7: **Sovereign CDS Spread Sensitivities sorted by θ_i.** This table reports regression results of sorting countries by different cross-sectional attributes. For each bin, the regression specification is given by $\Delta CDS_{it} = X_{it}^T \beta_i + \gamma_i R_t^{WF} + \delta_i R_{it}^{LF} + \epsilon_{it}$. The single sort refers to a country sort according to θ_i. In the double sort countries are first sorted according to their membership in the European Economic and Monetary Union (EMU) and then by their ranking of θ_i. Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	Single Sort		***Double Sort***			
			Non-EMU		EMU	
	Low θ_i	High θ_i	Low θ_i	High θ_i	Low θ_i	High θ_i
Local Index	-0.06	-0.07	-0.07	-0.20	-0.09	0.07*
	(-0.98)	(-0.99)	(-0.85)	(-1.43)	(-1.42)	(1.80)
FX	0.04	0.24***	0.03	0.09	0.16	0.34***
	(0.52)	(3.09)	(0.43)	(0.84)	(1.54)	(6.28)
FX Reserves	-0.10**	-0.10	-0.18**	-0.13	-0.03	-0.03
	(-2.29)	(-1.25)	(-2.52)	(-1.09)	(-0.84)	(-1.45)
Local Financials	-0.09	-0.15***	-0.10	-0.04	-0.05	-0.28***
	(-1.30)	(-3.12)	(-1.04)	(-0.33)	(-0.87)	(-4.47)
Stoxx 50	-0.37***	-0.21***	-0.51***	-0.37***	-0.18	-0.11
	(-3.87)	(-2.79)	(-5.22)	(-3.45)	(-1.32)	(-1.50)
World Financials	-0.14***	-0.21***	-0.10**	-0.15**	-0.23***	-0.30***
	(-3.80)	(-5.01)	(-2.04)	(-2.36)	(-3.48)	(-6.11)
10Y Bund	-0.05	-0.10**	0.00	-0.01	-0.08	-0.19***
	(-0.86)	(-2.00)	(0.00)	(-0.21)	(-0.79)	(-2.64)
IG Spread	0.06	0.04	-0.02	0.05	0.16**	0.03
	(1.41)	(0.86)	(-0.32)	(0.73)	(2.47)	(0.74)
HY Spread	0.06	0.02	0.11**	0.03	0.02	0.04
	(1.33)	(0.74)	(2.08)	(0.58)	(0.28)	(1.29)
P/E Ratio	-0.06*	-0.05***	-0.06	-0.02	-0.07*	-0.08***
	(-1.88)	(-2.76)	(-1.37)	(-0.58)	(-1.77)	(-3.70)
Vol. Premium	-0.01	0.00	-0.03	-0.01	-0.04	0.01
	(-0.14)	(0.01)	(-0.39)	(-0.11)	(-0.35)	(0.17)
Equity Flow	0.08	0.05	0.09	0.05	0.06	0.04
	(1.43)	(1.41)	(0.97)	(0.87)	(1.01)	(1.29)
Bond Flow	0.01	-0.02	0.09	0.04	0.04	-0.04
	(0.10)	(-0.34)	(0.76)	(0.27)	(0.41)	(-1.21)
N	585	808	277	305	307	504
R^2	0.28	0.37	0.42	0.39	0.28	0.48

change in the USD-value of exchange rate reserves and (iv) the weekly percentage return to the domestic orthogonalized Dow Jones Total Market Financials index.

If it is true that countries with a higher exposure to the financial system, as measured by θ_i (ΔBA_i), exhibit a higher CDS spread sensitivity towards the performance of financials, then we can identify this effect by interacting the local financials return, R_{it}^{LF}, with θ_i (ΔBA_i) whilst controlling for R_{it}^{LF} and θ_i (ΔBA_i) separately. Hence, we specify the regression model

$$\Delta CDS_{it} = X_{it}^T \beta + \gamma z_i + \delta R_{it}^{LF} + \rho z_i R_{it}^{LF} + \nu_t + \epsilon_{it}, \tag{1.5}$$

where z_i stand for either θ_i or ΔBA_i, and ν_t denotes a time fixed-effect. If Hypothesis 1 is correct, we expect ρ to be negative and statistically significant, so that a change in R_{it}^{LF} is augmented for countries with large z_i.

Table 1.8 reports the estimation results for Equation 1.5, with $z_i = \theta_i$ in specification (1) and $z_i = \Delta BA_i$ in specification (2). The coefficient estimates have the same sign for both specifications, reinforcing the conjecture that both θ_i and ΔBA_i measure similar underlying economic mechanisms. In both specifications, ρ is statistically significant and negative.[16] Furthermore, the local index return, the local exchange rate return and the change in local foreign exchange reserves all significantly co-move with changes in the sovereign CDS spread. The signs of the coefficients on these three factors are consistent with economic intuition and previous work. A deterioration in domestic economic conditions captured by a decrease in the local stock market results in an increase in the price of credit protection. Similarly, an increase in the price of USD expressed in terms of the domestic currency (equivalently, a devaluation in the domestic exchange rate) leads to an increase in the sovereign CDS

[16]The magnitude of the point estimate, however, differs markedly. To a large extent, this is driven by the degree of collinearity between ΔBA_i and R_{it}^{LF}. Countries growing their financial system at a faster rate also experience stronger fluctuations in the return to local financials. This correlation leads to a positive estimate of δ in specification (2), which somewhat offsets the effect of ρ.

Table 1.8: **Cross-sectional Regression**. This table reports the results of a cross-sectional panel regression of the form $\Delta CDS_{it} = X_{it}^T\beta + \gamma z_i + \delta R_{it}^{LF} + \rho z_i R_{it}^{LF} + \nu_t + \epsilon_{it}$. z_i stands for either θ_i (Specification 1) or ΔBA_i (Specification 2). Time fixed-effects are captured by ν_t. Reported coefficients are in basis points and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	(1)	(2)
Local Index	-82.67^{***}	-89.51^{***}
	(-4.11)	(-4.29)
FX	188.25^{***}	238.46^{***}
	(4.33)	(4.94)
FX Reserves	-1.12^{***}	-0.98^{***}
	(-3.62)	(-3.08)
Local Financials	31.57	60.03^{**}
	(1.39)	(2.52)
θ	-0.08	
	(-0.03)	
Local Financials * θ	-103.08^{**}	
	(-2.20)	
ΔBA		5.80
		(0.71)
Local Financials * ΔBA		-410.56^{***}
		(-3.55)
Intercept	0.61	-0.06
	(0.60)	(-0.06)
N	1006	912
Time Fixed Effects	Yes	Yes

spread. Lastly, an increase in domestic foreign exchange reserves, which may capture a stabilizing economy and exchange rate, leads to a decrease in the CDS spread.

The estimate for ρ suggests that a negative shock to the local financial system translates into an increase in spreads, and that the magnitude of the effect is larger for countries with a higher level of θ. This is also economically significant. A one standard deviation change to the return to the domestic financial system leads to a 4bps reduction in the CDS spread, holding θ fixed at unity.[17] In the case of Portugal, for example, a one standard deviation shock to local financials leads to a 2.1bps increase in the sovereign credit swap spread. The magnitude of this effect equates to roughly 5% of Portugal's average CDS spread level over the sample.

1.3.3.3 EMU Member Countries

Our second hypothesis concerns the differential effect of the global and local financial system on sovereign CDS spreads for countries in the Economic and Monetary Union of the European Union. Out of the 16 countries in our sample, 10 are EMU members. Hence, these countries share the euro as a common currency.[18] Monetary policy in Eurozone countries is defined and implemented by the European Central Bank (ECB). Crucially, the ECB has the exclusive authority to authorize the issuance of euro bank notes. Hence, eurozone countries cannot monetize any euro-denominated outstanding debt by printing domestic currency. Inflexibility in monetary policy and the inability to print domestic currency may affect a country's default probability, thus increasing its credit risk. For this reason we believe that during the recent financial crisis, eurozone CDS spreads may have exhibited

[17] The standard deviation refers to the standard deviation of the return to local financials if all observations are pooled.

[18] At the beginning of our sample in 2003, Slovenia had not joined the third stage of the EMU yet. It introduced the Euro as its currency on January 1^{st} 2007. Our empirical analysis treats Slovenia as an EMU member throughout the sample. However, this assumption is relatively innocuous because there are very few observations for Slovenia CDS spreads prior to 2007.

more sensitivity to the health of financial system than their non-eurozone counterparts.

Hypothesis 2. *If a change in the condition of the financial system matters for the price of sovereign CDS, then we expect this effect to be stronger for EMU-countries versus Non-EMU countries.*

To test this hypothesis, we stratify the sample by EMU and non-EMU countries as well as by sovereigns' levels of θ_i, leading to four bins. The two non-eurozone bins contain three countries each, whereas the eurozone bins contain five countries each. As before, we estimate Equation 1.4, where j designates the bin and j={Non-EMU & low θ), Non-EMU & high θ, EMU & low θ, EMU & high θ}.

The results of this analysis are reported in Table 1.7 under the double sorts tab. The estimated factor loadings γ_j are statistically significant and monotonically increasing for each bin. This suggests that even though credit risk in all countries in the sample was affected by the systematic risk posed by a collapse of the financial system, countries in the eurozone where more susceptible to this effect than non-eurozone countries. A test of the null hypothesis that the estimates of γ_j are equal for the two extreme bins, Non-EMU & low θ and EMU & high θ is rejected with 5% confidence. Eurozone countries in which the economy was more exposed to a deterioration of the financial system pre-crisis exhibit a significantly stronger sensitivity to the world financials factor.

In fact, the loading on the EMU & high θ bin is almost three times as large as the loading on the Non-EMU & low θ bin. Furthermore, the coefficient estimates are also economically significant. For eurozone countries with high levels of θ, a one standard deviation change in the return to global financials leads to a 0.3 standard deviation change in the level of the sovereign CDS spread. The point estimates for δ_j reveal a similar story. In fact, they are statistically insignificant for all but the EMU & high θ bin. However, for this bin, the factor loading is economically large and significant at the 1% level, corroborating the above results.

1.3.3.4 Exposure to Subprime Securities

Our third hypothesis addresses the common perception that subprime securities played a key role in the financial crisis. Securities backed with subprime mortgages were widely held by financial institutions and, as a result of increased default rates and delinquencies, lost a majority of their value during the financial crisis. If governments explicitly or implicitly assumed financial sector liabilities during this period, we might expect that a country's CDS spread sensitivity towards the financial system is larger if domestic banks were heavily invested in the subprime sector. This forms the basis for our third hypothesis.

Hypothesis 3. *If a change in the condition of the financial system matters for the price of sovereign CDS, then we expect this effect to be stronger for countries with higher exposures to the subprime mortgage sector.*

In order to compute a country's exposure to the subprime mortgage sector, we obtain a time series of the ABX.HE index. This index tracks the price of CDSs on a set of 20 equal-weighted, AAA-rated US subprime mortgage-backed securities issued within 6 month of each other. The first index launched in January 2006, with new on-the-run indices being introduced every six months, each time referencing 20 new subprime mortgage-backed securities. When an index starts trading, it is marked at a nominal value of 100. The up-front payment required to insure the underlying securities is then given by 100 minus the value of the index, taken as a percentage of the notional. Additionally, there exists a fixed annual payment, also expressed as a percentage of the notional. This quoting convention is standard in up-front CDS markets. Suppose, for the sake of example, that an investor would like to insure \$10m of underlying mortgage-backed securities. If the index trades at 70, this equates to an up-front payment of \$3m (30% of the \$10m notional). Hence the value of the index correlates inversely with the default likelihood of the underlying securities.

If a country's financial sector was heavily exposed to subprime securities, then the return to domestic financials should co-move with the performance of the ABX.HE index, assuming that the index is a good proxy.[19] Hence, for each country, we regress R_{it}^{LF} on the percentage return to the ABX.HE index. We then rank countries by the absolute magnitude of the standardized coefficient. If hypothesis 3 is correct, we should expect that countries in the high subprime exposure bin exhibit a stronger co-movement with local and global financials than countries in the low bin.

The first two columns in Table 1.9 refer to a single sort based on the absolute magnitude of the coefficient. Interestingly, both the low and high subprime exposure bins have similar loadings on the world financials return. Hence, whether or not a country's financial market was significantly exposed to the subprime mortgage market made little difference to the time-series properties of sovereign CDS spreads. Although market participants accounted for the systemic risk posed by the global financial sector, the degree of co-movement did not differ based on countries' subprime exposures. In fact, a test for $\gamma_{low} = \gamma_{high}$ cannot be rejected at conventional significance levels.

Focusing on the coefficient estimate for δ_i, it is apparent that the effect of the local financial sector on sovereign CDS spreads also does not conform to hypothesis 3. Again, a test for $\delta_{low} = \delta_{high}$ reveals that there is no statistically significant difference in coefficient estimates. The double sort based on subprime exposure and the level of θ confirms this result. While factor sensitivities for local and global financials generally increase in the absolute magnitude of θ, they do not differ depending on the degree of subprime exposure.

[19] Conversations with CDS and MBS traders anecdotally confirmed that the ABX.HE index is the most watched index in the subprime mortgage segment.

Table 1.9: **Sovereign CDS Spread Sensitivities sorted by Exposure to Subprime Securities**. This table reports regression results of double-sorting countries by their exposure to the subprime mortgage sector and θ_i. For each bin, the regression specification is given by $\Delta CDS_{it} = X_{it}^T \beta_i + \gamma_i R_t^{WF} + \delta_i R_{it}^{LF} + \epsilon_{it}$. Countries' exposure to sub-prime is determined by the magnitude of the coefficient in a regression of local financials returns on returns to the ABX.HE (AAA) index. Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	Single Sort		***Double Sort***			
	Low Exp.	High Exp.	Low Exp.		High Exp.	
			Low θ_i	High θ_i	Low θ_i	High θ_i
Local Index	0.04	-0.20**	-0.11	0.18***	-0.06	-0.11
	(0.92)	(-2.00)	(-1.21)	(2.91)	(-0.58)	(-0.70)
FX	0.16**	0.17**	0.14	0.16*	0.04	0.24**
	(2.51)	(2.32)	(1.25)	(1.88)	(0.36)	(2.34)
FX Reserves	-0.04**	-0.12*	-0.06	-0.02	-0.10	-0.14
	(-2.08)	(-1.84)	(-1.50)	(-0.84)	(-1.46)	(-1.40)
Local Financials	-0.25***	-0.01	-0.12	-0.32***	0.05	-0.12
	(-4.33)	(-0.13)	(-1.21)	(-4.35)	(0.54)	(-0.82)
Stoxx50	-0.26***	-0.28***	-0.33***	-0.22**	-0.39***	-0.24**
	(-3.12)	(-3.65)	(-2.63)	(-2.10)	(-3.00)	(-2.35)
World Financials	-0.18***	-0.19***	-0.15**	-0.24***	-0.13***	-0.22***
	(-3.93)	(-4.57)	(-2.34)	(-3.73)	(-2.61)	(-4.25)
10Y Bund	-0.11	-0.06	-0.00	-0.21*	-0.05	-0.08*
	(-1.53)	(-1.45)	(-0.02)	(-1.94)	(-0.63)	(-1.77)
IG Spread	0.04	0.04	0.07	0.02	0.02	0.04
	(0.91)	(0.89)	(1.11)	(0.28)	(0.36)	(0.81)
HY Spread	0.06	0.02	0.07	0.06	0.03	0.01
	(1.54)	(0.47)	(1.12)	(1.29)	(0.58)	(0.35)
Eq. Premium	-0.06**	-0.05**	-0.08	-0.05*	-0.05	-0.06**
	(-2.26)	(-2.32)	(-1.52)	(-1.81)	(-1.49)	(-2.43)
Vol Premium	-0.01	0.02	-0.03	0.02	0.03	0.01
	(-0.20)	(0.30)	(-0.35)	(0.21)	(0.40)	(0.17)
Eq. Flow	0.07*	0.04	0.09	0.02	0.06	0.04
	(1.66)	(1.09)	(1.32)	(0.32)	(0.80)	(0.97)
Bond Flow	-0.05	0.01	-0.04	-0.03	0.04	0.00
	(-1.07)	(0.17)	(-0.57)	(-0.41)	(0.26)	(0.01)
N	514	879	256	258	324	555
R^2	0.37	0.34	0.33	0.44	0.26	0.41

1.3.3.5 Explaining CDS Spread Levels

Up to this point, our analysis has focused on CDS spread changes, rather than levels. However, if a country's exposure to the financial sector affects its default intensity process, it should also affect the level of the sovereign CDS spread. To control for factors other than the financials exposure, we rely on structural models of default, such as Merton (1974), to furnish a set of control variables.[20] Ericcson, Jacobs and Oviedo (2009) show that leverage and asset volatility, two important theoretical determinants of credit risk, are also empirically correlated with the level of corporate CDS spreads. Hence, we compute the sovereign analogues to leverage and asset volatility using the quarterly time series of total debt outstanding over Gross Domestic Product and the 90 day rolling window volatilities of the domestic equity market. To control for the size of the country, as well as whether it is a member of the EMU, we utilize the USD level of total equity market capitalization and an EMU dummy. Using the set of covariates outlined above as control variables, we are now in a position to formulate and test the following hypothesis:

Hypothesis 4. *If a change in the condition of the financial system matters for the price of sovereign CDS, then we expect the level of the CDS spread to be higher for high-θ (ΔBA) versus low-θ (ΔBA) countries.*

To test this, we specify a cross-sectional panel regression with time fixed effects given by

$$CDS_{it} = X_{it}^T \beta + \gamma z_i + \nu_t + \epsilon_{it}. \tag{1.6}$$

In this specification, z_i stands for either θ_i or ΔBA_i, and time fixed-effects are captured by ν_t. If hypothesis 4 is correct, then we should expect a positive and statistically significant γ

[20]To simplify the analysis, we abstract away from the distinction between a sovereign's ability and willingness to pay, as in Eaton and Gersovitz (1981), as well as the post-default debtor-creditor bargaining game, as in Bulow and Rogoff (1989).

coefficient estimate. Furthermore, to investigate whether the private-to-public risk transfer was truly a new phenomenon during the financial crisis, we estimate Equation 1.6 before and after our breakpoint, the bankruptcy of Lehman Brothers.

Table 1.10: **Sovereign CDS Spread Levels**. This table reports results from a cross-sectional panel regression of CDS spread levels on explanatory variables. The regression specification is given by $CDS_{it} = X_{it}^T\beta + \gamma\theta_i + \delta\Delta BA_i + \nu_t + \epsilon_{it}$. Time fixed-effects are captured by ν_t. Specification (1) omits ΔBA_i, (2) omits θ_i and (3) includes both variables. Pre and Post refers to pre-crisis and post-crisis. The breakpoint is defined by the bankruptcy of Lehman Brothers (9/15/2008). Reported coefficients are standardized and t-statistics (in parentheses) are adjusted for heteroskedasticity. Significance at the one-percent, five percent and ten-percent level is denoted by ***, ** and * respectively.

	(1)		(2)		(3)	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
EMU Dummy	-30.67***	-47.51***	-30.86***	-73.59***	-31.46***	-69.59***
	(-7.87)	(-7.55)	(-8.15)	(-13.37)	(-8.21)	(-12.77)
Local MktCap	-12.00***	-40.10***	-14.66***	-52.79***	-13.01***	-40.19***
	(-4.49)	(-7.66)	(-6.23)	(-11.95)	(-4.56)	(-8.08)
Debt/GDP	41.36***	47.13***	53.01***	159.42***	48.92***	115.19***
	(5.44)	(3.52)	(8.28)	(16.40)	(6.48)	(8.98)
Volatility	137.66***	438.45***	23.86	259.30***	50.64	332.58***
	(3.06)	(13.34)	(0.51)	(7.72)	(0.94)	(9.27)
θ	37.92***	124.45***			17.57	106.11***
	(2.85)	(6.66)			(1.02)	(5.15)
ΔBA			145.25***	653.48***	125.18***	503.72***
			(5.26)	(15.46)	(3.69)	(9.96)
Intercept	-12.71	-118.33***	5.87	-114.45***	-2.73	-150.68***
	(-0.88)	(-6.49)	(0.43)	(-6.82)	(-0.17)	(-8.43)
N	240	708	235	671	235	671
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

The point estimates of γ shown in Table 1.10 for specification (1) and (2) suggest that both θ_i and ΔBA_i are important factors in determining the level of sovereign CDS spreads. The estimates of γ are economically large compared to the control variables. In specification (1), for example, a sovereign's debt to GDP ratio accounts for roughly 26bps of CDS spread level post-crisis, whereas θ_i accounts for roughly 39bps (using the cross-sectional average of the debt to GDP ratio and θ_i). As expected, the effect of θ_i is significantly weaker pre-crisis, around one third the post-crisis magnitude.

Interestingly, the EMU dummy has a large and negative effect on the level of sovereign CDS spreads across all specifications. This finding suggests that countries in the EMU were generally seen as less likely to default and hence traded at lower spread levels. To some extent, this is associated with EMU countries having better average credit ratings in our sample. Additionally, market participants may have implicitly assumed that countries in the EMU will provide mutual support and hence are unlikely to default unilaterally. Furthermore, the large difference in the coefficient magnitude pre and post crisis suggests that the status of EMU membership was particulary relevant during the financial crisis.

1.4 Conclusion

Our results document a private to public risk transfer related to countries' exposures to the financial system during the recent financial crisis. This economic channel led to significant co-movement between the price of insurance against default and the performance of the financial sector, both locally and globally. We show the pattern differs across countries operating under different monetary authorities. Although the level of CDS spreads is lower for countries in the EMU, their sensitivities to the health of the financial system are higher compared to non-EMU members.

For future research, it might also be useful to analyze a public to public risk transfer in addition to the private to public risk transfer. In light of the recent debt crisis surrounding Greece and other European Economies, several countries are considering extending significant aid packages. This fiscal insurance mechanism might also be reflected in sovereign CDS market prices. Not only could this shed further light on the default barrier of advanced economies, but it would also allow for the quantification of the wealth transfer among nations embedded in government guarantees.

Bibliography

[1] Ekkehart Boehmer and William L. Megginson. Determinants of Secondary Market Prices for Developing Country Syndicated Loans. *Journal of Finance*, 45:1517–1540, 1990.

[2] Jeremy Bulow and Kenneth Rogoff. A Constant Recontracting Model of Sovereign Debt. *Journal of Political Economy*, 97:155–178, 1989.

[3] Craig Burnside, Martin Eichenbaum, and Sergio Rebelo. Prospective Deficits and the Asian Currency Crisis. *Journal of Political Economy*, 109:1155–1197, 2001.

[4] Stijn Claessens and George Pennacchi. Estimating the Likelihood of Mexican Default from the Market Prices of Brady Bonds. *Journal of Financial and Quantitative Analysis*, 31(1):109–126, 1996.

[5] Darrell Duffie and Kenneth J. Singleton. *Credit Risk*. Princeton University Press, 2003.

[6] Jonathan Eaton and Mark Gersovitz. Debt with Potential Repudiation: Theoretical and Empirical Analysis. *Review of Economic Studies*, 48(2):289–309, 1981.

[7] Sebastian Edwards. LDC Foreign Borrowing and Default Risk: An Empirical Investigation 1976–80. *American Economic Review*, 74:726–734, 1984.

[8] Jan Ericsson, Kris Jacobs, and Rodolfo Oviedo. The Determinants of Credit Default Swap Premia. *Journal of Financial and Quantitative Analysis*, 44:109–132, 2009.

[9] Mark B. Garman and Michael J. Klass. On the Estimation of Security Price Volatilities from Historical Data. *Journal of Business*, 53:67–78, 1980.

[10] John Hull and Alan White. Valuing Credit Default Swaps (I): No Counterparty Default Risk. *Journal of Derivatives*, 8:29–40, 2000.

[11] Jesper Lund. A Model for Studying the Effect of EMU on European Yield Curves. *European Finance Review*, 2:321–363, 1999.

[12] Robert C. Merton. On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. *Journal of Finance*, 29(2):449–470, 1974.

[13] Jun Pan and Kenneth J. Singleton. Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads. *Journal of Finance*, 63(5):2345–2384, 2008.

Chapter 2

Do Macro-Economic Fundamentals Price Emerging Market Sovereign CDS Spreads?

2.1 Introduction

The recent financial crisis and ensuing recession has brought into sharp focus the issue of sovereign credit risk in emerging economies. As a result of the market turmoil and the spill-over effects to the real economy, emerging sovereigns worldwide realized unprecedented increases in the price of insurance against government default as measured by sovereign credit default swap (CDS) spreads. Heavily dependent on international trade and foreign capital, emerging economies were particularly vulnerable to deteriorating market conditions during the financial crisis. Hungary's 5 year CDS spread, for example, averaged 30bps from January 2001 to December 2007. From January 2008 to April 2010, however, the average spread realized an almost nine-fold gain to 261bps. In light of the significant increase in sovereign credit risk for emerging markets, there is renewed interest in the macro-economic determinants of sovereign CDS spreads. Empirically, country fundamentals play an important role in explaining sovereign credit spreads. Hilscher and Nosbusch (2010), for example, find that the change and volatility of a country's terms of trade have economically and statistically significant effects on the cost of sovereign borrowing. In this paper, I present and implement a pricing model for emerging market sovereign credit risk based primarily on macro-economic fundamentals.

The existing literature on the pricing and management of sovereign credit risk generally distinguishes between two broad approaches: structural and reduced-form. The structural approach to credit risk was pioneered by Merton (1974). In these types of models, the probability of default is determined by the distance between an issuer's assets relative to its liabilities.[1] The threshold level of assets at which default occurs is either given exogenously or derived endogenously as the outcome of the issuer's optimization problem. In reduced form models, on the other hand, the default event is not directly related to an issuer's solvency position. Rather, the default time is assumed to follow a stochastic hazard rate process governed by latent state variables (see Duffie and Singleton (2003)).

In this paper, I use a structural model based on macro-economic fundamentals to price sovereign CDS spreads. The application of this type of model to sovereign credit risk, however, is not straight forward. Whilst a firm's asset value can be reasonably ascertained using balance sheet data and market prices of traded securities, it is difficult to define and estimate the country-level equivalent.

Kulatilaka and Marcus (1987), for example, assume that GDP follows a stochastic process which determines a country's foreign debt capacity. As the sovereign levers up, the increasing amount of debt service induces a drag on GDP growth. Default occurs when the present value of consumption under default exceeds the present value of continuing the debt service. In Claessens and Pennacchi (1996), repayment capacity is summarized by a latent stochastic repayment process. Upon the first time this process hits zero, the country

[1] In Merton (1974), for example, the market value of debt is equal to the value of a simply contingent claim, a short put option, which can be valued in a Black-Scholes (1973) framework. Extensions of the Merton (1974) model have relaxed the default timing assumption (e.g. Black and Cox (1976)), allowed for an endogenous default decision (e.g. Leland (1994)) and relaxed the assumption on the continuity of the underlying stochastic process (e.g. Zhou (2001)).

defaults. The parameters governing the dynamics of this process are then calibrated using data on Mexican Brady Bonds. In Jeanneret (2009), the 'asset value' of the sovereign is given by the present value of future revenues, which is approximated by the value of the stock market index. Countries are trading off limited access to international markets post default against the cost of debt servicing.

This paper proposes, and empirically implements, a model of sovereign default risk on external debt based on observed exports, imports and international reserves. Using these country-specific macro-fundamentals, I define a country's ability to pay as the maximum amount of foreign currency available for repayment of external debt. The ability to pay is increasing in the present value of future exports as well as the current period foreign exchange reserves, and decreasing in the present value of future imports. This definition of sovereign foreign-currency solvency is closely related to a country's unobservable 'asset value', given by the present value of future revenues, in Jeanneret (2009). The joint dynamics of the ability to pay, its volatility and the level of outstanding external debt determine the level of country default risk and thus the sovereign CDS spread. The model is empirically tractable and implemented for a sample of 6 emerging economies (Czech Republic, Hungary, Poland, Romania, Russia, Turkey) for a period covering the recent financial crisis. A calibrated version of the model captures the widening of sovereign spreads during the crisis and provides a good fit for the time-series dynamics of CDS spreads. For the Czech Republic, Hungary and Poland, the average absolute model pricing errors are below 31bps. Furthermore, the correlation between model-implied and market CDS spreads is positive for all countries, and above 65% for five of them. Lastly, I use the model to measure the market-implied level of country liabilities. On average, the value of implied external debt is 13% larger than the reported level of debt.

The paper most closely related to this project is Karmann and Maltritz (2004). In

Karmann and Maltritz (2004), the ability to pay consists of the sum of the present value of net exports and foreign exchange reserves. This paper considers a more general setting in which a sovereign's foreign currency solvency can depend asymmetrically on its future exports and imports, as well as reserves. Furthermore, I do not rely on market bond yield data to compute the present value of exports and imports, but rather employ am asset spanning approach. Lastly, I allow the default threshold to be a function of the face value of debt as well as interest rates.

The remainder of this paper is structured as follows. Section 2.2 outlines the structural model and discusses the pricing of sovereign credit risk in this setup. The model is implemented for a set of 6 emerging economies in Section 2.3. Section 2.4 concludes.

2.2 A Structural Model of Sovereign Credit Risk

In this section, I describe a structural model of credit risk for emerging economies. Throughout, I assume that capital markets are frictionless and there are no information asymmetries. I develop this model from the viewpoint of a US investor and hence measure all variables in the model in \$US.[2]

Lastly, I assume that the sovereign finances itself exclusively with zero-coupon foreign debt. The face value of outstanding foreign debt is denoted by $\bar{k}$. The sovereign continuously rolls over existing debt, so that the maturity of outstanding debt is equal to T years at every point in time.

2.2.1 Ability to Pay

Given the assumptions above on sovereign debt structure it is clear that the repayment of outstanding liabilities is contingent on the sovereign's access to international capital. In

[2]This is without loss of generality. The model only requires that all variables are measured in a non-domestic currency.

times of economic distress, servicing existing debt crucially depends on the ability to raise foreign currency. In this model, I assume that a country can access foreign currency in two ways: through its international reserves and through international trade.

A sovereign can tap its current period international reserves to repay outstanding debt. Such reserves are generally regarded as an important indicator of the short-term financial health of a country and often used as an input in the determination of credit ratings. International reserves consist of assets held in reserve currencies, gold, SDRs and IMF reserve positions - all of which can be easily liquidated and used towards the repayment of debt.

For many emerging economies, exports constitute a large portion of GDP and generate significant foreign currency receipts which can be used to service outstanding liabilities. In the event of distress, I assume that a sovereign can raise foreign capital by collateralizing future exports and imports. While future exports generate inflows of foreign currency, future imports generate outflows. Using this line of reasoning, Karmann and Maltritz (2004) define the maximum amount of foreign currency a sovereign can raise at any given time as the difference between the present value of future exports and the present value of future imports. However, in this paper I assume a more general formulation, allowing for an asymmetric effect of future imports. In particular, I assume that in times of distress, a sovereign can commit to forgoing forever a constant fraction of imports, denoted $1 - \xi$. This fraction can be interpreted as an implementation of a fiscal austerity plan for a country in distress, whereby the sovereign reduces its current and future imports to accumulate additional reserves towards the repayment of debt. The remaining fraction ξ represents the portion of imports that is implicitly tied to exports (e.g. raw materials and intermediate goods) and hence cannot be forfeited. Thus, the difference between the present value of exports and ξ times the present value of imports acts as a collateral constraint, denoting the maximum amount of foreign currency a sovereign may borrow from supranational institutions or other sovereigns in times of distress.

Following the preceding discussion, I define a sovereign's ability to pay, V_t, as the maximum amount of foreign currency available for repayment of external debt. Let international reserves, exports and imports be denoted by FX_t, x_t and i_t respectively. The ability to pay is pinned down by the sum of current period reserves and the present value of future exports minus the ξ-adjusted present value of future imports. Hence,

$$V_t = FX_t + x_t^* - \xi i_t^* \tag{2.1}$$

where x_t^* denotes the present value of future exports and i_t^* denotes the present value of future imports:

$$x_t^* = \mathbb{E}_t \left[\sum_{s=0}^{\infty} m_{x,t+s} x_{t+s} \right], \tag{2.2}$$

$$i_t^* = \mathbb{E}_t \left[\sum_{s=0}^{\infty} m_{i,t+s} i_{t+s} \right]. \tag{2.3}$$

Here $m_{x,t+s}$ and $m_{i,t+s}$ denote the appropriate discount factors for future imports and exports. The determination of these discount factors, as well as the empirical implementation of Equations 2.2 and 2.3, is discussed in detail in Section 2.3.

2.2.2 V_t - Dynamics and the Default Threshold

As is customary in structural credit risk models, I assume that the bond issuer defaults when its asset value falls sufficiently low relatively to its liabilities. The asset value of the sovereign is given by its ability to pay, V_t. I denote the default trigger as ν_t. Computing sovereign default probabilities and thus sovereign CDS spreads requires that we make assumptions on the probabilistic dynamics of V_t and ν_t.

2.2.2.1 Ability to Pay Process

Following Lehrbass (1999) and others, I assume that the dynamics of V_t are governed by a geometric Brownian motion:

$$\frac{dV_t}{V_t} = rdt + \sigma dw^{\mathbb{Q}}, \tag{2.4}$$

where w denotes a standard Brownian motion under the risk neutral probability measure associated with the riskless money market account. The instantaneous riskless interest rate r and the volatility σ is assumed to be constant.

2.2.2.2 Default Threshold

Define $B(t,T) = e^{-r(T-t)}$ as the time t value of a default-free zero-coupon bond with maturity T. Following Black and Cox (1976), the default threshold $\nu(t)$ is given by the present value of the face value of debt:

$$\nu_t = \bar{k}B(t,T). \tag{2.5}$$

Hence, the sovereign defaults whenever the present value of its outstanding debt obligations falls below its current repayment capacity. As such, ν_t can be interpreted as a safety covenant enforced by sovereign bondholders - lenders force the sovereign into restructuring as soon as V_t hits ν_t. We can now formally define the sovereign's random time of default τ as

$$\tau = \inf\{t \geq 0 : V_t \leq \nu_t\}. \tag{2.6}$$

It is important to note at this point that the model only captures default due to the sovereign's inability to pay. Clearly, a sovereign's (un)willingness to pay could also trigger a default event, as in Eaton and Gersovitz (1981). Ecuador, for example, defaulted on a \$30.6mm interest payment in December 2008 despite international reserves in excess of \$5.5bn and a debt service to GDP ratio of less than 1%. However, willingness to pay is generally difficult to quantify and an extension of the model along these lines is left for future research.

2.2.3 Survival Probabilities

Using the setup discussed above, we can now compute the sovereign default probabilities as the first time the V_t process hits ν_t. In this model, default (and survival) probabilities are given in closed form under the $\mathbb{Q}$ probability measure (e.g. Black and Cox (1976)). Let $Q(s)$ denote the risk neutral survival probability from time zero through time $s \leq T$, conditional on the sovereign not yet having defaulted. More formally, $Q(s) = \mathbb{P}^{\mathbb{Q}}\{\tau \geq s | \tau > 0\}$. Under the dynamics for V_t and ν_t outlined above, we have that

$$Q(s) = N\left(\frac{\gamma - \frac{1}{2}\phi}{\sqrt{\phi}}\right) - e^{\gamma} N\left(\frac{-\gamma - \frac{1}{2}\phi}{\sqrt{\phi}}\right), \tag{2.7}$$

where γ and ϕ are given by

$$\gamma = \ln\left(\frac{V_0}{\nu_0}\right), \tag{2.8}$$

$$\phi = s\sigma^2. \tag{2.9}$$

It is straightforward to check that $Q(s)$ is increasing in γ. This is intuitive since γ represents the log inverse leverage ratio of the sovereign: higher γ implies a larger distance between a sovereign's ability to pay and the default threshold. Furthermore, $Q(s)$ is strictly decreasing in s, so that a longer time horizon makes default more likely. Indeed, we have that $Q(s) \to 0$ as $s \to \infty$. As expected, an increase in the volatility of V_t decreases the survival probability, other things equal.

2.2.4 Sovereign CDS Valuation

The model outlined above allows us to compute the sovereign's survival probabilities at each point in time for any given horizon $s \leq T$. Hence, we can use the model to value credit-sensitive contingent claims, such as CDSs. Denote the time to maturity of a CDS contract as T_N, where N specifies the number of coupon payment periods. Let the number of payment periods N be indexed by $j = 1, ..., N$. Furthermore, let h denote the length of each payment period, expressed in units of years. Thus, a j-period CDS has a maturity of $T_j = hj$ years. In the sovereign CDS market, the coupon frequency is usually semi-annual, so that $h = 0.5$. The coupon paid by the protection buyer is quoted as a percentage CDS_{T_N} of the insured notional, quoted on an annualized basis. CDS_{T_N} is know as the CDS spread. For the sake of simplicity and without loss of generality, I will assume that the underlying notional is equal to 1. Hence, conditional on the reference entity not defaulting, the protection buyer pays a coupon $hCDS_{T_N}$ at the end of each payment period. The CDS spread varies across maturities T_N, constituting a term structure of spreads.

In the event of default, the expected payment due to the holder of a credit swap is given by a fraction $1-R$ of the notional amount insured, where R denotes the constant risk neutral recovery rate on the underlying bond. Generally, $R < 1$, so that there is a loss for bondholders in default. In the case of a sovereign default, we can think of this loss as resulting from international trade sanctions or restricted future access to capital markets. The risk-neutral recovery rates market participants use for pricing emerging market sovereign CDS range from 20% to 30% of notional, implying a significant expected loss given default.

Since a CDS contract has a value of zero at inception, the fair spread CDS_{T_N} is set such that the value of the premium leg and the protection leg are equated. For simplicity, I assume that payments occur only on coupon dates, even if the reference entity defaults between two coupon dates. This greatly simplifies the analytics and has little effect on the pricing.

The premium leg of the CDS is the expected present value of future premia CDS_{T_N}, which are paid for the lifetime of the swap or until the underlying reference bond defaults, whichever is sooner. Hence, the value of the premium leg A_N for a credit swap with maturity T_N is given by the survival-adjusted discounted value of the stream of future premium cashflows:

$$A_N = hCDS_{T_N} \sum_{j=1}^{N} B(0,T_j)Q(T_j). \tag{2.10}$$

It is clear from the definition of A_N that any deterioration in the credit environment reflected by the survival probabilities $Q(T_j)$ will increase the value of holding protection on the reference entity.

Similarly, we can write the value of the protection leg C_N as the expected value of the payment due upon default, adjusted by the default probabilities during each coupon period. Since we assume that default can only occur on coupon dates, the value of the protection leg is given by

$$C_N = (1-R) \sum_{j=1}^{N} B(0,T_j)(Q(T_{j-1}) - Q(T_j)). \tag{2.11}$$

Given that a CDS contract has a value of zero at inception, we require that $A_N - C_N = 0$. Hence, the fair spread is given by

$$CDS(0,T_N) = \frac{(1-R)\sum_{j=1}^{N} B(0,T_j)(Q(T_{j-1}) - Q(T_j))}{h\sum_{j=1}^{N} B(0,T_j)Q(T_j)}, \tag{2.12}$$

where the survival probability $Q(T_j)$ from period 0 to period T_j is given by the structural model. In line with intuition, the CDS premium is decreasing in the sovereign recovery rate and increasing in the default probability.

2.3 Empirical Analysis

This section empirically implements the model outlined in Section 2.2 for a set of six emerging economies: the Czech Republic, Hungary, Poland, Romania, Russia and Turkey. I first discuss some salient features of the countries in the sample. Secondly, I outline a strategy for operationalizing the ability to pay as defined in 2.1. I then calibrate the model to observed sovereign CDS spreads and present the results. Lastly, I use the model to measure the market-implied level of country liabilities.

2.3.1 Features of the Dataset

I empirically implement the model for six emerging markets: the Czech Republic, Hungary, Poland, Romania, Russia and Turkey. All of these sovereigns have a domestic currency which is actively traded in the foreign exchange market. I use sovereign CDS data at the 5 year maturity mark from Markit based on the USD-denominated contract. This implies that the underlying deliverable obligations are bonds issued non-domestically in a standard specified currency (USD, Euro, Yen, Canadian dollar, Franc, and Pound). In addition to the CDS quotes, I also obtain information on the average recovery rate used by market participants in the pricing of the contract. I use external debt data from the World Bank Quarterly External Debt Statistics database as well as Datastream. External debt is calculated as the total public and private debt owed to nonresidents repayable in foreign currency, goods, or services. If the data is available, I use the stock of public and publicly guaranteed external debt as opposed to gross public and private external debt. Exports, imports and international reserves are available from Datastream on a monthly basis. I augment the time series whenever possible with data from the IMF. Lastly, I use stock market and interest rate data from Datastream and Wharton Research Data Services.

It is instructive to present country summary statistics for several variables that will be useful in the empirical implementation. Table 2.1 reports time series averages for these variables. The sample exhibits significant cross-sectional heterogeneity in terms of size and CDS spreads. Clearly, the sample sovereigns differ significantly by nominal GDP. Indeed, whereas Russia represents the 12^{th} largest economy by GDP in 2009, Hungary ranks in 50^{th} place. However, all countries in the sample rely significantly on international capital flows, as evidenced by their exports to GDP ratios. Lastly, even though the ratio of external debt to GDP does not vary strongly cross-sectionally, the average level of CDS spreads ranges from 37bps in the case of the Czech Republic to 332bps for Turkey. It should be noted that

Table 2.1: **Summary Statistics**: This table reports time series averages from Jan-2001 to Dec-2009. GDP is reported in \$bn nominal terms. The CDS spread is measured at the 5 year maturity mark and reported in basis points. Debt refers to a sovereign's foreign currency public debt. If this data is not available, debt denotes the total stock of external debt, private and public.

	GDP (\$bn)	**CDS (bps)**	**Debt to GDP**	**Exports to GDP**
CZE	132	37	36%	61%
HUN	106	96	31%	60%
POL	321	57	47%	28%
RON	109	167	33%	27%
RUS	846	181	32%	30%
TUR	459	332	38%	16%

the time series averages for the CDS spreads is significantly higher if we condition on the period from 2007 - 2009.

2.3.2 Determining Ability to Pay

Recall that the ability to pay is defined as $V_t = FX_t + x_t^* - \xi i_t^*$. While this definition is intuitively appealing, it is non-trivial to operationalize empirically. Hence, this section is concerned with the estimation of x_t^*, i_t^* and ξ.

Recall that x_t^* and i_t^* are the present discounted values of future exports and imports, discounted using stochastic discount factors $m_{x,t+s}$ and $m_{i,t+s}$. While, a priori, one might expect $m_{x,t+s}$ and $m_{i,t+s}$ to be equal, it will become clear below why this is not the case. It is evident that estimating x_t^* (i_t^*) requires knowledge both of the expected future evolution of x_t (i_t) as well as the discount factors. I will address both points below.

2.3.2.1 Time Series Evolution of Exports and Imports

I assume that both the log of exports and the log of imports follow random walks with drifts. Hence,

$$\Delta \log x_{t+1} = \mu_x + \epsilon_{t+1} \tag{2.13}$$

$$\Delta \log i_{t+1} = \mu_i + \nu_{t+1}, \tag{2.14}$$

where ϵ_{t+1} and ν_{t+1} are distributed iid normal. I empirically estimate μ_x and μ_i as the average of monthly log changes in observed exports and imports over the sample period. Using the dynamics specified above, we can easily compute the s-period ahead optimal linear forecast of the level of exports and imports:[3]

$$\mathbb{E}_t x_{t+s} = x_t e^{s\mu_x}, \tag{2.15}$$

$$\mathbb{E}_t i_{t+s} = i_t e^{s\mu_i}. \tag{2.16}$$

Finally, we can express the present value of future exports and imports as

$$x_t^* = \mathbb{E}_t \left[\sum_{s=0}^{\infty} m_{x,t+s} x_t e^{s\mu_x} \right], \tag{2.17}$$

$$i_t^* = \mathbb{E}_t \left[\sum_{s=0}^{\infty} m_{i,t+s} i_t e^{s\mu_i} \right]. \tag{2.18}$$

Given a specification for the stochastic discount factors, it is straightforward to compute the above expressions.

2.3.2.2 Discount Factors

Since exports and imports are non-traded quantities, estimating $m_{x,t+s}$ and $m_{i,t+s}$ is non-trivial. For tractability, I assume that both discount factors are constant through time and

[3] The derivation for exports is as follows. The optimal s-period ahead linear forecast of the level of log exports is given by $\mathbb{E}_t \left[\log x_t + s\mu_x + \sum_{v=1}^{s} \epsilon_{t+v}\right]$. Applying the exponential transformation on both sides and ignoring the Jensen's term yields the result. Lutkepohl and Xu (2009) show that this naive forecast may perform as well or better than the true optimal forecast in the presence of specification and estimation uncertainty.

given by m_x and m_i. An extension of this model with time-varying risk premia is left for future research.

Furthermore, I assume that the World CAPM holds for equity markets. Hence, there is no segmentation among markets and country-specific risk is completely diversifiable. In turn, this implies that the only source of global systematic equity risk is the world market portfolio. Thus, the returns to the claims on future exports and imports x_t^* and i_t^* are spanned by one existing tradable asset, the market portfolio.

Let r_t^x and r_t^i denote the percentage return to x_t^* and i_t^* respectively. Since log changes in both exports and imports are random walks, we have that

$$r_t^x = \frac{x_t^* - x_{t-1}^*}{x_{t-1}^*} = \frac{x_t - x_{t-1}}{x_{t-1}}, \tag{2.19}$$

$$r_t^i = \frac{i_t^* - i_{t-1}^*}{i_{t-1}^*} = \frac{i_t - i_{t-1}}{i_{t-1}}. \tag{2.20}$$

Hence, under the World CAPM it must be that

$$\mathbb{E}(r_t^x - r^f) = \beta_x \mathbb{E}(r_t^m - r^f), \tag{2.21}$$

$$\mathbb{E}(r_t^i - r^f) = \beta_i \mathbb{E}(r_t^m - r^f), \tag{2.22}$$

where the world market portfolio return is given by r_t^m and r^f denotes the riskless rate. Equations 2.21 and 2.22 state that the expected excess returns, i.e. the risk premia, of x_t^* and i_t^* are linearly related to the world risk premium. Hence, given knowledge of β_x and β_i, we can easily compute the appropriate export (import) risk premia and thus discount factors. Letting $\lambda = \mathbb{E}(r_t^m - r_t)$ and assuming continuously compounded returns, we have that

$$\begin{pmatrix} m_x \\ m_i \end{pmatrix} = \begin{pmatrix} e^{-\beta_x \Lambda - r_f} \\ e^{-\beta_i \Lambda - r_f} \end{pmatrix}. \tag{2.23}$$

The country-specific discount factors for exports and imports are thus given by the riskfree discount rate plus a risk premium adjustment, which depends linearly on the β coefficients.

It is easy to see that, once we have estimated β_x, β_i, r_f and λ, we can compute the present value of exports and imports in closed form. Indeed, x_t^* and i_t^* are given by the following Gordon-type formulae:[4]

$$x_t^* = \frac{x_t}{r_f + \beta_x \Lambda - \mu_x}, \tag{2.24}$$

$$i_t^* = \frac{i_t}{r_f + \beta_i \Lambda - \mu_i}. \tag{2.25}$$

I empirically estimate β_x and β_i using ordinary least squares time series regressions at the quarterly frequency. I use as a proxy for the world market portfolio return the percentage return of the MSCI World Index, denoted in \$US. The US 30 Day T-Bill yield serves as a proxy for the riskless rate. For each of the countries in the sample, I estimate

$$r_t^j - r^f = \alpha + \beta_j \left(r_t^m - r^f \right) + \epsilon_t, \tag{2.26}$$

where $j \in \{x, i\}$. The sample period covers Jan-1990 to Feb-2010. Lastly, I estimate λ as the average excess total return of the MSCI World Index from Dec-1969 to Feb-2010 at the monthly frequency.

Table 2.2 reports the results of this analysis. It is evident from Panel A that for most countries, the β-coefficients are significant at the 10% level for both imports and exports. Furthermore, all estimated coefficients are positive, implying that the returns to x_t^* and i_t^* are strongly pro-cyclical. A look at the sovereigns' export and import composition may help in explaining this finding. In the case of Hungary, for example, pro-cyclical durables such as machinery and transport equipment account on average for 59% of exports and 40% of imports (in the period 2001–2005). Panel B reports the world equity premium, as proxied by the average excess return of the MSCI World index, as 0.48% on a monthly basis, which equates to 5.74% annually. Although smaller in magnitude than the US equity premium,

[4] In fact, $x_t^* = \frac{x_t}{1 - e^{\mu_x - \beta_x \Lambda - r_f}}$. However, for small values of a variable y, we can approximate $e^y \simeq 1 + y$. Rewriting, we get the classic Gordon formula.

Table 2.2: β**-Exposures and Risk Premia**: Panel A reports the coefficient estimate, standard error and R^2 of the regression $r_t^j - r^f = \alpha + \beta_j(r_t^m - r^f) + \epsilon_t$, where j denotes either exports or imports, r^f is the 30-Day US Treasury Bill yield and r^m denotes the return on the MSCI World Index. The sample period is Jan-1990 to Feb-2010 at the quarterly frequency. Panel B reports the average monthly cum-dividend return of the MSCI World minus the 30-Day US Treasury Bill yield from Dec-1969 to Feb-2010. Panel C computes the discount rates for exports and imports, given by $\mathbb{E}(r_t^j) = r^f + \beta_j \Lambda$.

	CZE	**HUN**	**POL**	**ROM**	**RUS**	**TUR**
	Panel A					
	Export Return					
Beta	0.46	0.55	0.31	0.23	0.35	0.26
SE	0.14	0.16	0.17	0.14	0.18	0.16
R^2	0.12	0.13	0.04	0.04	0.06	0.03
	Import Return					
Beta	0.45	0.45	0.40	0.45	0.40	0.38
SE	0.21	0.17	0.23	0.31	0.21	0.19
R^2	0.06	0.08	0.04	0.03	0.05	0.05
	Panel B					
	MSCI World					
λ	0.48%					
$\mathbb{E}(r^f)$	0.46%					
	Panel C					
	Expected Returns					
Exp.	0.68%	0.72%	0.61%	0.57%	0.63%	0.58%
Imp.	0.68%	0.68%	0.65%	0.67%	0.65%	0.64%

the estimated value is in line with existing literature on the world equity premium. Using the point estimates reported in Panel A and the estimates for λ and the average riskfree rate in Panel B, I compute the export and import discount rates $r^f + \beta_x\lambda$ and $r^f + \beta_i\lambda$ in Panel C. The estimated discount rates fall in a relatively tight range, from 6.29% to 8.68% annually. Using these values, as well as estimates for μ_x and μ_i, we can now compute the value of Equations 2.24 and 2.25.

2.3.2.3 Determination of ξ

The previous sections outlined how to estimate the present value of future exports and imports, x_t^* and i_t^*. The last element needed to compute the ability to pay V_t is the parameter ξ. Recall that ξ represents the portion of imports that is implicitly tied to exports (e.g. raw materials and intermediate goods). The remaining $1 - \xi$ fraction of imports can be relinquished in case a sovereign needs to raise foreign capital in times of distress.

It is difficult to estimate ξ empirically since it is not an observable quantity. While, in principle, one could analyze the commodity composition of a sovereign's imports and thus imply a proxy value of ξ, it would likely involve a significant degree of subjective judgement. Hence, I treat ξ as a free parameter and calibrate it to provide the best fit between the model and market CDS spreads.

2.3.3 Calibration

In this section I calibrate the model to market data by searching over different values of ξ to minimize pricing errors. The model is implemented at a monthly frequency using the dataset discussed in Section 2.3.1. The sample period under consideration is January 2001 to February 2010, but differs slightly across countries due to data availability. The calibration is implemented as follows. First, I fix ξ between 0 and 1. Given ξ, I empirically determine all relevant pricing parameters in the model:

$$\{V_t, \nu_t, \sigma, R\}\,. \tag{2.27}$$

Lastly, I use the model to price a sovereign CDS at the 5 year maturity and compute the pricing errors between the model-implied and market CDS spreads. I then calibrate ξ to minimize the average absolute pricing error over the sample. Below, I outline in detail the determination of the parameters in Equation 2.27.

Each month I compute V_t as the ξ-adjusted difference between the present value of future exports and imports plus the current period foreign exchange reserves. Using the Gordon formulae derived in Equations 2.24 and 2.25, V_t is given by

$$V_t = FX_t + \frac{x_t}{r_f + \beta_x \Lambda - \mu_x} - \xi \frac{i_t}{r_f + \beta_i \Lambda - \mu_i}, \tag{2.28}$$

where β_x, β_i and Λ are kept constant over the sample at their estimated values, given in Section 2.3.2.2. The export and import growth rates μ_x and μ_i are estimated from log-changes in country exports and imports over the sample.[5] The international reserves FX_t are taken directly from the data. Putting this together, we can construct the monthly time-series of V_t.

Having computed the sovereign's ability to pay, I now turn to the default threshold, $\nu_t = \bar{k}B(t,T)$. I use as a proxy for $\bar{k}$ the total amount of outstanding external debt, measured at the quarterly horizon. Since the timing of the model is monthly, I update the value of $\bar{k}$ at the beginning of each quarter and keep it constant until the next quarter. In this model there is only one outstanding debt issue per sovereign. Hence, I set the maturity parameter T equal to each country's average external debt maturity. The 30 Day US Treasury Bill yield is used as a proxy for the instantaneous riskfree rate r.

Finally, we need to estimate σ, the volatility of V_t, as well as the recovery rate, R. I use as an estimate for σ the 90-month rolling volatility of log changes in V_t, but note that the results are quantitatively similar if σ is fixed over the entire sample. The recovery rate R is set to the average recovery rate used by market participants, which differs across sovereigns and averages 20% cross-sectionally.

Using the methodology outlined above, I calibrate the model to minimize the average

[5] The Gordon formulae are only valid if $r_f + \beta_x \Lambda > \mu_x$ and $r_f + \beta_i \Lambda > \mu_i$. In empirical implementations, however, this condition is not guaranteed. Hence I assume that an emerging sovereign's export (import) growth rate will converge to an 'average' growth rate as the economy matures, given by average annual world GDP growth of 2%.

Table 2.3: **Calibrated Values of ξ**: The calibration minimizes the average absolute basis point difference between model-implied and market CDS spreads over the sample period by searching over ξ.

Country	ξ
CZE	37.17%
HUN	33.27%
POL	29.62%
ROM	33.40%
RUS	64.54%
TUR	17.35%
Avg	35.89%

absolute pricing error between model-implied and market CDS spreads for each country. Table 2.3 reports the results of the calibration. For all countries in the sample, the calibration converges with an interior solution for ξ. The Czech Republic, Hungary, Poland and Romania have similar values of ξ, in line with the notion that these sovereigns have comparable economies. It is important to note that an economic interpretation of these numbers is difficult since ξ is an unobservable quantity. The average absolute calibration pricing errors are discussed in detail in 2.3.4 (see Table 2.4).

2.3.4 Results

In this section I discuss the results of the calibrated model. First, I show that the average absolute pricing errors of the model are generally small and that model-implied and market CDS spreads are highly correlated. Secondly, I show that the estimates of V_t are economically reasonable. Lastly, I argue that the model can capture the significant increase in spreads during the recent financial crisis.

I report the average absolute model pricing errors in Table 2.4. Given that the dynamics of the model are driven purely by changes in macro-economic fundamentals and do not incorporate any market data, such as bond yields or stock market returns, the fit of the model is surprisingly good.[6] Indeed, for the Czech Republic, Hungary and Poland, the average pricing errors are below 31bps across the sample. It should also be noted that the period under consideration was partly characterized by very high levels of volatility. Nevertheless, most countries in the sample exhibit a strong positive correlation between the market and model-implied CDS spreads. This indicates that, in addition to the level,

Table 2.4: **Model Pricing Errors and Correlations**: The model pricing error (PE) is defined as the average absolute basis point difference between model-implied and market CDS spreads. The correlation column reports the correlation coefficient of model-implied and market CDS spreads.

Country	PE	Corr.
CZE	19.39	0.78
HUN	30.77	0.92
POL	26.02	0.75
RON	78.20	0.76
RUS	86.66	0.65
TUR	227.59	0.23

the model also provides a reasonable characterization of the time-series dynamics of CDS spreads. This is especially true for Hungary, where the correlation between model and market spreads exceeds 90%. The model does not provide a satisfactory fit for Turkey, with an average absolute pricing error of 230bps and a model-market CDS spread correlation of 23%. This may be partially attributable to the fact that Turkey is among the most developed countries in the sample. In fact, Turkey is often classified as a newly industrialized nation. Thus, the drivers of Turkey's economy may be different - average exports as a percentage of GDP, for example, are merely 16%, compared to Hungary's 60% (see Table 2.1).

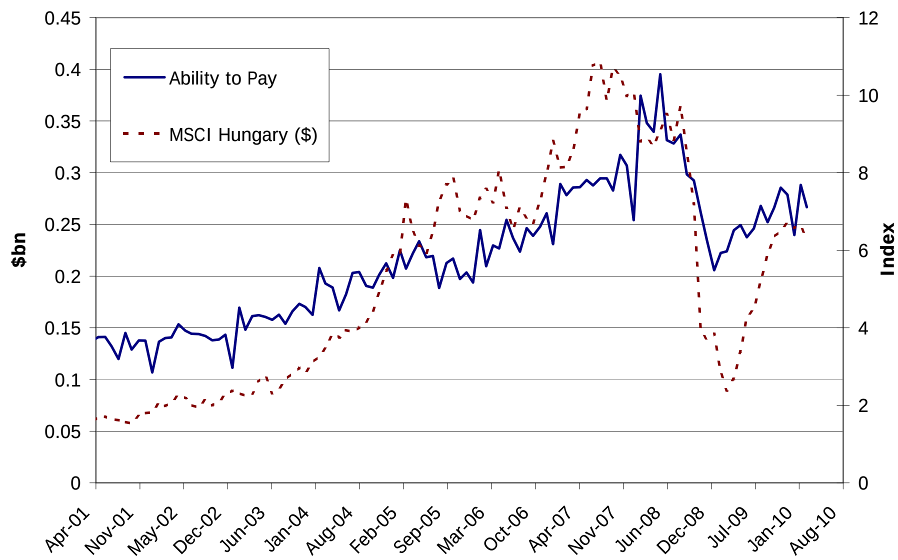
While the pricing errors of the model are generally small, it is important to examine

[6]Note that $\Delta V_t = a\Delta x_t - b\Delta i_t + \Delta FX_t$ for constants a and b, so that changes in V_t are driven primarily by changes in the model fundamentals: exports, imports and reserves. Since all fundamentals in this model are $US denominated, exchange rate volatility also plays a role.

whether one of the main variables driving the performance of the model, the ability to pay, is economically reasonable.

Firstly, I compare the estimated time series of V_t to a different proxy for the country wealth process: the domestic stock market. Lehrbass (1999) argues that the discounted future stream of a country's GDP is a good indicator of the sovereign's asset value. Since, on average, corporate profits are a large part of GDP, and the stock market value is a function of the present discount value of future profits, the $US-denominated value of the domestic stock market index is a proxy for the value of underlying assets in foreign currency. Figure

Figure 2.1: **Ability to Pay and Country Index (Hungary)**: This figure plots the time series of Hungary's ability to pay and a measure of the local stock market, the MSCI Hungary. Both quantities are measured in $US.



2.1 shows the time-series performance of the $US-denominated MSCI country index for Hungary. Although not perfectly correlated, it is evident that V_t captures the economic improvement from 2001 to 2007 as well as the significant downturn in 2008 and the subsequent late-2009/early-2010 recovery.

Secondly, to ascertain the relative magnitude of V_t in each country, I compute the average annual ratio of the ability to pay relative to nominal GDP. Table 2.5 reports the results, as well as the volatility of the log changes of V_t over the sample. For most countries

Table 2.5: **Ability to Pay and Volatility**: This table reports the time series average of the ability to pay relative to GDP from Jan-2001 to Dec-2009. σ is computed as the annualized standard deviation of log changes of V over the sample. The country-specific value of ξ is set to its calibrated level.

	V/GDP	σ
CZE	6.46	47%
HUN	2.06	37%
POL	3.32	39%
RON	1.93	36%
RUS	1.78	29%
TUR	1.31	38%

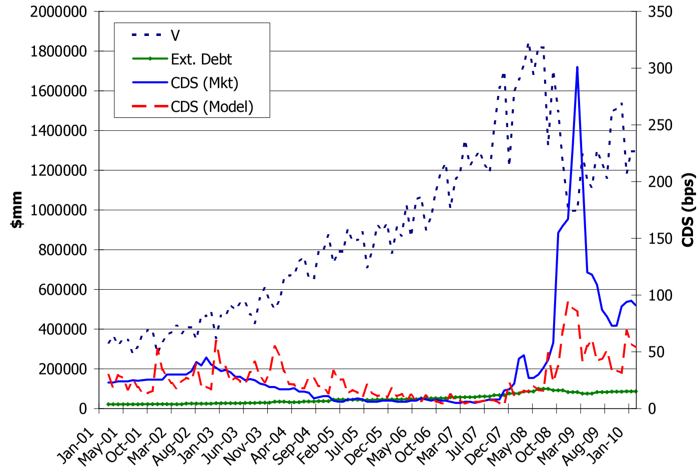
in the sample, the average ratio of the ability to pay relative to GDP seems economically reasonable. Recall that V_t denotes the maximum amount of foreign currency a sovereign could access in times of distress - hence, the ability to pay is an upper bound to the sovereign wealth process. In the case of the Czech Republic, the ratio seems rather high. While it is difficult to judge whether a ratio of V_t to GDP of 6.5 is too high, I point to the fact that the Czech Republic has the largest share of exports relative to GDP of the six sovereigns (see Table 2.1).

The third column in Table 2.5 reports the volatility of V_t over the sample. Somewhat surprisingly, σ is large in magnitude for all sovereigns, ranging from 29% per annum for Russia to 47% per annum for the Czech Republic. In fact, in this model the volatility of the underlying macro-economic fundamentals is further augmented by present-valuing the infinite stream of future exports and imports each period. The level of σ is a large contributing factor to the overall fit of the model.

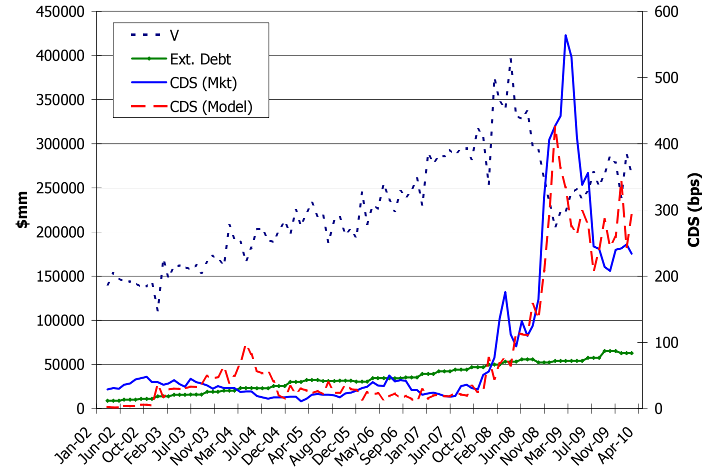
In the discussion above, I show that the model fits well in terms of pricing errors and that the resulting values of V_t are economically reasonable. Lastly, I analyze the time series behavior of the model CDS spreads vis-à-vis their market equivalents. Figures 2.2 and 2.3 plot the time series of the ability to pay V_t, the level of external debt $\bar{k}$ as well as the model-implied and market CDS spreads.

The figures visually reaffirm that a model of sovereign CDS spreads based only on macro-economic fundamentals provides a reasonable fit to market data. In particular, Figure 2.2 shows that the model captures a large part of the spread widening during 2001 and 2002 as well as during 2007 and 2008 for the Czech Republic, Hungary and Poland. Interestingly, we also capture the spread tightening in late 2009 as a result of economic recovery and the subsequent widening in early 2010 when concerns about Greece's debt sustainability came to the fore. In Figure 2.3, we still capture the increase in spreads during 2007 and 2008, but the model significantly overshoots in the case of Turkey. Similarly, the pricing errors for Romania are large in the beginning of the sample. On the other hand, we capture well the periods of turmoil in the early and late 2000s in Russia.

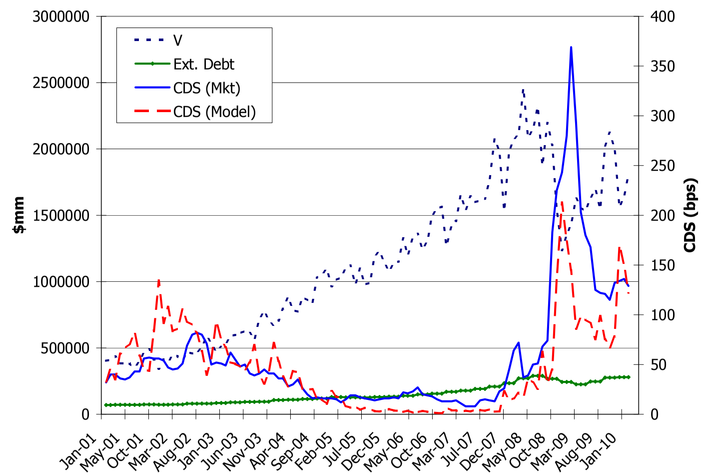
Moreover, this model allows us to disentangle the significant increase in CDS spreads during the recent financial crisis as a function of macro-economic fundamentals. For all countries in the sample, the ability to pay shows a significant deterioration in mid-2008. This was a direct result of the global economic downturn, which significantly impacted the flow of international trade in emerging economies. Simultaneously, several countries in the sample experienced pronounced currency devaluations and, seeking foreign exchange stabilization, depleted parts of their international reserves. The confluence of these factors resulted in a plunge in sovereigns' ability to pay. With a high level of external debt accumulated through the previous years, and the stock of debt essentially fixed in the short run, countries' CDS spreads spiked. For all six emerging nations in the sample, the model does a good job in fitting the run-up in sovereign CDS spreads during the recent crisis.



(a) Czech Republic

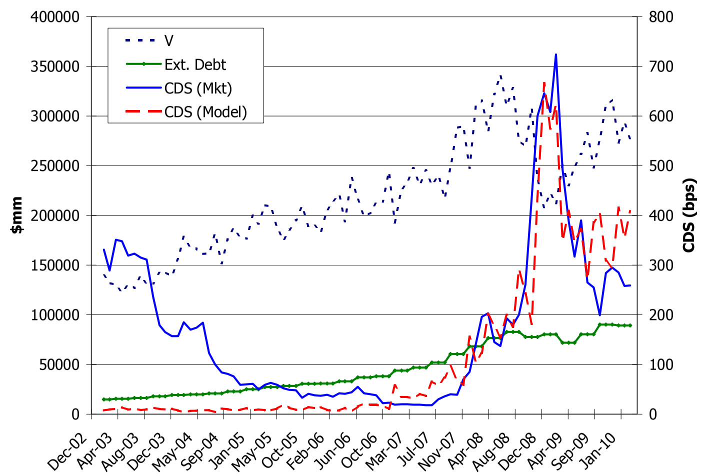


(b) Hungary

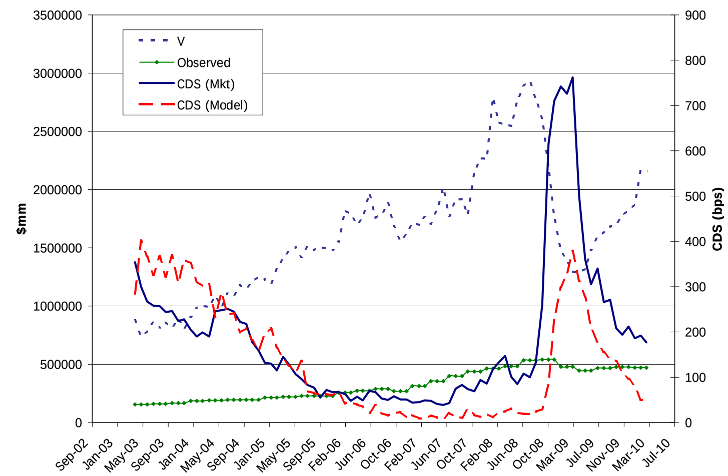


(c) Poland

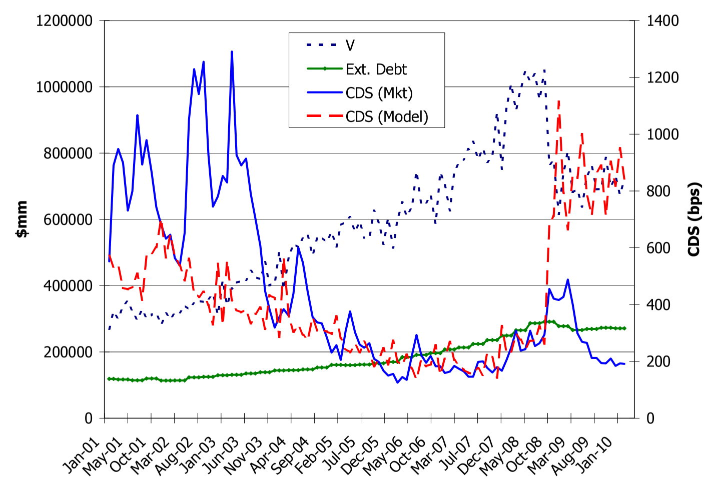
Figure 2.2: **Market and Model-Implied CDS Spreads (Czech Republic, Hungary and Poland)**: This figure plots the model-implied and market CDS spreads as well as countries' ability to pay and the level of external debt. The country-specific value of ξ is set to its calibrated level.



(a) Romania



(b) Russia



(c) Turkey

Figure 2.3: **Market and Model-Implied CDS Spreads (Romania, Russia and Turkey)**: This figure plots the model-implied and market CDS spreads as well as countries' ability to pay and the level of external debt. The country-specific value of ξ is set to its calibrated level.

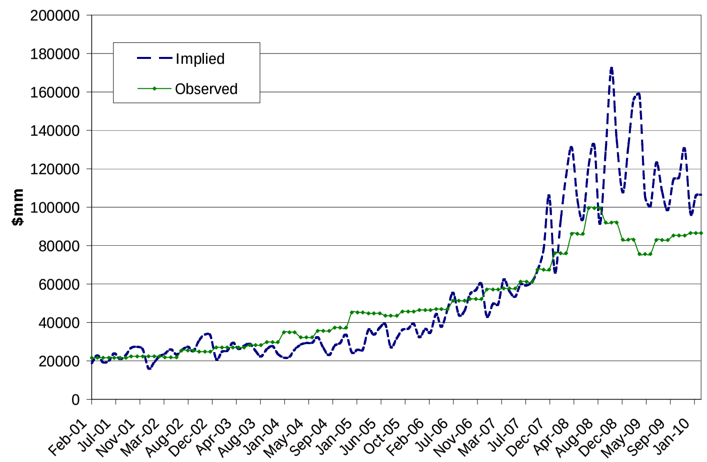
2.3.5 Implied External Liabilities

In this section, I offer a different interpretation of the pricing errors discussed in Section 2.3.4. The sovereign CDS spread is crucially affected by the default boundary ν_t and thus by the face value of external debt, $\bar{k}$. In the previous analysis, I have taken the value of external debt directly from the data. However, this only serves as a proxy for the true value of sovereign liabilities - additional leverage in the form of guarantees and subsidies to the private sector or other nations may be priced in for sovereign CDS spreads but may not be observable in the data. Under the assumption that the model is an accurate description of the data and that pricing errors are primarily related to the mismeasurement of outstanding liabilities, I solve for the face value of external debt that sets to zero the monthly difference between model-implied and market CDS spreads. In effect, this allows us to transform the pricing errors from basis points into the level of debt in $US.

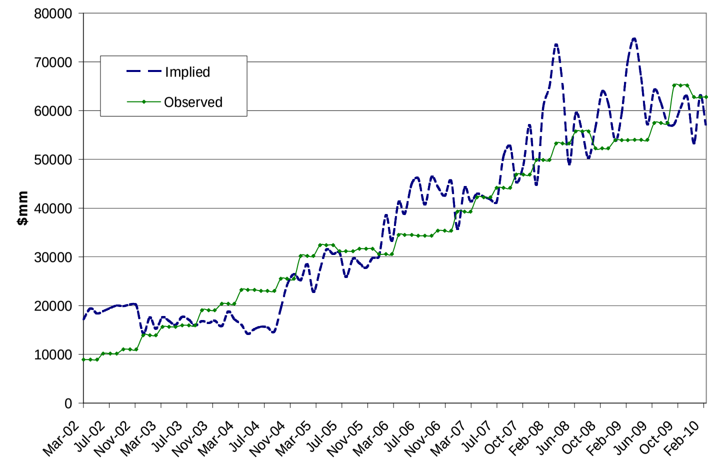
Table 2.6: **Model-Implied and Observed External Debt**: This table reports the observed and model-implied value of outstanding debt in $bn. The country-specific value of ξ is set to its calibrated level.

Country	**Imp.**	**Obs.**	**(1)/(2)**
CZE	55.13	49.72	1.11
HUN	37.34	35.13	1.06
POL	183.21	151.52	1.21
ROM	47.71	42.42	1.12
RUS	421.56	324.94	1.30
TUR	180.19	184.09	0.98

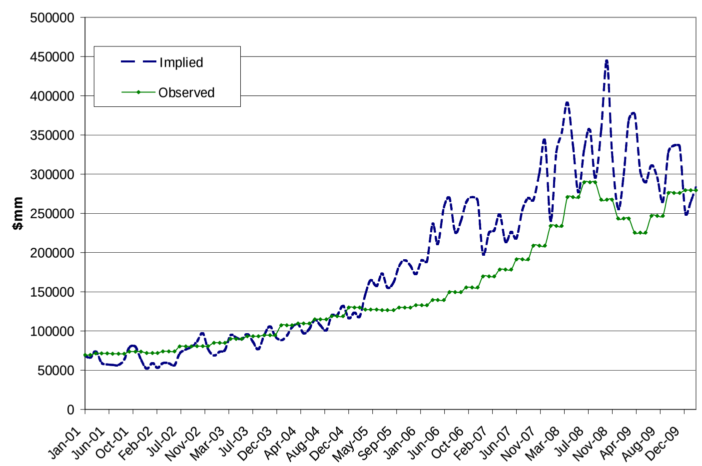
Table 2.6 reports the average level of external debt as taken from the data, as well as the average level of implied debt. Interestingly, the model suggests that, on average, the value of external liabilities is too low to justify the level of market CDS spreads. This



(a) Czech Republic

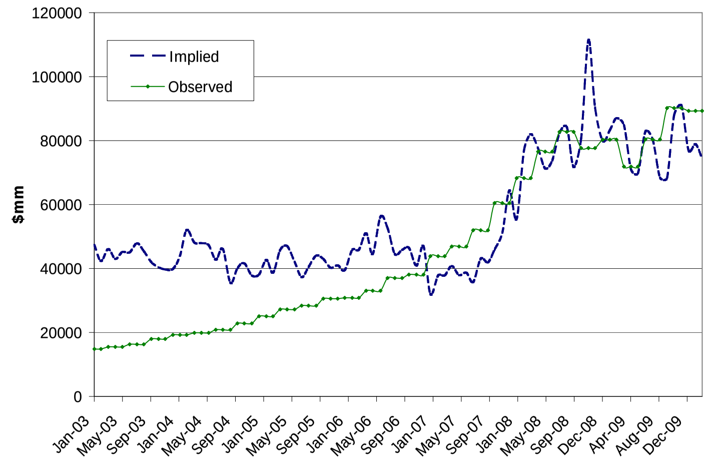


(b) Hungary

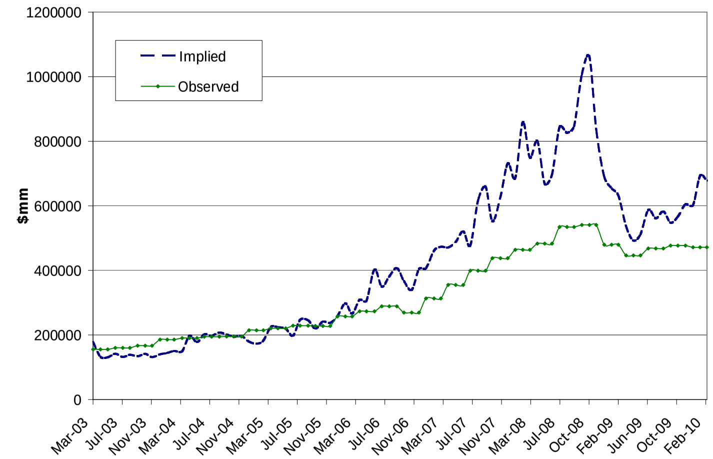


(c) Poland

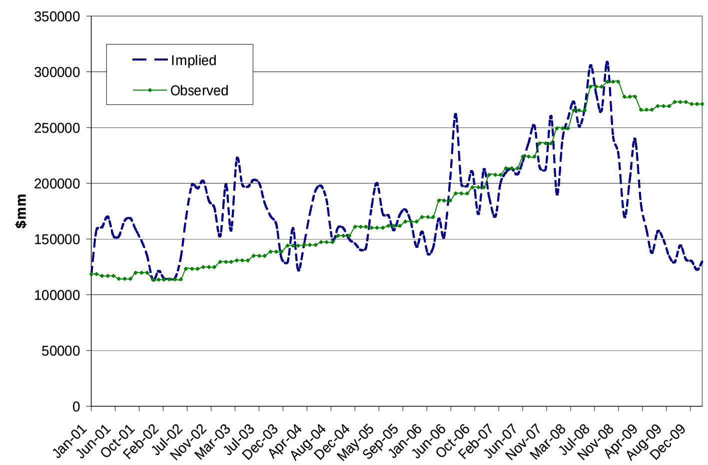
Figure 2.4: **Observed and Model-Implied Debt Levels (Czech Republic, Hungary and Poland)**: This figure plots the model-implied and observed level of sovereign external debt. The implied value of debt is the level of external debt that equates market and model-implied sovereign CDS spreads. The country-specific value of ξ is set to its calibrated level.



(a) Romania



(b) Russia



(c) Turkey

Figure 2.5: **Observed and Model-Implied Debt Levels (Romania, Russia and Turkey)**: This figure plots the model-implied and observed level of sovereign external debt. The implied value of debt is the level of external debt that equates market and model-implied sovereign CDS spreads. The country-specific value of ξ is set to its calibrated level.

is true for all countries in the sample except Turkey. In fact, external liabilities should be roughly 13% higher than their reported levels if we want to match observed CDS spreads.

Figures 2.4 and 2.5 show the time-series behavior of the level of model-implied external debt. The implied value of debt is significantly more volatile than the actual value due to the possibility that the model pricing errors may be affected by many other factors. Nevertheless, these figures are instructive as a visualization of pricing errors. For the Czech Republic, Hungary, Poland, Russia and Turkey the implied values of $\bar{k}$ track closely the actual stock of external debt, except during the recent crisis. In the case of Romania, the implied value of debt is generally higher than the observed value, which reflects the fact that the model underprices Romanian sovereign CDS in the beginning of the sample period. In future research, it may be of interest to explicitly include government subsidies and guarantees in a structural model of sovereign credit risk.

2.4 Conclusion

This paper develops and applies a structural model of sovereign credit risk based on macroeconomic fundamentals. The model is based on a sovereign's access to international capital through exports, imports and international reserves. I define a country's ability to pay as the maximum amount of foreign currency available for repayment of external debt. The ability to pay is increasing in the present value of future export as well as the current period foreign exchange reserves, and decreasing in the present value of future imports. In the model, the joint dynamics of the ability to pay and a sovereign's outstanding external debt determine the level of country default risk and thus the CDS spread. The model is empirically tractable and implemented for a sample of 6 emerging economies (Czech Republic, Hungary, Poland, Romania, Russia, Turkey) for a period covering the recent financial crisis. A calibrated version of the model captures the widening of sovereign spreads during the crisis and provides a good fit for the time-series dynamics of CDS spreads. For the Czech Republic, Hungary and Poland, the average absolute model pricing errors are below 31bps. Furthermore, the correlation between model-implied and market CDS spreads is positive for all countries, and above 65% for five of them. Lastly, I use the model to measure the market-implied level of country liabilities. On average, the value of implied external debt is 13% larger than the reported level of debt, which may indicate the presence of implicit or explicit off-balance sheet guarantees.

Bibliography

[1] Fischer Black and John C. Cox. Valuing Corporate Securities: Some Effects of Bond Indenture Provisions. *Journal of Finance*, 31(2):351–367, 1976.

[2] Fischer Black and Myron Scholes. The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81(3):637–654, 1973.

[3] Damiano Brigo and Fabio Mercurio. *Interest Rate Models - Theory and Practice*. Springer Verlag, 2001.

[4] Stijn Claessens and George Pennacchi. Estimating the Likelihood of Mexican Default from the Market Prices of Brady Bonds. *Journal of Financial and Quantitative Analysis*, 31(1):109–126, 1996.

[5] Darrell Duffie and Kenneth J. Singleton. *Credit Risk*. Princeton University Press, 2003.

[6] Jonathan Eaton and Mark Gersovitz. Debt with Potential Repudiation: Theoretical and Empirical Analysis. *Review of Economic Studies*, 48(2):289–309, 1981.

[7] Jens Hilscher and Yves Nosbusch. Determinants of Sovereign Risk: Macroeconomic Fundamentals and the Pricing of Sovereign Debt. *Review of Finance*, 2010.

[8] John Hull and Alan White. Pricing Interest-Rate-Derivative Securities. *Review of Financial Studies*, 3(4):573–592, 1990.

[9] Alexandre Jeanneret. The Dynamics of Sovereign Credit Risk. EFA 2009 Bergen Meetings Paper, 2009.

[10] Alexander Karmann and Dominik Maltritz. Assessment of Sovereign Risk for South America: A Structural Approach. In Michael Frenkel, Alexander Karmann and Bert Scholtens (Eds.), *Sovereign Risk and Financial Crises*, Springer Verlag, 2004.

[11] Nalin Kulatilaka and Alan J. Marcus. A Model of Strategic Default of Sovereign Debt. *Journal of Economic Dynamics and Control*, 11(4):483–498, 1987.

[12] Frank Lehrbass. A Simple Approach to Country Risk. Working Paper, 1999.

[13] Hayne E. Leland. Corporate Debt Value, Bond Covenants, and Optimal Capital Structure. *Journal of Finance*, 49(4):1213–1252, 1994.

[14] Helmut Luetkepohl and Fang Xu The Role of the Log Transformation in Forecasting Economic Variables. CESifo Working Paper Series No. 2591, 2009.

[15] Robert C. Merton. On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. *Journal of Finance*, 29(2):449–470, 1974.

[16] Chunsheng Zhou. The Term Structure of Credit Spreads with Jump Risk. *Journal of Banking & Finance*, 25(11):2015–2040, 2001.