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Time-Variation in the Pricing of Country Fundamentals in Sovereign Credit Spreads

Thesis Summary

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Contents

Abstract

An expanding strand of macro-finance investigates whether the relationship between asset prices and their fundamental determinants are stable or vary through time. Empirical results in the sovereign credit risk literature unanimously support time-variation, however the roots of these findings received less attention.

The theoretical part of the thesis contributes a model of sovereign credit risk that extends the framework of Eaton and Gersovitz (1981) to incorporate aspects of the external share of government debt, funding liquidity crises and political economy preferences. The model calls attention to several variable interactions that may explain findings of time-variant effects in reduced-form models.

The empirical part first shows that the log-linear functional link between sovereign credit spreads and ratings is more robust than the linear specification used in much of current empirical work. However, even in the log spreads specification, fundamental effects are found to be time-varying. The role of fundamentals overall seem to have declined in the eurozone sovereign crisis, even though the role of the debt ratio has increased exactly in this period. This lends support to the wake-up call hypothesis regarding debt repricing in spreads. This repricing was of a quantitatively important magnitude.

1 Introduction

1.1 Motivation

Understanding the determinants of sovereign credit spreads is important for policymakers, taxpayers and investors alike. Policymakers and taxpayers are interested in the drivers of sovereign spreads[1], because public debt service costs (a significant part of government expenditures) depend on sovereign credit spreads, the price of credit risk. Different policy actions are optimal when the path of future spreads is more/less uncertain, when there is a high/low probability of a large increase in spreads. Knowing which country fundamentals determine credit spreads facilitates choosing policies that lowers the cost of servicing public debt.

Investors are interested in the drivers of credit spreads, because spreads directly influence the market value of bonds in secondary markets. An increase in credit spreads causes a valuation loss for bond investors, which is realized either if bonds are sold prior to maturity or in the case that the government defaults on debt. A model of the data generating process of spreads translates investor predictions about economic fundamentals into credit spreads and this is necessary for active trading to choose investment strategy, for risk management to develop proper stress scenarios, and for portfolio management to gauge diversification benefits.

However, there is a lot of uncertainty surrounding predictions about future credit spreads. Both the underlying factors are difficult to forecast and the data generating process of credit spreads is difficult to pin down. This latter aspect, what factors determine credit spreads and how, has been the subject of an extensive literature on sovereign credit risk. Theoretical considerations, as discussed in the thesis, allow many factors (fundamentals and non-fundamentals) to influence pricing, but empirical estimation of partial effects is hindered by a small number of independent observations, the fact that relevant factors are correlated and that many factors have only lagged and noisy proxies available. Therefore it is not possible to arrive to a single-best model of sovereign credit risk determination.

It is obvious from encounters of market participants (e.g. traders, portfolio managers regularly express their views in media appearances) that they have heterogenous views about both the future of the economy (fundamentals) and about which fundamentals they consider to be important in shaping prices in the market. Although theory and empirical data point out general possibilities as to how credit spreads may be determined, they leave ample room for market participants to choose different models and to compete with each other in this respect, which then, reinforces model uncertainty. In particular, investors are interested in successful forecasting not only how the economy will evolve, but how the 'true' model linking the economy to credit spreads, i.e how other investors will model this link, will evolve.

This view of the market leads up to the subject matter of the thesis, time-variation in the relationship between fundamentals and credit spreads. Are the empirical data really consistent

[1] Sovereign (credit) spreads refer to sovereign (hard-currency) bond yield spreads over US Treasury or German Bund yields and sovereign CDS spreads.

with changing weights of fundamentals in credit spread determination over time? Or is the commonly found time-variation the result of inadequate data and/or model misspecification? Even if a true time-invariant model existed, the data difficulties (lagged, noisy, correlated proxies) or a misspecified model (omitted relevant variables, variable interactions and wrong functional form) could lead to an erroneous rejection of effects that are stable in time.

Although answering the above questions with certainty is not possible due to data limitations, the goal of the thesis is to provide a proper theoretical elaboration of possible omitted factors, elaboration and checks of possible functional form misspecification, and an empirical procedure with an appropriate testing method, which is adequate for particularities of the data set and application at hand. This allows a contribution to the extant literature in providing a more refined answer to the above questions and explanations for some of the common findings on the subject matter so far. Such a contribution, as argued above, is also important outside of the research community, for both debtors (policymakers, taxpayers) and investors.

1.2 Structure of the thesis

The main text of the thesis is organized into three parts.

Part I describes concepts of sovereign borrowing, sovereign credit risk and provides a review of the literature. The first chapter of this block, Chapter 2, reviews the theoretical literature and arrives to a list of theoretically relevant fundamental determinants of sovereign credit risk. The next chapter describes basic properties of key indicators of sovereign credit risk – ratings, bond and CDS spreads. Chapter 4 turns to the empirical literature and conducts an extensive meta-analysis of the literature results. The last section of Chapter 4 reviews the segment of the empirical literature that specifically relates to time-variation of fundamental effects in the determination of sovereign credit risk proxies, sovereign credit spreads and ratings.

Part II and Part III present my additions to this literature.

Part II of the thesis proposes a new theoretical model of sovereign credit risk. The model follows the cost-benefit framework of Eaton and Gersovitz (1981), but adds three non-standard elements. These elements, though non-standard in this framework, have each been elaborated separately by different segments of the literature and are understood by the research community to be important drivers of sovereign risk. The main contribution of this modelling exercise is bringing these factors together under one umbrella. This permits identifying important interactions between these aspects, which is overlooked by partial models.

Part II ends with a brief chapter, Chapter 7, that states the main hypotheses regarding time-variation of fundamentals priced in sovereign credit spreads.

Part III constitutes the empirical contributions of the thesis. A key task to resolve is selecting the appropriate model specifications and estimation techniques to use from the vast number of models that the empirical literature has proposed. Chapter 8 investigates empirical regularities of sovereign credit ratings and sovereign credit spreads. The analysis shows how both of these

measures relate to the probability of default itself and link the two measures based on these results.

Chapter 9 presents methodological tools used in the literature and carries out an extensive Monte Carlo exercise that studies how various tests of parameter stability perform in the context of variables characterized by the empirical regularities uncovered in Chapter 8 and using various empirical model specifications of the existing empirical literature. Chapter 8 and 9 thus reduces the set of specifications to a few that are expected to provide a good fit to true coefficients and low (Type I and Type II) errors of coefficient stability tests. Chapter 10 uses these specifications and carries out hypotheses tests. A battery of specifications (out of the ones that were found to be appropriate earlier) are used to arrive to robust results. The chapter also investigates some possible reasons for the findings.

The current document also largely follows this structure.

2 Relevant literature – brief overview

2.1 Theoretical literature

There are two distinguishing features of sovereign credit risk that differentiates its analysis from credit risk analysis in general. First, the repayment of government debt cannot be enforced, but depends on the voluntary (sovereign) choice of the government. Second, the number of sovereigns (governments) and their credit events are small compared to what can be observed in case of corporate and household debt.

Eaton and Gersovitz (1981) provides the first formal model that takes the first feature, the *willingness to pay* aspect of sovereign credit risk, into account. In this paper and in the mainstream sovereign debt theory including the more recent quantitative literature (Aguiar and Gopinath, 2006; Arellano, 2008) that followed, governments are viewed as rational and benevolent actors that carry out a cost-benefit analysis that weighs whether repayment or default is optimal for society. Default occurs when the value of debt repudiation is higher than the value of repayment.

The benefit of defaulting is usually assumed to be the value of debt (or its fraction, the actual haircut). The assessment of costs, however, have been versatile and have covered various aspects of lost reputations, sanctions, economic and political costs (e.g. Panizza, Sturzenegger and Zettelmeyer, 2009, provides a review). The thesis relates to a strand that stresses domestic economic costs that increased credit risk or default may entail through the impact on the domestic financial sector. The general mechanism proposed by this strand is that increasing sovereign credit risk erodes financial intermediary balance sheets by destroying the collateral and liquidity value of government securities. This results in reduced bank lending to the private sector, which causes a drop in investment and economic activity (Brutti, 2011; Bolton and Jeanne, 2011; Gennaioli, Martin and Rossi, 2014; Bocola, 2016).

Other than the willingness to pay, the *ability to pay* aspect of defaulting could be relevant in sovereign risk. Debt sustainability (e.g Ghosh et al., 2013) and funding liquidity aspects (often coupled with self-fulfilling features) have been such analyzed features of sovereign credit risk (Sachs, Tornell and Velasco, 1996; Calvo and Mendoza, 2000; Cole and Kehoe, 2000). External shocks such as various forms of contagion and spillovers (Giordano, Pericoli and Tommasino, 2013) are also important in credit risk that relate to funding liquidity.

Based on the theoretical literature a host of macroeconomic, political and institutional factors could be relevant for sovereign credit risk. These include, among others, the debt ratio, real economic growth and its volatility, central bank reserves, external debt, foreign-currency debt, current account balance, fiscal balance, real interest rates, political uncertainty. Theory is useful to identify important channels and types of effects of fundamentals on sovereign credit risk. However, theory also points out the many ways fundamentals are interrelated with each other in complex, often non-linear relationships. Based on these interrelationships and non-linearities, partial effects of fundamentals estimated are expected to vary by the given context. This makes it probable that fundamental effects will also vary in time.

2.2 Key indicators of sovereign risk

The infrequency of observed credit events in the sovereign debt market (the second distinguishing feature of sovereign risk mentioned above), led much of the empirical literature to use proxies of sovereign credit risk rather than direct observations of defaults.[2] Edwards (1983) was a seminal paper that first used credit spreads of foreign currency obligations as the dependent variable. Eventually, the development of bond markets led to secondary market (hard currency) bond spreads becoming the standard left-hand side variable to use. These had the advantage of being continuous measures. Later, credit ratings and CDS spreads also became regularly used proxies.

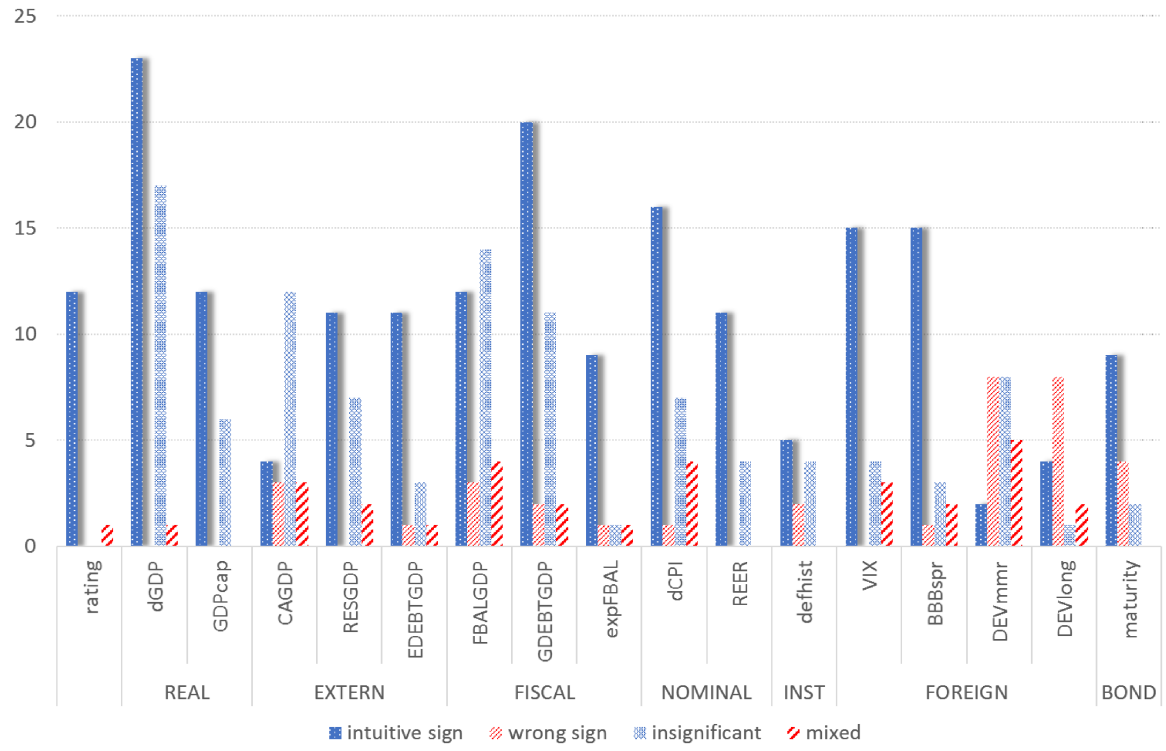
These proxies of credit risk each have their drawbacks. Ratings are lagged measures of credit risk with predictable persistence in their trends (Altman and Rijken, 2004; Al-Sakka and ap Gwilym, 2009) and mean reversion (Cruces, 2006) and ratings tend to focus on long-term credit trends leaving out business cycle related aspects. Sovereign bond and CDS spreads, by contrast, have a substantial risk premium component (Remolona, Scatigna and Wu, 2008; Longstaff et al., 2011) that is shown to be determined by global processes rather than domestic fundamentals.

[2]Credit events as binary dependent variables have been employed in the early literature (see McFadden et al., 1985, and its references) and have continued to be used by a minor strand. These papers are less interesting here, because the small number of observations does not permit studying structural changes in the model.

2.3 Empirical literature

The review of the empirical literature in Chapter 4, that relies on an assessment of more than 70 studies, has the main conclusion that empirical models relating credit risk (as proxied by ratings and spreads) to country fundamentals are not robust. Figure 1 shows that in case of many fundamentals, a considerable share of studies found the effect to be insignificant, or even to contrast the sign predicted by theory, or the sign was mixed among specifications estimated.

Figure 1: Signs and significance of key variables in the empirical literature



Sources: author's calculations based on studies reviewed in Chapter 4 of the thesis.
Notes: The figure shows the number of studies where each explanatory variable had the: a) correct sign and was significant (intuitive sign), b) was significant but had the opposite sign as expected from theory (wrong sign), c) was insignificant, d) had mixed signs and/or significance across models.
Explanatory variable abbreviations: dGDP: real GDP growth rate; GDPcap: GDP per capita; CAGDP: current account to GDP; RESGDP: foreign currency reserves to GDP; EDEBTGDP: external debt to GDP; FBALGDP: fiscal balance to GDP; GDEBTGDP: government debt ratio; expFBAL: expected fiscal balance to GDP; dCPI: consumer price growth; defhist: history of previous default; REER: real effective exchange rate; VIX: VIX index (S&P500 implied volatility); BBBspr: corporate credit spreads (US: BBB to Treasury, EU: KfW to Bund); DEVmmr: developed country short rate (US: Fed, EU: ECB rate); DEVlong: developed country long-maturity interest rate; maturity: time to maturity or duration of bond.

The reason for heterogeneity in findings is related to differences in estimation techniques, included regressors, functional form of the dependent and the data sample used. A meta-analysis of the literature results suggests that insignificant effects were more often found in models that had spreads specified in linear instead of log form, in (quasi-)differenced specification forms as opposed to levels specifications, as well as in models that included many explanatory variables.

For some variables the country sample (emerging or developed) appears to be important in the estimated effect.

2.4 Time-variance in fundamental effects

The segment of the empirical literature that directly discusses the subject matter of the thesis, whether effects of fundamentals have changed over time, has been active for approximately a decade.

This line of research documents that the sovereign risk – fundamentals relationship contains structural breaks on longer time samples that include the global financial and eurozone sovereign crisis. However, different authors found different variables to have had such changed effects depending on the sample, estimation technique and included regressors used.

There are a few consensus results that have emerged. The role of external factors and contagion are usually found to have increased in crisis. Also, an often found conclusion of studies evaluating eurozone crisis experiences is that government debt has become more important in pricing (e.g. Schuknecht, von Hagen and Wolswijk, 2009; Bernoth and Erdogan, 2012; Giordano, Pericoli and Tommasino, 2013).

Theoretical justification for findings relate to imperfect information, information costs and behavioral biases leading to a 'wake-up call' effect (Goldstein, 1998) or jumps between multiple equilibria due to various possible reasons (De Grauwe and Ji, 2013). An alternative, econometric, explanation for estimated time-variation in effects is that empirical models are misspecified (Dailami, Masson and Padou, 2008; Delatte, 2014).

2.5 My publications in the field

My first publication relating to this subject matter is Kocsis and Mosolygo (2006) that evaluates how the hard-currency bond spreads – ratings relationship changed between two cross-sections (January and December 2005). We document in this study that the sensitivity of spreads to ratings materially declined in this period. I studied the role of regionality and factors of CDS spread comovements in Kocsis and Nagy (2011) and extended this analysis to three other asset classes in Kocsis (2014). In the former study we also found that it was volatilities of spreads that have contributed more to increased covariances than changes in cross-correlations (the loadings on systemic factors changed less). In Kocsis and Monostori (2016) we studied time-variance of fundamental effects aggregating the information in fundamental proxies into forward-looking factors. This study confirmed an increased role of debt in the eurozone sovereign crisis and an increased role of political-institutional factors after 2012. In Fülöp and Kocsis (2018) we used information on fundamentals in Reuters news to study their effect on sovereign credit spreads. We found a limited role of domestic fundamentals on *changes* in spreads, however global fundamentals were significant also in the information content that the VIX index supplies about global comovements.

3 Hypotheses

The thesis investigates three hypotheses.

The first two hypotheses consider the general claim of the empirical literature that the role of country fundamentals is time-varying in sovereign credit risk pricing.

In the thesis I focus on the cross-sectional (pricing) effect of fundamentals on sovereign spreads. These cross-sectional effects show the spread increments that investors demand for holding sovereign bonds and long CDS positions of worse credit quality due to fundamentals. I assess time-variance in both the linear and the logarithmic sovereign credit spreads specifications, i.e time-variation in the basis point and percentage pricing effects of fundamentals on spreads.

The null hypotheses are stated in terms of time-homogeneity of pricing effects, because much of the traditional sovereign credit risk literature assumes this and statistical tests of structural breaks also set up the null in favor of stability.

Hypothesis 1a. *(Fundamental effects) The pricing effect of country fundamentals in sovereign credit spreads is stable in time.*

Hypothesis 1b. *(Fundamental effects (log spreads)) The pricing effect of country fundamentals in the logarithm of sovereign credit spreads is stable in time.*

The second hypothesis considers the time-homogeneity of the variance share attributed of fundamentals. Only the logarithmic specification is considered.

Hypothesis 2. *(Fundamental variance explained) The variance share attributable to country fundamentals in the cross-sectional variance of log sovereign credit spreads is stable in time.*

The third hypothesis is concerned with the claim in the empirical sovereign credit risk literature that the crisis in the eurozone periphery, and specifically Greece, has led investors to reprice the importance of the debt ratio in credit risk assessment. The explanation commonly provided is the so-called 'wake-up call hypothesis' attributed to Goldstein (1998), which claims that in crises investors reprice fundamentals more generally based on the observed relative weaknesses of the country at the epicenter of the crisis. I use the logarithmic functional form for the sovereign spread dependent variable.

Hypothesis 3. *(Debt ratio wake-up call) The pricing effect of the government debt-to-GDP ratio in the logarithm of sovereign credit spreads has increased in the sovereign crisis.*

4 Theoretical contributions

The theoretical model developed in Part II of the thesis is built on the classic endowment economy framework of Eaton and Gersovitz (1981) with the main focus on the cost-benefit analysis

of the rational government regarding the default policy decision.[3] The model aims to extend this framework in several directions to capture important missing aspects and determinants of credit risk. Most of these extensions entail features that have been shown to be important by empirical work or that have been rationalized by theorists as discussed in Chapter 2 in detail. The key objective here is to bring the most important aspects of sovereign risk under one umbrella.

A central assumption of the model is that declaring non-payment results in triggering a domestic economic crisis with some probability. The baseline values and ranges for the depth, duration and probability of such output losses are calibrated from the relevant literature and a large historical data set (125 countries 1960-2010) compiled for the purposes of the thesis.

Output loss effects of a default are in line with classic and the more recent, quantitative, sovereign debt models (e.g Aguiar and Gopinath, 2006; Arellano, 2008, and many others). An extension compared to this branch, however, which assumes external debt finance, is that I also incorporate domestic bondholdings directly into this framework.[4] The primary concern with omitting domestic debt from sovereign credit risk models is that domestic debt impacts sovereign credit risk in a substantially different way than does external debt. Notably, external-debt-only models disregard a crucial cost of default: haircuts on government securities adversely impact the balance sheet and liquidity of domestic bondholders. As domestic bondholders are often financial intermediaries, sovereign defaults risk a credit crunch with significant adverse repercussions on the macroeconomy.

If the government calculates with the possibility of a domestic crisis in case of a default, then larger indebtedness may act to deter strategic defaults and enforce the debt contract. This contradicts standard results of the mainstream sovereign debt literature that claims a positive relationship between indebtedness and credit risk. A corollary of a weaker or even negative relationship between debt and credit risk are high predicted public debt ratios, which is consistent with empirical experience and which is difficult to explain in mainstream sovereign debt models. There is now a considerable body of literature that theoretically explains and empirically supports the direct effects of sovereign credit risk on growth through impairment of domestically held bond values. The model presented in Chapter 5 uses the basic insights of this line

[3] The model is a stylized, mostly static, deterministic model that serves an illustrative purpose through allowing comparative static analysis. It does not consider the endogenous investor decision about interest rates and government choices other than the default decision are also limited. The model also keeps most of the simplifications in the Eaton and Gersovitz (1981) framework: an endowment real economy model that abstracts from prices and monetary phenomena; there is no production function, goods or labor market; private savings are restricted to government bonds. There have been several papers that discussed sovereign risk in more general frameworks (e.g. Mendoza and Yue, 2012; Corsetti et al., 2013) and others that discussed relevance of monetary aspects, but the majority of the sovereign risk literature abstracts from these perspectives.

[4] Standard models built on the Eaton and Gersovitz (1981) framework have external creditors supplying funds for government deficit spending, which directly enters current household consumption utility (all endowments are consumed without saving). Although this parsimonious external-debt-only framework was well-suited to study developing country debt finance, domestic public debt was important in both developed and emerging markets in many other periods (Reinhart and Rogoff, 2011, provides ample historical evidence) and it has played a pivotal role in sovereign credit market stress recently in the financial crisis of 2008-2009 and in the eurozone debt crisis of 2010-2012.

of research by adding the possibility of a default-triggered domestic crisis. The intensity of the crisis is assumed to partly depend on the stock of public debt held domestically, the haircut on bonds and a model parameter that is related to both the vulnerability of the banking sector to losses and the importance of the banking sector in the economy.

The second direction in which the classic framework is extended relates to political economy aspects of default. In standard models, a benevolent government is assumed, which decides on default and borrowing with the objective of maximizing domestic consumption utility. The current model allows political preferences to also play a role regarding these decisions.[5]

The political economy extension has two elements in the current model. The first relates to how debt issuance and debt servicing enter the utility function. Whereas external debt trivially affects consumption utility through capital flows (in an endowment economy without savings bond issuance increases current consumption and subsequent debt repayments reduces it), the effect of domestic debt on consumption utility is not straightforward, because domestic bondholders consume less when the debt is issued.[6] Therefore domestic debt could be viewed as a policy tool for redistribution between investors and taxpayers. In Appendix C.1 I put forward a simple endogenous fiscal policy model along these lines, which relies on a distinction between patient (domestic) investors and impatient voters. Based on this narrative net borrowing even in case of domestic issuances is utility-enhancing. Other papers (Song, Storesletten and Zilibotti, 2012; Müller, Storesletten and Zilibotti, 2016; D'Erasmo and Mendoza, 2016) also consider distributional effects of domestic debt finance, but from other perspectives.

Another political economy parameter represents voter preferences about a repayment/default decision and adds an immediate (positive or negative) value to current utility once default is declared. Repaying debt obligations represents a stance on basic market institutions such as private property rights and are highly valued in advanced economies even without recourse to possible crisis effects of default or redistribution effects between bondholders and taxpayers. At the other extreme, public opinion in countries experiencing default are often hostile toward the market mechanism, international and domestic bond investors, and so: repayment. Obviously, a government interested in enhancing the more general utility of the people that it represents has to consider these preferences in its decision-making.

The third direction that the classic Eaton and Gersovitz (1981) model is extended is including the possibility of a government funding liquidity crisis. This is carried out in Chapter 6. In contrast to the standard line of thinking that default leads to market exclusion, here the sequence

[5] Again, this idea is not new, the sovereign debt literature has studied political aspects from its early stages. An important benchmark paper that includes political partisanship into the quantitative sovereign framework is Cuadra and Sapriza (2008).

[6] This dilemma links to a vast literature that ponders the general value of domestic government debt finance in a closed economy and what explains its existence. Barro (1974) famously argued that debt finance does not alter overall utility, while Barro (1979) highlighted the role of debt finance in tax smoothing. Most models with government bonds held by domestic banks refer to Holmström and Tirole (1998), which rationalizes holding bonds as a store of liquidity. Grobéty (2018) shows that this functionality of government bonds promotes economic growth. This issue is also related to a vast literature on fiscal multipliers, consumer myopia and credit constraints, since these can also rationalize domestic debt issuance.

is reversed: there may be a stop of market funding, which may or may not lead to an eventual default and debt restructuring. The recent crisis in Europe provides ample cases in which governments lost access to private funding markets, but a default was avoided. In the model, if such a funding liquidity crisis is realized, the government has to resort to alternative funding sources (international bailouts and central bank lending of last resort), which is subject to international relations and domestic fundamentals (e.g. central bank reserves and short term funding needs).[7]

The model is investigated within the parameter space that aims to characterize a large sample of emerging and developed economies. This is more general compared to the extant quantitative literature, which mainly calibrates its parameters to the experience of Argentina. Argentine data may successfully represent several Latin American experiences, but it is significantly different from many other countries, especially middle-income emerging markets and developed countries where defaults are rare. Identifying plausible parameter bounds and baseline values is a central part of these chapters, because this provides a means to discern which channels of fundamental effects already assumed by the model setup may be more or less relevant in reality. Most importantly, these parameter bounds and baseline values provide a tool to evaluate how fundamental interactions influence sovereign risk and whether these effects are different in normal and crisis times. These are important for the general objective of the thesis, because reduced-form empirical models usually do not take interactions into account,[8] which could be a plausible reason for observed time-variation in estimated effects.

4.1 Model implications

Chapter 5 defines SDV, the strategic default value: the relative value of default over repayment[9] and much of the discussion in Chapter 5 and 6 relates to how SDV depends on various parameters of the model.

A comparative statics approach is used: the baseline value of SDV is evaluated for typical emerging market and developed countries and then, parameter ranges observed in the historical

[7] This extension relates to a large strand of papers that consider exogenous sources of liquidity shocks and self-fulfilling crises (e.g. Calvo, 1988; Cole and Kehoe, 2000, and others). More generally the issue is related to aspects of the ability of sovereigns to repay debt. The mainstream sovereign debt literature preferred the willingness to pay aspect of defaults over the ability to repay due to the (valid) argument that governments usually have larger resources at their disposal to adjust to servicing debt, even though this could be politically unfeasible. Defaults are then a willingness to pay problem except if we consider political limits to fiscal adjustments as exogenously given, in which case the ability to repay aspect becomes relevant. A related idea is fiscal space (Ghosh et al., 2013; Ghosh, Ostry and Qureshi, 2013). A separate strand on debt renegotiations, market exclusion (Luo and Wang, 2018) and in particular negotiations of bailouts (Fink and Scholl, 2016; Roch and Uhlig, 2018) is closely related, since in case of lost market access default usually hinges on the possibility of external assistance. Closest to the line of thought in my model is a recent paper by Bølstad and Elhardt (2017).

[8] Given the large number of potential fundamentals, there would be an infeasible number of factor combinations, so a theoretical model is needed for guidance in selecting relevant interactions.

[9] SDV is a shorthand for the value difference between default and repayment, which determines whether a strategic default occurs. Other papers do not use a separate name for the difference, but rather write out $V^B - V^G$ for bad and good credit standing values or $V^D - V^R$ for values of the default and repayment policy explicitly. Introducing SDV is for notational ease, since the difference is used more often than its constituents. SDV can be interpreted as the inverse of the willingness to repay.

data set are used to assess how variation of fundamental parameters between the observed ranges would change SDV. Such an exercise is used to see which fundamentals are more/less important in changing SDV (i.e. sovereign credit risk), whether the effect is non-linear and whether it is related to the value of other fundamental parameters.

A conclusion of the analysis is that in case of most fundamental parameters, the effect on SDV depends on the level of other fundamentals. Analytical derivations show that even the sign of the effect is ambiguous in this regard. Another result is that within the model framework and under the historical (plausible) parametrization most fundamental effects on SDV are largely linear.

More generally, the theoretical chapters of the thesis show that the included aspects are quantitatively important determinants of sovereign credit risk under plausible parametrization of the model and their omission may hinder a proper analysis. Related to the subject matter of the thesis, these characteristics of sovereign issuance could also be important in explaining why the sensitivity of sovereign debt prices to fundamentals changes over time and within crises, in particular.

- In contrast to an uncontested result in the theoretical literature since Eaton and Gersovitz (1981) that the motivation to default increases with the debt-to-output level, I showed both analytically and numerically (calibrating parameters to emerging market and developed country data) that the sign of the debt ratio effect is ambiguous and depends on several other factors. Higher debt decreases spreads when trend growth is high compared to real interest rates, but increases it when trend growth is lower. Higher debt decreases spreads when debt is domestic and the probability and depth of a default-triggered crisis is large. Higher debt increases spreads when debt is external or when it is foreign-currency denominated and there is a large probability of a funding liquidity crisis.

- In this framework output fluctuations (even of crisis proportions) play a small role in the default decision. However, if output fluctuations have a bearing on trend growth expectations, which is a significant factor of the default decision, they could be highly important drivers of sovereign spreads. These results are in line with results of popular quantitative sovereign debt models (e.g. Aguiar and Gopinath, 2006, and a line of research since).

- Current account and fiscal balances in these models were restricted to be consistent with a stable structural debt ratio. These balances tend to be countercyclical due to this restriction, worsening when trend growth improves and improving when trend growth declines. This is in line with emerging market experiences. Because trend growth improvements lower the motivation to default, the model predicts that sovereign spreads decline when current account and fiscal balance deficits deteriorate. This contradicts what one would expect based on an ability to pay perspective of defaults, i.e that spreads would decline when balances improve. Empirical literature results concerning the effect of the current

account on spreads have been particularly ambiguous as shown in Chapter 4 (see Figure 1) and the mixing of these two underlying effects may be a reason.

- Official reserves are predicted to play a limited role in sovereign debt pricing, but could significantly reduce the chance of a funding crisis in times when external liquidity conditions worsen.

- The vulnerability of the banking system could play an important role. The model predicts that larger financial deepening decreases the willingness to default. This is consistent with the observation of low spreads in developed markets that have large financial sectors and domestic government securities markets. However the models also predict, contrasting empirical literature evidence and ability to pay arguments, that more vulnerable banking sectors increase the motivation to repay, because transmission of default-induced losses to the economy would be larger.

- The political economy variable that represents a preference for debt repayment vs default, which is likely to be highly correlated with strength of market institutions, may often have a decisive impact on spreads. This factor becomes especially relevant when there is a low perceived output cost of a crisis (debt is low, foreign-held, is not perceived to affect the financial sector or the financial sector is less important) and it is also predicted to have larger relative impact in funding liquidity crises. In contrast, a significant chance of a default-triggered crisis deters politically-motivated sovereign defaults.

The model proposed in Part II of the thesis also supports a simple explanation for observed changes in fundamental effects on spreads. Within the model framework fundamental effects on SDV are approximately linear. However, linear fundamental effects on SDV translate into non-linear effects on spreads when SDV is stochastic and is distributed normally about its mean. (Although this is outside the model, investors pricing credit risk need to forecast values of fundamentals determining SDV, which leads to uncertainty about how SDV changes compared to the present.) As the expected value of SDV nears zero from below, marginal increases in SDV causes the probability of default to climb at a faster pace, because the probability density function is increasing in this region. This implies that all fundamental effects on spreads become larger in countries and time periods, in which the probability of default is higher.

As mentioned, there are important limitations of the model considered in Chapter 5 and 6. First, interest rates (though regime-dependent and calibrated to data) are set exogenously, whereas investors are likely to react to changes in the willingness to repay and the probability of funding liquidity induced defaults. Second, a fixed (structural) debt ratio is assumed in contrast to other studies where issuance is endogenous. Third, dynamics are much simplified as basically a two-period model is considered (a short-term and a long-term). Fourth, stochastics are limited to realization of only four states of nature. Other restrictions such as assuming an endowment

economy, abstracting from capital formation, monetary phenomena may also be important, but are shared with the bulk of the sovereign literature.

In Appendix C.2 I present a model that endogenizes interest rates, allows gradual changes in the debt ratio and adds a few more dynamic and stochastic elements to this model and still leads to very similar results.

5 Empirical contributions

Empirical sections rely on a data set assembled of CDS, bond spreads (EMBI Global or yield spreads to German Bund), credit ratings – which are available at daily frequency – and macroeconomic variables – mostly quarterly frequency – on a sample of 60-countries in the 1999-2016 date range.

5.1 Preliminary empirical analysis

The empirical part of the thesis (Part III) begins with a chapter that assesses various empirical properties of ratings and sovereign credit spreads.

Rating persistence and predictability are confirmed. Both ratings and spreads have a larger fraction of total variation originating from the cross-section than the time series. Ratings seem to be robustly associated with credit spreads in the cross-section, but not in the time series. The lagged nature of ratings as well as external-shocks-related time series variation of credit spreads seem to confound the time series relationship of these measures. Overall it seems that the relationship between spreads and ratings is better grasped in the cross-section and through the levels of these indicators. Dynamic analysis would need two components: one of an error-correction of spreads toward the long-run relationship with ratings, and another short-term innovations component that is related to common factor shocks.

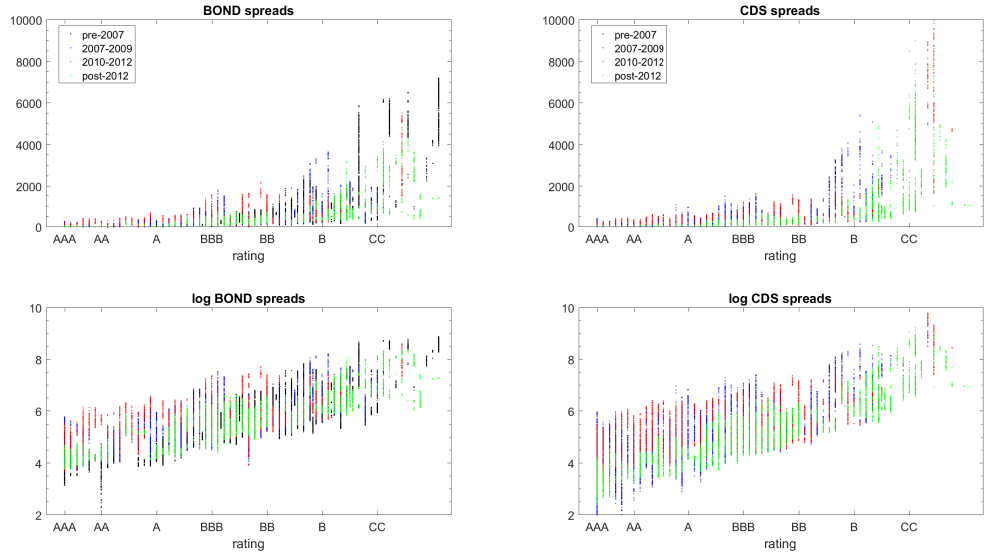
A key empirical result is the derivation that log spreads have a more robust functional link with ratings (and fundamentals affecting SDV linearly) than linear form of spreads do. The first step of this derivation is an empirical link of a logistic form between ratings and default probability (linearity with log-odds). Sovereign spreads are then linked to these measures with their theoretical link to default probability. With additional assumptions on the dynamics of SDV a linear relationship is recovered between SDV (its linear fundamental determinants) and log spreads.

Figure 2 largely corroborates this derivation as it suggests that the empirical link between spreads and ratings is approximately log-linear.

The chapter also discusses other reasons to choose a log specification for spreads. To sum up spreads are better modeled in a logarithmic functional form than in linear terms, because:

- spreads are exponentially related to (linearized) ratings and the log-odds of default;

Figure 2: Spreads versus ratings (pooled data)



Sources: Bloomberg, author's compilation.
Notes: Sovereign bond and CDS spreads in nominal and logarithmic terms vs sovereign credit ratings (agency averages).

- the volatility of nominal spreads is strongly linked to spread levels, whereas the volatility of log spreads is independent of spread levels, which implies that the most important drivers of spreads are related multiplicatively to spreads;
- linear spread models will have large heteroscedasticity and parameter estimates will be sensitive to the sample selection, whereas log spread models will be less affected;
- logarithmic spread changes at low frequencies are close to being normally distributed, whereas simple spread changes are not normal due to higher kurtosis.

5.2 Methodology

The methodological chapter reviews the standard statistical methods that are used for assessing structural breaks, i.e the changes of coefficients across time samples. The chapter also reviews the empirical methods in the sovereign credit risk literature that are concerned with estimating and testing time-variation in fundamental effects.

The main accomplishment of the chapter is a Monte Carlo exercise that (i) simulates dependent variables (i.e sovereign spreads), latent fundamentals and fundamental proxies (i.e ratings and other observed macroeconomic variables) taking into account the empirical regularities of these variables in the preliminary empirical analysis of Chapter 8, (ii) evaluates how various model specifications and testing procedures perform in terms of discriminating time-variance and time stability in effects and (iii) assesses how various model specifications perform in terms of estimating the fundamental effects on spreads in terms of RMSE.

The Monte Carlo results show that, given the data generating process and data availability similar to the context of the empirical application of the thesis, the best model specifications to use are the levels specifications that allow period-specific coefficients of fundamentals with controls of the common global component either via time fixed effects ('Levels 5') or a risk premium proxy such as the VIX index ('Levels 4'). These specifications are formally:

$$\begin{aligned} \log S_{i,t,s} &= \beta_t' Z_{i,t} + \gamma_t + \zeta 1_{s=CDS} + u_{i,t,s}, \\ \log S_{i,t,s} &= \beta_t' Z_{i,t} + \gamma VIX_t + \zeta 1_{s=CDS} + u_{i,t,s}, \end{aligned} \tag{1}$$

where log spreads are determined by a vector of fundamental proxies Z with period-specific coefficients β_t (both size $Kx1$); the mentioned controls of global time-series variation within spreads (the second terms on the right-hand side); a fixed effect, ζ, that allows a constant difference between CDS and bond spreads (CDS spreads and bond spreads are stacked in the panel). The disturbance terms are assumed to be mean zero, iid random variates with correlations allowed across cross-section units and in time. Model parameters are estimated by panel least squares dummy variable method and double clustered standard errors (Thompson, 2011) are used.

I also estimate a state space version of this model ('EMalgo 19'), which restricts the β_t process to be a random walk. In this model the measurement equation is (1) and the state dynamics are given by:

$$\beta_t = \beta_{t-1} + \nu_t, \qquad \nu_t \sim N(0, Q), \tag{2}$$

with Q the covariance of innovations. The state innovations, ν_t are normally distributed, but correlations are allowed. In this setup, the measurement equation disturbance, u_{its} are assumed to be independent and also normally distributed, though heteroskedasticity is allowed. Under this setting a Kalman-filter can be used to estimate the expectation and variance of β_t and the EM algorithm (Dempster, Laird and Rubin, 1977) is used to estimate parameters of the model iteratively.

Note that none of these specifications include cross-section fixed effects. Specifications with fixed effects (Levels 2, 3 analogous to 4 and 5) are still used in the thesis for robustness checks, but are not preferred, because in a setting where proxies are lagged and noisy observations of persistent fundamentals (which is arguably the current case) these specifications tend to both imprecisely estimate fundamental effects and overreject time-invariance as shown in the Monte Carlo exercise.

5.3 Results on time-variation

5.3.1 Time-variance in fundamental pricing

F-tests are used to assess time-variation of fundamental effects on sovereign spreads. A battery of specifications are considered, both where ratings are the key proxy and where several other fundamental variables jointly proxy fundamental effects (Table 1). In all cases, the tests strongly reject time-invariance and favor the alternative hypotheses of Hypothesis 1a and 1b.

Table 1: F-tests of fundamental effect time-variance

	F-test for Spreads				F-test for Log Spreads			
Model specification	F-stat	ν_1	ν_2	p-value	F-stat	ν_1	ν_2	p-value
PANEL A: Fundamentals measured by ratings								
Levels 5	6.639	60	3938	0.000	7.284	60	3938	0.000
Levels 5a	10.058	180	3938	0.000	4.783	180	3938	0.000
Levels 5b	8.073	240	3595	0.000	3.514	240	3595	0.000
Levels 4	6.595	60	3938	0.000	7.960	60	3938	0.000
Levels 2	7.113	60	3938	0.000	11.786	60	3938	0.000
Levels 3	7.280	60	3938	0.000	9.280	60	3938	0.000
PANEL B: Fundamentals based on multiple proxies								
Emp Lit 1	4.696	329	2905	0.000	3.727	329	2905	0.000
Emp Lit 2	3.865	423	2913	0.000	3.222	423	2913	0.000
RAT + Emp Lit 2	4.447	470	2913	0.000	3.646	470	2913	0.000
Theory 1	6.725	376	2743	0.000	3.486	376	2743	0.000
Theory 2	6.912	282	2743	0.000	3.731	282	2743	0.000

Sources: author calculations.
Notes: The table reports F-tests for parameter restrictions regarding time-variation of fundamental coefficients within regressions of sovereign spreads (left panel) and the logarithm of sovereign spreads (right panel). The F-tests estimate unrestricted models with period-specific coefficients and restricted models with fixed coefficients and assess whether the data support the case for the restriction (time-invariance). Panel A estimates restrictions for only the credit rating level variable (Levels 2,3,4,5) which differ in including period effects/VIX index and cross-section effects. Levels 5a also includes the rating changes in the past two quarters and its lag and (5b) includes also real GDP growth rate in the potentially time-varying set. Panel B turns to 'Levels 5'-type model setup with inclusion of the following variables: Emp Lit 1: debt ratio, real GDP growth, reserves to GDP, current account to GDP, fiscal balance to GDP, GDP per capita in all 'Emp Lit' specifications and additionally: CPI yoy (Emp Lit1); WGI indices of political stability, corruption, rule of law (Emp Lit 2 and RAT + Emp Lit) and ratings (RAT + Emp Lit). The Theory 1 specification includes the debt ratio interacted with credit to gdp, external government debt to GDP, reserves to GDP, current account to GDP, WGI rule of law and political stability, corruption and the debt ratio interacted with the latter two indices. Theory 2 is more parsimonious in that it adds up and includes as single variables: reserves and current account; political stability and government effectiveness; corruption and rule of law; and only includes debt ratio interaction with corruption. Theory 2 also includes the domestic debt and external debt variables.

These results lead to the following statements:

Thesis 1a. *(Fundamental effects) The hypothesis that the pricing effect of country fundamentals in sovereign credit spreads is stable in time is rejected.*

Thesis 1b. *(Fundamental effects (log spread)) The hypothesis that the pricing effect of country fundamentals in the logarithm of sovereign credit spreads is stable in time is rejected.*

Kruskal-Wallis tests compare the variance share attributed to fundamentals across four periods (pre-crisis, financial crisis, sovereign crisis, post-crisis) and confirm that variance share estimates have changed over time in all model specifications considered. All models seem to agree that fundamentals had high explanatory power in the cross-section of spreads before the financial crisis. The log spreads specifications show a decline in the fundamental variance share in the financial crisis and even more in the sovereign crisis, before a gradual ascent in the explained share of the variation at the end of the sample. Therefore:

Thesis 2. *(Fundamental variance explained) The hypothesis that the variance share of fundamentals in the cross-sectional variance of log sovereign credit spreads is time-invariant is rejected.*

The chapter investigates several possible reasons for these findings.

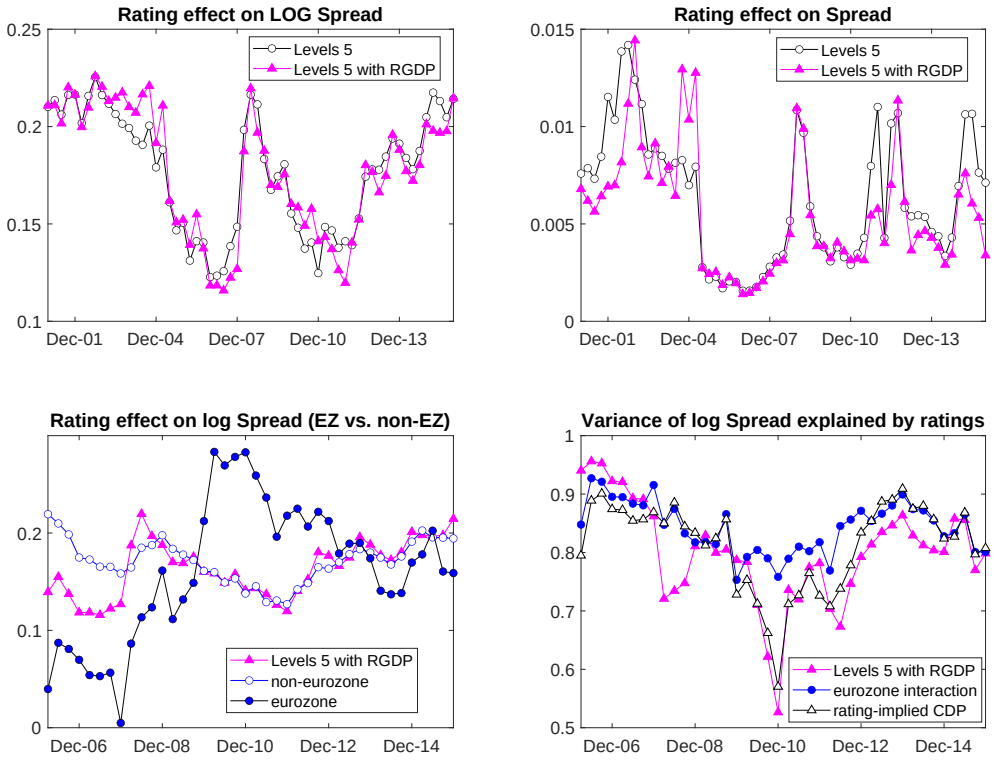
In the case of linear spreads (top right plot in Figure 3) the approximately log-linear relationship between spreads and its determinants has the consequence that global shocks automatically change estimated fundamental sensitivities, because a deterioration in global conditions increases spreads of higher risk issuers more than those of low risk issuers. Spread sensitivities to ratings therefore co-move positively with the mean level (or global factor) of spreads. A plausible reason is that spread volatilities (standard deviation of daily changes) increase with the spread level and due to that bonds/CDS positions with higher spreads are affected more by systemic risk. Finance theory then suggests that investors would command larger risk premia for holding these positions.

The logarithmic transformation of spreads (top left plot in Figure 3) successfully mitigates much of this heterogeneity, because in percentage terms, spreads react much more similarly to global risk shocks. Log spread sensitivity to ratings therefore changes to a lesser extent (i.e not orders of magnitude) and global risk aversion leads to close to uniform shifts in the full cross-section of log spreads.

The log specification is also not perfect in eliminating risk shocks. Low-risk issuers tended to experience a somewhat larger effect on their spreads in percentage terms. Though this was not always the case. In the market pricing of credit risk before the financial crisis, the market has discounted the sovereign risk in credit ratings increasingly more even in log spreads. Also in the financial crisis there was a substantially repricing of credit risk raising the slope even in log spreads at the height of the crisis. Search for yield in the former period and funding liquidity shocks in the latter period were widely cited developments in these times, which could have had an impact on log spread rating sensitivity.

Another factor, especially evident in the sovereign crisis, seems to have come from rating agency lagged reactions compared to the market in marking down the credit quality of risky developed country issuers. The financial crisis triggered a large fiscal reaction in developed countries due to which the market has increased spreads (and differentiation, Figure 3 bottom left plot) in this segment, which has led to a drop of the sensitivity of log spreads to ratings in general. Until the second part of the sovereign crisis period, such deviation between market and rating agency perceptions of credit risk also substantially lowered the variance share of the cross-section of log spreads that ratings could explain (Figure 3 bottom right plot). As rating agencies eventually caught up with the market, the sensitivity of log spreads to ratings (and the variance share explained by ratings) has increased back.

Figure 3: Rating effects and rating variance share



Sources: Bloomberg, author's compilation.
Notes: The figure shows estimated rating coefficient time series on log spreads (top left), linear spreads (top right), log spreads with the sample segmented by eurozone membership (bottom left) and time series of the variance share attributed to fundamentals (bottom right). The baseline Levels 5 specification is used with and without real GDP growth (RGDP) to control for business cycle effects (where included real GDP growth also has time-varying coefficients). In the bottom right plot all specifications are 'Levels 5' with real GDP growth included. Specification 'eurozone interaction' adds rating interaction with a eurozone dummy variable (with time-varying coefficients) and 'rating-implied CDP' refers to a specification where – instead of ratings – the cumulative default probabilities calculated from rating transition matrices and observed default frequencies are used. Note that plots in the top and bottom panel have different date axes.

5.3.2 Time-variance in public debt pricing

Studies in the empirical sovereign risk literature that have considered time-variation of debt pricing identified the increased role of this fundamental in sovereign spreads during the sovereign crisis. The main explanation offered was the wake-up call hypothesis (e.g. Beirne and Fratzscher, 2013; Giordano, Pericoli and Tommasino, 2013) a theory attributed to Goldstein (1998) that investors, when experiencing a crisis, reprice assets based on the characteristics of the crisis country. This may have its roots in imperfect information (Ahnert and Bertsch, 2015) or behavioral biases as investors overreact to crisis shocks.

Table 2 reports regression results with subperiod dummy variables to estimate time-variation in debt ratio pricing. The baseline subperiod is chosen to be the financial crisis (period 2) since the focus of interest is whether debt ratio pricing increased subsequently in the sovereign crisis

Table 2: Debt ratio effects on EM/DEV credit risk (Regression results)

Regr. spec	(A) debt only		(B) w/ratings		(C) w/macro		(D) RAT depend		(E) w/CXeff	
Dependent	Log SPR		Log SPR		Log SPR		RATING		Log SPR	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Regressors (debt)										
debt	0.862***	(0.110)	-0.619***	(0.094)	0.116	(0.125)	5.633***	(0.391)	1.530***	(0.103)
debt_DEV	-2.065***	(0.108)	0.082	(0.103)	-1.072***	(0.110)	-6.966***	(0.316)	0.042	(0.183)
debt*p1	0.479***	(0.139)	0.886***	(0.137)	1.270***	(0.178)	0.133	(0.492)	0.006	(0.082)
debt*p3	0.482***	(0.157)	0.465***	(0.128)	0.454***	(0.147)	-0.639	(0.563)	0.477***	(0.079)
debt*p4	1.143***	(0.157)	0.735***	(0.126)	0.966***	(0.140)	0.796	(0.577)	0.999***	(0.085)
debt_DEV*p1	-0.552***	(0.141)	-0.587***	(0.134)	-1.001***	(0.143)	-0.406	(0.364)	-0.499***	(0.114)
debt_DEV*p3	1.129***	(0.144)	0.499***	(0.131)	1.024***	(0.127)	3.142***	(0.422)	0.605***	(0.104)
debt_DEV*p4	0.308**	(0.139)	-0.310**	(0.126)	0.342***	(0.121)	3.233***	(0.403)	-0.438***	(0.110)
Regressors (other)										
constant	-447.290***	(2.993)	-535.674***	(3.069)	-394.505***	(2.901)	786.135***	(11.986)	-522.528***	(5.877)
rating			17.882***	(0.369)						
RGDP yoy			-4.539***	(0.309)	-6.104***	(0.447)	-9.352***	(2.022)		
CA/GDP					1.032***	(0.172)	0.957	(0.979)		
RES/GDP					-0.032	(0.095)	0.144	(0.369)		
CorruptLow					-62.160***	(1.727)	-307.592***	(4.073)		
Pol Stab					0.670	(1.686)	-2.937	(6.630)		
FBAL/GDP					-1.504***	(0.376)	3.007*	(1.765)		
Period effects	Yes		Yes		Yes		Yes		Yes	
Cross-section effects	No		No		No		No		Yes	
R-squared	0.497		0.865		0.724		0.771		0.861	
Adj R-squared	0.482		0.860		0.714		0.765		0.854	
No.of cross-sections	55		52		51		51		55	
No.of pool observ	3620		3238		3094		2902		3693	

Sources: as described in Appendix A.

Notes: The table reports regression results with the log spread as the dependent variable except in specification (D) where credit ratings are the dependent. (For convenience log spreads are divided by 100 so that all coeff's are 100 times larger in the output. Otherwise several coeff's of interest would be of magnitude 0.01 and differences across specifications would be more difficult to see.) Explanatory variables include: the government debt ratio (debt) in percentage points (its coeff. means log spreads change by 0.01 for each percentage point increment in the debt ratio); the debt ratio interacted with developed country dummy variable; (p1,p3,p4) period-dummy interactions of the latter two variables; and other macroeconomic variables (RGDP yoy: year-on-year real GDP growth; CA/GDP: current account balance; RES/GDP: reserves/GDP; WGI Control of Corruption; WGI Political Stability; FBAL/GDP: fiscal balance) or ratings (three agency rating averages, linear scale) as controls. See Appendix Table A for further information. Period dummies used relate to the 2000-2006 (p1), the 2010-2012 (p3) and the 2013-2016 (p4) time periods. Clustered standard errors are reported in parentheses. Asterisks denote usual significance levels at 1, 5 and 10 percent.

period. I also look at a split of the sample along the developed/emerging country categories by including interactions with a developed country dummy variable (debt_DEV).[10] With this regression setup the coefficient of interest is that of debt*p3, which assesses how much the effect of the debt ratio changed from the financial crisis to the sovereign crisis (period 3) within the emerging market group of countries. (The sum of coefficients of debt*p3 and debt_DEV*p3 shows how much the effect changed in developed countries.)

The results confirm the wake-up call hypothesis relating to the pricing of debt within sovereign credit spreads in both emerging markets and developed countries. Debt ratio coefficient estimates have significantly increased in the sovereign debt crisis compared to the baseline financial crisis period according to all specifications. However, ratings did not seem to be recalibrated in the sovereign crisis period according to specification (D), where credit ratings are the regression dependent variables. Developed countries also experienced an additional repricing of debt in

[10]To assess the validity of the wake-up call effect, I would argue that it is important to base the analysis on a sample that is related less directly to the epicenter of the crisis. When one estimates split sample regressions with crisis countries (i.e ones that experienced large spread increases) constituting a significant share of the cross-section sample, then by the design of least squares fitting the relatively bad fundamentals of the crisis countries will tend to be found significant in influencing spreads. This, however, may only tell us which fundamentals differentiate crisis countries from non-crisis countries rather than telling us whether investors had really repriced these fundamentals. A better test of wake-up calls is to look at a different (non-crisis) country segment altogether. If the bad fundamentals of crisis countries receive higher spreads also in this sample, then the wake-up call argument is better supported.

the sovereign crisis. Moreover, rating agencies also appear to have reacted by increasing the sensitivity of ratings to the debt ratio in this group of countries.

Thesis 3. *(Debt ratio wake-up call) The hypothesis that the pricing effect of the debt ratio on logarithmic sovereign credit spreads increased in the sovereign crisis is accepted.*

The regression also provides suggestions on whether or not such effects lasted. Interestingly, in period 4 log spreads appear to have become even more sensitive to the debt ratio (the coefficient of debt*p4 is larger than the one on debt*p3). This contradicts other studies, which instead found such rising sensitivity of spreads to debt to have been temporary (Kocsis and Monostori, 2016; Audzeyeva and Fuertes, 2018). Compared with these studies, the sample difference could perhaps explain the result – the finding here of longer-term increase pertains to emerging markets in general.

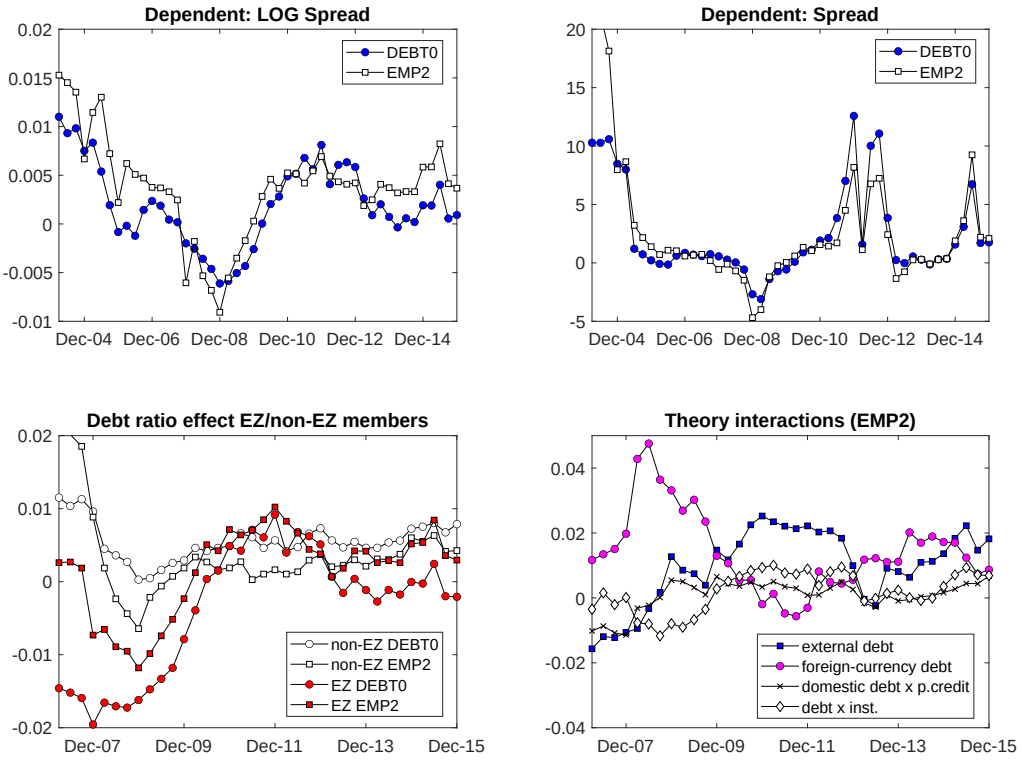
To check robustness of results, period-specific coefficient models are also estimated for the debt ratio. These are displayed in Figure 4. The top left plot that uses log spreads supports Thesis 3. However the higher sensitivity to debt before the financial crisis also suggests that it may be that the debt ratio effect was underpriced in the global financial crisis rather than being overpriced afterwards. The pricing effect on linear spreads (top right plot) is more erratic, but also largely supports the tendencies seen in log spread pricing.

Splitting the sample and possible effects by EZ/non-EZ countries (bottom left plot) corroborates regression results above. It was eurozone (log) spreads that became significantly more sensitive to debt pricing in the sovereign crisis compared to the global crisis, in fact reversing a previous negative effect of debt on spreads. However, non-eurozone country (log) spreads also experienced a repricing of the debt ratio, albeit to a smaller extent.

Finally, the bottom right plot of Figure 4 turns to debt ratio interactions proposed by the theoretical models to provide some background for these findings. I include four debt-related factors that the theoretical chapters propose. The first two relate to (government) external and foreign-currency debt to GDP. The theoretical models propose that the effect of external debt depends on real interest rates vs trend growth (a willingness to pay aspect), whereas foreign currency debt relate to sovereign risk via funding liquidity conditions (an ability to pay aspect). When market funding deteriorates, there is an increased chance that a sovereign with high foreign-currency debt might be caught up in a funding crisis especially if there is a weak backstop from central bank last-resort-lending and relations with international official creditors are problematic (as was the perceived case in the eurozone). This perception could already lead to a self-fulfilling panic and increasing spreads as argued by De Grauwe and Ji (2013). In case of the eurozone the foreign currency debt in not a good proxy of this effect (most debt is denominated in euros), so external debt could step in to pick up the funding liquidity risk.

The third variable is domestic debt/GDP interaction with a financial development variable. This is to capture the commitment device of domestic debt in countries with a large financial sector. Based on the theoretical model, a large domestic financial sector holding public debt

Figure 4: Debt ratio pricing in sovereign credit spreads



Sources: author's compilation.
Notes: The figure shows the estimated time-varying coefficients of the debt ratio in 'Levels 5' panel regression with log spreads (top left, bottom plots) or spreads as dependent (top right). Regarding regressors included 'DEBT0' only has the debt ratio included and a constant. 'EMP 2' include macroeconomic and political-institutional variables that have been commonly used in the empirical literature. The bottom left plot models also have the debt ratio interacted with EZ dummies to trace separate effects inside and outside this block. Bottom right plot models have interactions of the debt ratio with external share of debt, foreign-currency debt, domestic share and private credit to GDP interacted, and the negative of WGI control of corruption (INST).

would supply additional motivation for the government to repay as a default could have adverse economic implications (as in Acharya, Drechsler and Schnabl, 2014; Gennaioli, Martin and Rossi, 2014). While the former, willingness to pay, effect acts to reduce spreads, the latter, aspect acts to increase them via augmenting concerns about the ability to pay.

Finally, the debt ratio interaction with an institutional background proxy (WGI control of corruption) is also included in the model. When the debt ratio is high and market-friendly institutions are lacking, there is a greater chance of opportunistic behavior on the part of government and conflicts with official lenders regarding conditionality terms, which increases the chances of a default.

The bottom right plot of Figure 4 suggests that the debt ratio increase seen in both developed and emerging markets was mostly related to a repricing of the risk that external government indebtedness means for investors. Because this increase simultaneously occurs with the elevated pricing of eurozone sovereign debt, the coefficient of external debt may pick up the increased

funding liquidity risk as much as the change in real interest rate vs trend growth perceptions. The changes in effects are less pronounced in case of the last two factors.

5.3.3 Implications

Both investors and policymakers need to be aware of the uncertainty that fundamental repricing means within the pricing of sovereign debt instruments. The empirical models in the thesis call attention to a quantitatively significant effect in this regard. For example, a country with a 60 percent debt ratio experienced a 30-80 percent increase in its credit spreads between 2008 and 2012 according to baseline models due to debt repricing alone. The increase within the group of advanced countries and the increase of external (public) debt effects were even larger. These magnitudes are large enough to potentially cause significant losses for investor that are unprepared for model uncertainty and it is a factor that government policymakers need to consider when issuing debt.

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