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The re-pricing of sovereign risks following the Global Financial Crisis

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THE RE-PRICING OF SOVEREIGN RISKS FOLLOWING THE GLOBAL FINANCIAL CRISIS

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Abstract

How strong has been the effect of the Global Financial Crisis (GFC) on systemic risk in sovereign bond markets? Was the increase in credit spreads relative to triple-A benchmarks which followed the GFC the result of higher sovereign credit risk or the result of a re-pricing that reflected changes in broader market conditions and risk aversion? In this paper we examine these issues by specifying a sovereign credit yield curve which relates sovereign yield spreads to credit ratings and global variables. The model allows for time-variation in both the price of credit risk and the average spread across all rating categories, which proxies the effect of global risk factors on yield spreads. We use daily data of ten-year bond yields and ratings from a large database of 64 countries, covering both emerging markets and developed economies, for the period from 1/1/2000 to 1/1/2015. Our estimates suggest that sovereign risk premia increased significantly after the GFC with most of the increase due to a re-pricing of broader market risks rather than an increase in the quantity or price of sovereign risk per se. This increase in global risk could be the result of a flight-to-quality from lower-rated sovereign bonds to AAA benchmark bonds. Interestingly, we find that global risk in the sovereign bond market is driven by global variables that relate to investor confidence, volatility risk, central bank liquidity and the slope of the yield curve in the US.

Keywords: sovereign risk; credit yield curve; Global Financial Crisis; credit ratings.

JEL classification: C58; G12; G17; G24

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1. Introduction

With the Global Financial Crisis (GFC) turning into a sovereign debt crisis for Greece in particular but also for other vulnerable countries of the euro area, bond yields of several sovereigns across the globe increased significantly relative to high-quality benchmark bonds. The re-emergence of sovereign risk during the GFC boosted the volume of the empirical literature on the driving forces of the observed re-pricing of risks ever since.

The observed re-pricing of sovereign risks during the GFC was largely the result of deterioration in country-specific fundamentals, as reflected for example in the deterioration of sovereign ratings during the crisis. However, there is an increasing awareness in the recent literature on sovereign risk that a significant component of the sovereign credit spread is driven by global factors such as increased risk-aversion and market volatility.

For example, Arghyrou and Kontonikas (2012) acknowledge that, during the crisis, both macro fundamentals and international factors gained in importance in determining sovereign credit spreads. Aizenman et al. (2013) find that a structural break occurred during the crisis as the role of fiscal fundamentals increased and global market volatility (proxied by the TED spread) emerged as a key pricing factor. Beirne and Fratzscher (2013) find that both the deterioration of countries' fundamentals and a sharp rise in the sensitivity of markets to fundamentals during the crisis has led to the widening of sovereign credit spreads. Longstaff et al. (2011) argue that a global risk factor is driving most of the variation in sovereign bond yields, while Ang and Longstaff (2013) attribute the repricing of sovereign risk to system-wide factors, rather than macroeconomic fundamentals. Dahlquist and Haseltoft (2012) find evidence for time-varying risk premia in sovereign bond markets with both local and global factors jointly predicting bond returns. Interestingly, the global factor predicts bond returns with a similar or higher explanatory power compared with the local factors and it is closely linked to US bond risk premia and the global business cycle.

Several recent papers have focused on the role of global factors in determining sovereign risk premia in the euro area. Georgoutsos and Migiakis (2013) and Heinz and Sun (2014) relate euro-area sovereign credit spreads to global investor confidence and market volatility. De Grauwe and Ji (2013) find that the sovereign debt crisis in the euro area was to a large extent the result of system-wide factors related to the non-existence of a lender of last resort for sovereigns rather than country-specific fundamentals. Evidence reported in Saka, Fuertes and Kalotychou (2015) provides support for this line of argument. Other works (e.g. Bernoth and Erdogan (2012), Beirne and Fratzcher (2013)) have shown that the significance of fiscal-fundamental variables for sovereign spreads has increased in the aftermath of the GFC. Also, the pricing of macroeconomic fundamentals in sovereign bonds is found to be related to shifts in market sentiment and a varying degree of risk aversion (see, for example, Bruneau et al. (2014), Delate et al. (2014) and Gomez-Puig et al. (2014)).

What remains unclear in the extant literature is whether global variables affect sovereign credit spreads *directly* in the form of a global risk premium or *indirectly* by affecting the price of risk of country-specific fundamentals. This is an important issue because, in the first case, higher global risk will lead to an upward shift of the entire sovereign yield curve across all sovereigns, whereas in the second case, the effect of an increase in global risk will differ across sovereigns, depending on the sensitivity of the market price of sovereign risk to global factors.

The present paper investigates whether the re-pricing of global risks in sovereign bond markets during the GFC was due to an increase in the price of sovereign risk or an increase in global risk, which led to a general increase in the yield spread of all sovereigns relative to high quality benchmark bonds such as US treasuries or German bunds which are regarded by investors as safe haven assets. For this purpose we illustrate a simple model of sovereign credit spreads which accounts for time variation of both the quantity and the price of sovereign risk but also for time variation of a common factor, reflecting global variables such as global monetary policy and risk aversion. In the empirical application, we use sovereign ratings to proxy for country-specific fundamentals and fit a ratings-based yield spread model of ten-year bonds of sixty four sovereigns over a time period spanning a period of fifteen years (2000-2015).

Our estimation strategy proceeds in three steps. We first estimate the model with constant parameters and find that ratings explain around 80% of the cross-sectional variation of sovereign spreads. The GFC seems to have induced a shift in the model parameters, particularly the constant term, which is related to the cross-sectional mean of the sovereign risk premium and global factors such as expectations about global risk-free rates and risk attitudes of investors.

In a second step, we allow for time-variation of the parameters in order to infer the degree to which spreads have varied due to changes in sovereign ratings (i.e. the quantity of credit risk), changes in the sensitivity of spreads to ratings (i.e. the price of credit risk) or changes in risks due to broader factors (global risk). Our results indicate that, while rating downgrades following the GFC explain part of the increase in sovereign yield spreads, most of the increase is due to a permanent increase in global risk. Furthermore, although the re-pricing of sovereign risk has led to a general widening of yield spreads relative to benchmark bonds such as US treasuries or German bunds, this effect was relatively stronger for AAA- and AA-rated sovereign bonds than for BB- and B-rated bonds. This observation suggests that there might be a flight-to-quality effect in place which exerted stronger upward pressure on yield spreads of sovereign bonds which are closer substitutes to safe haven assets such as US treasuries or German bunds.

In a final step, we estimate a Markov regime-switching model of global risk as a function of global variables such as investor confidence, volatility risk, global central bank liquidity and the US term spread. We find evidence that global risk plays an important role by affecting sovereign spreads directly. The driving forces of the global risk premium differ, depending on whether the market is in a high or in a low volatility regime. Investor confidence and volatility risk play a role in both regimes. This is not the case for global central bank liquidity and the US term spread. During the low-volatility regime before the GFC, the US term spread is found to be a significant driver of global risk. In contrast, during the high-volatility regime following the GFC, the changes of the US and the euro-area monetary base are found to exercise significant effects on the global risk premium. Hence, the ample provision of central bank liquidity following the GFC has helped reduce sovereign spreads. One possible interpretation of this finding is that, following the GFC, the information content of the term spread as a predictor of future risk-free interest rates has been distorted due to the quantitative easing of the Fed and other major central banks.

The rest of the paper is as follows: Section 2 outlines a simple model of the sovereign yield spread relative to a default-free benchmark bond and presents a tractable econometric specification of the model. Section 3 presents the data and section 4 reports the estimation results of three model specifications, i.e. a constant parameter, a time-varying parameter and a regime-switching model specification. Section 5 concludes.

2. The model and econometric specification

2.1 Theory

Following Duffie and Singleton (1999, 2012) and Lando (1998), we illustrate a simple reduced-form model for pricing a defaultable sovereign bond relative to a default-free benchmark bond. Assume that the sovereign issues at time t a zero-coupon bond with time to maturity n. If the issuer might default before the maturity of the bond, then, in addition to the risk of changes in the risk-free rate, both the magnitude and the timing of the payoff are subject to uncertainty. In this case, it is often convenient to view the bond as a portfolio of two securities: a security that pays $1 at date t+n if the sovereign survives and a security that pays a random recovery rate if the sovereign defaults before maturity (see Duffie and Singleton (2012)). If we make the simplifying assumption that the recovery rate is zero (see e.g. Lando (1998)), then the yield to maturity, R_t^n, of the bond is given as an exponential affine function of short-term interest rates and a credit risk premium over the life of the bond:

$$R_t^n = \left(P(t,n)\right)^{-\frac{1}{n}} = E_t^*\left(e^{\frac{1}{n}\cdot\int_t^{t+n}[r(u)+s(u)]du} \right) \tag{1}$$

where $P(t,n)$ is the price of the bond, E_t^* is the risk-neutral expectations operator conditional on information available at time t, r is the short-term risk-free rate and s is the default risk premium.

Using the above general framework, we can now determine the yield spread of a sovereign bond relative to a benchmark sovereign of the highest credit quality. To this end, we assume that (a) there are j=0,…,J sovereign bonds with identical time to maturity, n, each bond being issued by a different sovereign, j; (b) j=0 is a benchmark bond, i.e. the bond of the sovereign with zero probability of default, $s_0=0$[1]; (c) short-term risk-free rates for all j=1,…,J sovereigns are related to the short-term risk-free rate of the benchmark country through the Uncovered Interest Parity condition, $r_j = r_0 + fx_j$, where fx_j is the currency risk premium of currency j vis-à-vis base currency 0. Note that $fx_j = 0$ if the sovereign bond j is issued in the currency of the benchmark country or if sovereign j operates in the same currency area with the benchmark country, for example, if the sovereign belongs to the euro area, where Germany is the benchmark country. Under these assumptions, the yield spread of bond j relative to the benchmark bond 0 is given by:

$$R_{jt}^{n} - R_{0t}^{n} = E_t^{*}\left[e^{\frac{1}{n}\cdot\int_t^{t+n} r_0(u)du} \cdot \left(e^{\frac{1}{n}\cdot\int_t^{t+n}[s_j(u)+fx_j(u)]du} - 1 \right)\right] \qquad (2)$$

2.2 Econometric specification

In order to derive an econometrically tractable specification of eq. (2), we assume that the conditional sovereign risk premium (including currency risk) is linearly related to the rating of bond j relative to the benchmark: $E_t^{*}(\frac{1}{n}\cdot\int_t^{t+n}[s_j(u)+fx_j(u)]du)=\beta_t c_{jt}$, where c_{jt} is the rating of sovereign j relative to sovereign 0 (the benchmark) and β_t is a time-varying coefficient which reflects the pricing of credit and currency risk in bond markets.[2] Hence, the yield spread can be expressed as an exponential function of the sovereign's rating relative to the benchmark:

$$R_{jt}^{n} - R_{0t}^{n} = a_t \cdot e^{\beta_t c_{jt}} \qquad (3)$$

[1] We make this assumption in order to simplify notation. In the real world, even the bonds of the most solvent sovereigns are not free from credit risk. However, even if $s_0>0$, eq. (2) would still hold with s_j as the credit risk premium of sovereign j *relative* to sovereign 0.

[2] Bhatia (2002), Sy (2002), Correa et al. (2012), Aizenman et al. (2013) and Acharya et al. (2014), among others, have used sovereign ratings to proxy sovereign credit risk. Aizenman et al. (2013) find that ratings are economically important and statistically significant determinants of sovereign credit spreads in the EU even after controlling for a host of domestic and global fundamental factors.

where $e^{\beta_t c_{jt}}$ represents the idiosyncratic part of sovereign risk and parameter $a_t = E_t^* e^{\frac{1}{n}\cdot\int_t^{t+n} r_0(u)du}$ is a common factor which determines the yield spread of all sovereigns independent of their rating. This common (or "global") risk factor determines the position of the sovereign yield curve and is related to expectations about the path of the risk-free rate, and hence, expectations about the stance of monetary policy in the benchmark country.

In a final step, we can log-linearize eq. (3) using a first-order Taylor series expansion around the time t cross-sectional mean of the sovereign risk premium, $e^{\beta_t c_t}$:

$$\ln(R_{jt}^n - R_{0t}^n) = \alpha_t + \beta_t c_{jt} + \varepsilon_{jt} \qquad (4)$$

where the common factor is now $\alpha_t = E_t^* \frac{1}{n}\cdot\int_t^{t+n} r_0(u)du - \ln(1-e^{\beta_t c_t}) - \frac{e^{\beta_t c_t}}{1-e^{\beta_t c_t}}\beta_t c_t$ and we have added an error term with zero mean and constant variance, ε_{jt}.

Note that eq. (4) accounts for time variations of both the quantity (c_{jt}) and the price (β_t) of sovereign credit risk but also for time variation of the average yield spread (common factor) across all rating categories (α_t). Variations in α_t reflect risk factors stemming from broader market developments other than sovereign credit risk such as (i) expectations about monetary policy in the benchmark country, as indicated by the term $E_t^* \frac{1}{n}\cdot\int_t^{t+n} r_0(u)du$, and (ii) factors that affect the cross-sectional mean of the sovereign risk premium, i.e. average perceived risk across all sovereigns, as indicated by the term $-\ln(1-e^{\beta_t c_t}) - \frac{e^{\beta_t c_t}}{1-e^{\beta_t c_t}}\beta_t c_t$. Such factors could relate to investors' risk aversion and systemic confidence, systemic liquidity conditions and global economic fundamentals.

3. Data and stylized facts

Our data consist of daily bond yields for sixty four countries, retrieved from Thomson Reuters Datastream[3] covering the period from 1/1/2000 to 1/1/2015.[4] We have also

[3] Original sources vary. For a full list see Table A in the Appendix.

collected from Bloomberg daily data on the ratings assigned by the three largest credit ratings agencies (CRAs) (i.e., Fitch, Moody's and Standard and Poor's) for each of the countries, for the whole sample. Next, we grouped the countries into rating categories from the highest investment-grade AAA to the extremely speculative grade CCC.

Ratings data have been transformed from alphanumeric to arithmetic values on a scale from one to seven, where the value of one (1) corresponds to the highest rating category (AAA) and the value of seven (7) to the extremely speculative grade (CCC). It should be noted that downgrades in ratings equal to CCC and lower relate to bonds undergoing a restructuring or a default. Thus, we have excluded them from our analysis, in order to address the issue of systematic sovereign credit risk pricing, as explained in the previous section, i.e. without computational complications that incorporating recovery values would impose.

The daily frequency of the ratings data enables us to mark any rating change of a sovereign at the day of the announcement. On the other hand, including several rating agencies leads to the necessity for adopting a rule in order to mark ratings changes; we use the 'second best rating' regulatory principle[5], meaning that at the day that a category rating change has been made we change the sovereign's rating to a higher (in the case of an upgrade), or lower (in the case of a downgrade) category, provided that one of the two other CRAs had already rated the sovereign higher or lower, respectively.

Figure 1 shows the evolution of the relative size of ratings categories over time. Following the GFC, the number of AAA-rated countries declined whereas the number of low-rated countries (particularly BBB) increased significantly.

[Insert Figure 1, around here]

The downgrades started before the collapse of Lehman and, in particular, in the aftermath of the freeze of the money market, in August 2007, and the average sovereign rating had already been lowered even before the eruption of the euro-area

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[4] Thus, our dataset contains around 4000 observations for each of the countries; however, for some of the countries the start dates of the sample vary, depending on data availability.

[5] Papers examining events and announcements frequently rely on other techniques for marking rating changes, such as the marking changes depending on which of the agencies moves first (see, for example, Gibson et al., 2016a and Gibson et al., 2016b).

sovereign debt crisis in the second quarter of 2010. Still, in the aftermath of the Lehman collapse, we find that (a) downgrades were more frequent than upgrades and (b) they were more aggressive than previously. Specifically, in the first sub-period there exist seven downgrades and 16 upgrades, whereas in the post-Lehman period there exist 16 downgrades and seven upgrades.

After calculating the spreads for all countries and for each point in time, vis-à-vis the benchmark countries[6], we take the average spread for each of the six rating categories and its standard deviation, in daily frequency; Then, we divide each of the six rating categories into three sub-categories, hence, we end-up with eighteen ratings categories[7]. Note that the rating categories we use correspond to the investment- and non-investment-grade, hence, from AAA to B, excluding CCC, which are associated with an upcoming credit event. Figure 2 plots the evolution of the sovereign yield curve over time.

Table 1 provides descriptive statistics for the sovereign bond spreads across the rating categories. The table shows that in the aftermath of the Lehman collapse, spreads increased relatively more in the higher rating categories, than in the lower rating categories; i.e. the spread demanded by bond investors in the non-benchmark AAA and AA rating category has risen substantially (75% for AAA and more than 50% for AA), whereas in the case of BB bonds the rise has been negligible and in the case of B bonds the spreads increased only modestly. In contrast, spreads of BBB bonds have declined after the GFC. These findings suggest that, although all sovereign spreads increased after the GFC, the increase was proportionally stronger in the highest rating categories.

[Insert Table 1, around here]

[Insert Figure 2, around here]

[6] See Table B, in the Appendix.

[7] These correspond to (i) the average spread, (ii) the high value of the spread, by adding one standard deviation, and (iii) the low value of the spread by deducting one standard deviation. Note that we chose not to take into account 'notches' in our rating category formation, as the reliability of the statistical inference of the categorization of spreads to the underlying rating categories wpuld be endangered, due to the limited number of sovereigns with regularly available data of bond yields. Moreover, the technique of marking the 'low-', 'average-' and 'high-'yielders in each rating category is very frequently used in asset pricing models.

On the other hand, the correlation among the spreads of different rating categories has risen significantly in the post-2008 period, suggesting that yield spreads were increasingly driven by a common factor in the aftermath of the GFC.

4. Empirical analysis

4.1. Panel data estimates of the sovereign yield curve

Before we proceed with the estimation of the time-varying parameter model of eq. (4), we estimate the constant parameter version of the model as a benchmark. We do this for the whole sample as well as for the two sub-samples before and after the GFC in order to test whether there was a change in market pricing behaviour. Table 2 reports estimates of a panel regression with random effects and the first two lags of the spread as instruments; additionally, a fixed effects specification has been tested as an alternative and the null of random effects could not be rejected. Panel A of Table 2 reports estimation results for the whole sample, 2000-2015.

The model coefficients are significant at the 1% level and the model's explanatory power is quite high as ratings alone explain 84% of the cross-sectional variation of yield spreads. The cross-section correlation of residuals is reasonably low but the correlation of residuals with ratings is high and negative (correlation coefficient of -0.45). Since higher rating numbers correspond to lower credit quality, the negative correlation between ratings and residuals implies that the model on average overprices credit risk for sovereigns with low credit quality and vice versa.

[Insert Table 2, around here]

Is the effect of ratings economically significant? Since spreads are an exponential function of ratings, the effect of a change in the rating by one notch on the sovereign spread depends on the rating category, whereby the spread of a high rated sovereign will incur a smaller increase than the spread of a lower rated sovereign. Thus, while a hypothesized downgrade from double-A (in our arithmetic scale takes the value of 4) to single-A (our arithmetic scale is equal to 7) would be expected to add only around 60 basis points (α*exp(0.228x4)-α*exp(0.228x7)), a downgrade from double-B to single-B would be expected to add around 580 basis points (α*exp(0.228x14)-α*exp(0.228x17)).

Next, in order to test for changes in the parameters, we estimate the model in the two sub-samples before and after the collapse of Lehman in September 2008 (Panel B of Table 2). Our estimates suggest that the mean compensation for sovereign credit risk, *ln(α)*, has increased substantially in the aftermath of the GFC, implying that investors have demanded a higher compensation for credit risk, irrespective of the credit rating of the sovereign. In fact, the Wald test reported in the bottom of Table 2 rejects the null that the constant is equal in both sub-samples, suggesting that the increase in the mean compensation for sovereign credit risk after the fall of Lehman in September 2008 is significant. Interestingly, the slope coefficient of credit ratings, β, which reflects the price of credit risk, has decreased somewhat in the aftermath of the GFC, suggesting that the responsiveness of sovereign spreads to changes in credit risk has declined on average across rating categories. However, this result should be treated with caution since it could be due to omitted variable bias.[8]

4.2. Estimation of the sovereign credit yield curve with time varying parameters

We now turn to the estimation of the time-varying parameter model. In order to do this, we employ non-linear least-squares to estimate eq. (4) for each day, *t*, across the sample of sovereign spreads, obtaining one estimate of the parameters α_t and β_t for each day. Table 3 reports the results of the estimation.

[Insert Table 3, around here]

As expected, the mean of both α and β are close to the estimates of our panel regressions in Table 2, they are statistically significant at the 5% level and the explanatory power of the model is again satisfactory with an implied adjusted R-square of 75%. Interestingly, the cross-section dependence of the residuals is significantly lower than in the panel regression model (-0.177 compared to -0.453), implying that time-variation in the model parameters can partly account for the mispricing of the panel regression model for lower rating categories.

[8] Omitted variable bias could result from the fact that ratings are correlated with country fundamentals which are not included in the regression reported in Table 2. In this case, our estimate of β in the post-crisis period may be biased downwards if the correlation between ratings and country fundamentals increased following the fall of Lehman. We used GMM and lagged spreads as instruments in order to control for omitted variable bias. Note that our estimates of α are not affected by omitted variable bias since the constant is uncorrelated with time-varying fundamentals.

[Insert Figure 3, around here]

Figure 3 plots the evolution of the model parameters estimates over time. The figure suggests that the level of the global risk premium, α, has increased permanently after the GFC -- from about 20 basis points before to more than 40 basis points on average after the crisis. This permanent increase in the global risk factor suggests that the increase in credit spreads following the GFC was the result of a re-pricing that reflected broader market conditions and risk attitudes of investors rather than the result of higher credit risk per se. Interestingly, our estimates suggest that the price of credit risk, β, remained relatively stable over time, even after 2009, when the GFC turned into a sovereign debt crisis for Greece and other vulnerable countries in the euro area. In other words, it appears that, following the GFC, credit spreads increased due to the rating agencies' downgrades of sovereign debt, i.e. due to higher quantity of sovereign risk, but investors did not demand a higher average price per unit of sovereign risk.

Did the increase in global risk affect sovereign spreads uniformly or is the effect different across rating categories? Table 4, Panel A, reports the estimated spreads per rating category for three sub-periods: before, during and after the GFC. Our estimates suggest that, although the increase in global risk after 2007 has affected all sovereign spreads across rating categories, higher-rated sovereign bonds were relatively more affected. For example, the average spreads of the AAA and AA categories doubled after the GFC (from 34 bps to 67 bps for AAA and from 64 bps to 114 bps for AA bonds) whereas the average spread of the B category increased only slightly from 928 bps to 956 bps. This is due to the fact that credit risk explains a low fraction of the spread for higher-rated sovereigns, hence, an increase in the average spread across all ratings (α) has a bigger impact on their spread.

[Insert Table 4, around here]

Panels B and C of Table 4 report the relative contribution of the credit risk component and the global risk component of credit spreads across rating categories. As expected, the contribution of the credit risk component in the yield spread decreases with the rating, i.e. credit risk explains a larger fraction of the spread for lower rated sovereigns relative to higher rated sovereigns, in line with results documented in Longstaff *et al.* (2011). In particular, we find that during the period 2000-2007, credit risk explains 99.5% of the average yield spread of the B category, compared to 86.5% for the AAA category. Interestingly, during and after the GFC, the contribution of credit risk declines in particular for higher-rated sovereigns whereas at the same time the contribution of the global risk factor, α, increases for the same categories. For example, for AAA bonds, the contribution of credit risk to the yield spread declines from 86.5% in 2000-2007 to 66.9% in 2009-2015 whereas the contribution of the global risk factor increases during the same period from 13.5% to 33.1%. In contrast to higher-rated sovereigns, spreads of lower-rated sovereigns continue to be driven almost entirely by credit risk even during and after the GFC. For example, the relative contribution of credit risk in B-rated sovereign spreads declines only slightly from 99.5% before the GFC to 97.7% after the GFC.

4.3. A Markov regime-switching model of the global risk factor

According to our theoretical model, outlined in Section 3, the common risk factor (global risk) across sovereign yield spreads is related to expectations about future risk-free interest rates in the benchmark country and factors that affect the cross-sectional mean of the sovereign risk premium, such as investors' risk aversion, systemic liquidity conditions and global economic fundamentals.

In order to model the time-variation of the global risk factor, we estimate a Markov regime-switching model of global risk, in which we include variables that reflect (i) expectations about global monetary policy conditions and (ii) market sentiment and risk.[9] Exogenous variables are examined under a general-to-specific approach; first, we regressed global risk on each variable separately; second, we formed a multiple-variable specification of global risk, in which all variables which have been found significant in the first step were included, and; third, we selected the setup that contains only significant variables.[10]

[9] The dependent variable is our estimate of the global risk premium (α) in Figure 3.

[10] We used the following variables as regressors: institutional investor confidence indicators for the US stock market, US consumer confidence, the volatility risk premium, the combined monetary base in the US and the euro area, yields and rates of various long- and short-term UST notes and the Federal Funds rate. Results are available upon requests.

The explanatory variables used in the final setup are (i) institutional investor confidence[11], (ii) the volatility risk premium (VIX minus realized volatility, see, Longstaff et al. (2011)), (iii) the monthly rate of change of the combined monetary base of the Fed and the ECB and (iv) the spread between the ten year and the two year US Treasury bond yield. All data are monthly and cover the period from 2002:1 to 2015:1. Sources of the data are the International Center for Finance of the Yale School of Management (for the institutional investor confidence index) and Datastream (for the rest of the series). The Markov regime-switching model is specified as follows:

$$\alpha_t(s) = \theta_0(s) + \rho(s) \cdot \alpha_{t-1} + \sum_{i=1}^{k} \theta_i(s) \cdot x_{it} + e_t \tag{5}$$

where α_t is the estimate of the global risk premium from Section 4.2, $s \in \{1,2\}$ is the unobserved state, $\rho(s)$ and $\theta_i(s)$, $i=0,\ldots,k$ are state-dependent parameters, x_{it} are the exogenous variables and $e_t \sim (0 \;\; , \;\; \sigma(s))$ is a residual with state-dependent volatility. Table 5 reports estimation results of eq. (5) and Figure 4 plots the smoothed probabilities of each of the two regimes. Regime 1 is a high volatility regime that largely captures the period after the GFC, whereas regime 2 is a low volatility regime that largely captures the pre-crisis period.

[Insert Table 5, around here]

[Insert Figure 4, around here]

The estimation results reported in Table 5 suggest that global risk in the sovereign bond market is driven by variables that relate to investor confidence, volatility risk, central bank liquidity and the slope of the yield curve in the US. The volatility risk premium is found to be significant in both regimes. Higher volatility risk raises the global risk premium for sovereign bonds, in line with the results of Longstaff *et al.* (2011). Higher investor confidence in the US stock market increases

[11] We used the demeaned 'Buy-on-dips' component of the institutional investor confidence index for the US stock market from the International Center for Finance of the Yale School of Management, see http://som.yale.edu/faculty-research/centers-initiatives/international-center-finance/data/stock-market-confidence-indices/stock-market-confidence-indices.

the global risk premium for sovereign bonds, likely indicating a flight-to-quality effect. Interestingly, the effect of investor confidence is stronger in the high-volatility regime.

Finally, positive changes of the monetary base are associated with a lower global risk premium, whereas a steepening of the yield curve of the US Treasuries is associated with a higher global risk premium. Hence, it appears that the provision of ample liquidity by the Fed and the ECB following the GFC led sovereign bond premiums across the entire credit yield curve to decrease.[12] On the other hand, under the low-volatility regime (regime 2), if the slope of the yield curve steepens due to, for example, the prospect of higher inflation and, thus, higher risk-free rates, the premium demanded by investors in sovereign bonds irrespective of their ratings, also increases.

It is interesting, however, to note that the monetary base and the term spread are significant in either one of the two regimes; in the first (high-volatility) regime, the changes of the US and the euro-area monetary base are found to exercise significant effects on the global risk premium, whereas in the second (low-volatility) regime the US term spread is found to be significant. One possible interpretation of this finding is that, following the GFC, the information content of the term spread as a predictor of future risk-free interest rates has been distorted due to quantitative easing of the Fed and other major central banks.

5. Conclusions

Using a large database of bond yields and ratings from sixty four countries covering a period of fifteen years, we examine whether a simple reduced-form model of pricing sovereign bonds based on sovereign ratings may capture the systematic credit risk component of sovereign spreads. We examined the model under various setups and, overall, we find that indeed there is a highly significant relationship anchoring spreads to sovereign ratings. However, our results indicate that a re-pricing of sovereign risks took place during the GFC. Next, we examined whether this re-pricing was the result of deteriorating sovereign creditworthiness combined with

[12] The effect of non-standard monetary policy on sovereign bond yields has already been documented in the literature -- see, e.g., Neely (2015), Saka *et al.* (2015), Sobrun and Turner (2015) and Bowman *et al.* (2015).

lower tolerance for sovereign credit risk (i.e. higher price of risk), or the result of an increase in system-wide risk.

We find that sovereign downgrades in the period 2007-9 help explain part of the increase of sovereign spreads, but cannot explain the overall increase in sovereign bond yields, in particular for higher-rated sovereigns. Furthermore, the market sensitivity to changes in ratings (the "price of risk") does not seem to increase following the GFC. If anything, the price of risk seems to decline somewhat after the GFC.

On the other hand, we find that the component of the risk premium that relates to broader market conditions has increased substantially in the aftermath of the GFC, leading to a persistent increase in sovereign credit spreads, particularly for higher-rated sovereigns, which is not sufficiently explained by the systematic deterioration of sovereign creditworthiness. This increase is shown to be related to global market sentiment and volatility risk, suggesting a flight-to-quality effect in sovereign bond markets. Finally, we find evidence that increased provision of liquidity and asset purchases of major central banks following the GFC have contributed to lowering the average yield spread across sovereign borrowers.

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Annex

Table A: Description of the time-series data

Country	Data range	Source	Remarks
Argentina	2001-2015	BofA-ML	Excluded from the sample from 1/1/2002 to 31/8/2006 (due to default).
Australia	2001-2015	TR-DS	
Austria	2001-2015	TR-DS	
Belgium	2001-2015	TR-DS	
Brazil	2001-2015	TR	Main guarantor: US, debt denominated in US$: 92%.
Bulgaria	2006-2015	TR	
Canada	2001-2015	TR-DS	
Chile	2007-2015	TR	
China	2002-2015	TR-DS	
Colombia	2002-2015	TR	
Croatia	2008-2015	TR	
Czech Rep.	2000-2015	TR-DS	
Germany	2001-2015	TR-DS	
Denmark	2001-2015	TR-DS	
Dominican Rep.	2001-2015	Ba	Excluded from the sample from 1/4/2004 to 29/12/2006 (due to default).
Ecuador	2001-2015	TR	Excluded from the sample from 1/12/2008 to 1/1/2010 (due to default).
Egypt	2007-2015	TR	Main guarantor: US, debt denominated in US$: 36%.
Spain	2001-2015	TR-DS	
Finland	2001-2015	TR-DS	
France	2001-2015	TR-DS	
Greece	2001-2015	TR-DS	Excluded from the sample from 1/11/2011 to 10/12/2012 (due to debt restructuring).
Hong Kong	2001-2015	TR	
Hungary	2001-2015	TR-DS	
Iceland	2003-2015	TR	
Ireland	2001-2015	TR-DS	
India	2001-2015	TR	
Indonesia	2003-2015	TR	Main guarantor: US, debt denominated in US$: 75%.
Italy	2001-2015	TR-DS	
Jamaica	2004-2015	Ba	94% of debt denominated in US$.
Japan	2001-2015	TR-DS	
Kenya	2004-2015	TR	56% of debt denominated in US$.
Latvia	2004-2015	TR	
Lebanon	2001-2015	Ba	Main guarantor: US, debt denominated in US$: 93%.
Lithuania	2003-2015	TR	
Malaysia	2001-2015	TR	
Mexico	2001-2015	TR-DS	Main guarantor: US, debt denominated in US$: 52%.
Morocco	2004-2015	BofA-ML	Main guarantor: US, debt denominated in US$: 22%.
New Zealand	2001-2015	TR-DS	
Nigeria	2007-2015	TR	75% of debt denominated in US$.
Netherlands	2001-2015	TR-DS	
Norway	2001-2015	TR-DS	
Pakistan	2004-2015	TR	Main guarantor: US, debt denominated in US$: 55%.
Peru	2008-2015	TR	
Philippines	2001-2015	TR	70% of debt denominated in US$.

Note: 'TR' is Thomson Reuters, 'TR-DS' is Thomson Reuters Datastream, 'BofA-ML' is Bank of America-Merril Llynch and 'Ba' is Barclays. Figures about the proportion of debt denominated in foreign currency, correspond to the year 2014 (source: World Bank, 'International Debt Statistics' database, http://datatopics.worldbank.org/debt/ids/).

Table A (continued)

Country	Data range	Source	Remarks
Poland	2001-2015	TR-DS	
Portugal	2001-2015	TR-DS	
Romania	2007-2015	TR	
Russia	2003-2015	TR	Main guarantor: US, debt denominated in US$: 62%.
Singapore	2001-2015	TR	
Slovakia	2007-2015	TR	
Slovenia	2007-2015	TR	
South Africa	2000-2015	TR-DS	
South Korea	2000-2015	TR-DS	
Sweden	2001-2015	TR-DS	
Switzerland	2001-2015	TR-DS	
Taiwan	2001-2015	TR	
Thailand	2001-2015	TR	
Turkey	2010-2015	TR	Main guarantor: US, debt denominated in US$: 62%.
Uganda	2010-2015	TR	
United Kingdom	2001-2015	TR-DS	
United States	2001-2015	TR-DS	
Ukraine	2001-2015	BofA-ML	
Venezuela	2004-2015	BofA-ML	
Vietnam	2007-2015	TR	55% of debt denominated in US$.

Table B: Groups of countries according to the sovereign used as benchmark			
United States	**Germany**	**Japan**	**United Kingdom**
Argentina-AR	Austria-AT	China-CN	India-IN
Australia-AU	Belgium-BE	Hong-Kong HK	South Africa-ZA
Brazil-BR	Bulgaria-BG	Indonesia-ID	
Canada-CA	Czech-CZ	Malaysia-MA	
Chile-CL	Denmark-DN	Singapore-SG	
Colombia-CO	Spain-ES	Taiwan-TW	
Dom. Rep.-DO	Finland-FI	Thailand-TH	
Ecuador-EC	France-FR		
Egypt-EG	Greece-GR		
Iceland-IS	Croatia-HR		
Jamaica-JM	Hungary-HU		
Kenya-KE	Ireland-IE		
Korea-KR	Italy-IT		
Lebanon-LB	Lithuania-LI		
Mexico-MX	Latvia-LV		
Morocco-MO	Netherlands-NL		
New Zealand-NZ	Norway-NO		
Nigeria-NG	Poland-PL		
Pakistan-PK	Portugal-PT		
Peru-PE	Romania-RO		
Philippines-PH	Slovakia-SK		
Russia-RS	Slovenia-SI		
Turkey-TU	Sweden-SE		
Ukraine-UA	Switzerland-CH		
Uganda-UG			
Venezuela-VE			
Vietnam-VN			

Note: Criteria used in order to identify the benchmark for each country in the sample are, one or several of the following ones: (i) proportion of the debt being denominated in the currency of the benchmark, (ii) geographical approximation, (iii) trade flows, (iv) political ties (e.g. participation in monetary or currency unions and organizations) and (v) holdings of bonds of the sovereign by entities residing in one of the benchmark countries. Fort this purpose se use the “Principal Global Indicators”, of the Inter-Agency Group on Economic and Financial Statistics, see http://www.principalglobalindicators.org/.

Table 1: Sovereign bond spreads per rating category

	Mean	Std. dev.	Min.	Max.	$\hat{\rho}$ (AAA)	$\hat{\rho}$ (B)
1/1/2000-1/1/2015						
AAA	0.37	0.15	0.07	1.15	1	0.32
AA	0.97	0.48	0.24	2.69	0.63	-0.06
A	2.45	0.57	1.33	4.67	0.41	0.52
BBB	3.93	1.16	2.02	8.44	0.52	0.11
BB	5.72	1.58	3.01	13.46	0.45	0.26
B	7.01	2.01	3.09	38.43	0.32	1
1/1/2000-15/9/2008						
AAA	0.28	0.13	0.07	1.15	1	0.26
AA	0.65	0.31	0.24	2.19	0.08	-0.36
A	2.33	0.67	1.33	4.67	0.35	0.48
BBB	4.02	1.42	2.02	8.44	0.55	0.31
BB	5.72	1.79	3.15	13.46	0.38	0.24
B	6.43	2.06	3.09	38.43	0.26	1
15/9/2008-1/1/2015						
AAA	0.48	0.07	0.41	1.07	1	0.56
AA	1.44	0.25	1.06	2.69	0.48	-0.07
A	2.62	0.32	2.23	3.85	0.74	0.64
BBB	3.81	0.62	2.91	6.13	0.69	0.56
BB	5.73	1.23	3.01	11.72	0.66	0.54
B	7.84	1.61	5.29	16.68	0.55	1

Note: Columns under the ρ-heading contain average correlation of each ratings with the triple-A rated and single-B rated series, respectively.

Table 2: GMM estimation of random effects model

Panel A: 2000-2015

	Value	**Std. error**	**p-value**
$\ln(\alpha)$	-1.409**	0.065	0.000
β	0.228**	0.007	0.000
Adj. R-squared	**SSR**	**RMSE**	**RE vs. FE** (Hausman test)
84.1%	692.2	0.498	0.023 [0.881]

Residuals cross-section autocorrelation	**Residuals correlation with *ratings***
$\rho(\varepsilon_{it}, \varepsilon_{jt})$	$\rho(\varepsilon_{it}, c_{it})$
0.181	-0.453

SVR test (Ng, 2006)	q=2	q=3	q=4
	3.871**	1.463	1.710

Panel B: sample separation

	Value	**Std. error**	**p-value**
2000-2008:9			
$\ln(\alpha)$	-1.751**	0.144	0.000
β	0.254**	0.019	0.000
Adj. R-squared	**SSR**	**RMSE**	**RE vs. FE** (Hausman test)
82.4%	507.1	0.537	0.296 [0.568]
2008:10-2015			
$\ln(\alpha)$	-0.923**	0.172	0.000
β	0.189**	0.012	0.000
Adj. R-squared	**SSR**	**RMSE**	**RE vs. FE** (Hausman test)
90.9%	115.2	0.299	0.013 [0.901]
Wald test of a structural break in ln(α) in 2008:9		Chi-square	p-value
		32.302	0.000

Note: The table presents random effects GMM (Swamy-Arrora weights) with the use of first and second lags of spreads as instruments; asterisks (*,**) denote 10% and 5% significance and brackets contain p-values. White period correction technique has been applied. Also, q corresponds to the discrete spacing intervals; the null of independence is rejected (at 5%) if |SVR|>1.96.

Table 3: Time-varying parameters and diagnostics

Period average values:	Coefficients	Std. error	p-value
$\frac{\sum_{t=1}^{T}\ln(\alpha_t)}{T}$	-1.182** (0.443)	0.718 (0.312)	0.049 (0.067)
$\frac{\sum_{t=1}^{T}\beta_t}{T}$	0.201** (0.025)	0.075 (0.029)	0.000 (0.016)
Diagnostics			
Adj. R-squared	**SSR**	**RMSE**	**Jarque-Berra**
75.5% (18.2%)	45.94 (37.07)	1.529 (0.649)	8.15 [0.031]
$\frac{\sum_{t=1}^{T}\varepsilon_{it}}{T}$	$\frac{\sum_{t=1}^{T}\sigma^{\varepsilon}{}_{it}}{T}$	**kurtosis**	**skewness**
-0.11 (0.188)	1.1 (0.629)	2.8 (1.296)	-1.52 (0.576)
Correlation of residuals with ratings		$\rho(\varepsilon_{it}, c_{it})$ = -0.177	

Note: The table presents average values of the estimated parameters for the entire period of the sample; asterisks (**) denote 5% significance for the whole sample, numbers in brackets are average p-values and numbers in parentheses indicate standard deviations of the measures. SSR is the value of the sum of squared residuals and RMSE is the root mean squared errors. Errors of the estimation are corrected with Stock and Watson (2008) formula.

Table 4: Decomposition of the systematic component of sovereign spreads per rating category

Panel A: Implied spread per rating category (in basis points)						
2000-2007	34	64	125	244	476	928
2007-2009	52	91	160	280	492	862
2009-2015	67	114	194	330	562	956
Panel B: Relative contribution of the credit risk component (β*c_j)						
2000-2007	86.5%	93.1%	96.5%	98.2%	99.1%	99.5%
2007-2009	75.3%	85.9%	92.0%	95.4%	97.4%	98.5%
2009-2015	66.9%	80.6%	88.6%	93.3%	96.0%	97.7%
Panel C: Relative contribution of the common factor (alpha)						
2000-2007	13.5%	6.9%	3.5%	1.8%	0.9%	0.5%
2007-2009	24.7%	14.1%	8.0%	4.6%	2.6%	1.5%
2009-2015	33.1%	19.4%	11.4%	6.7%	4.0%	2.3%

Table 5: Markov regime switching model of the common factor (alpha)

First regime (s=1)			
Explanatory variable	**Coefficient**	**Std. error**	**p-value**
c	0.059	0.045	0.1945
alpha(-1)	0.798	0.069	0.000
Investor confidence	0.319	0.162	0.049
Volatility risk premium	0.002	0.001	0.002
Δ log(monetary base)	-0.003	0.001	0.030
UST 10y – UST 2y	0.013	0.011	0.211
log(σ(s))	-3.167	0.080	0.000

Second regime (s=2)			
Explanatory variable	**Coefficient**	**Std. error**	**p-value**
c	0.025	0.008	0.003
alpha(-1)	0.808	0.049	0.000
Investor confidence	0.111	0.065	0.089
Volatility risk premium	0.002	0.001	0.000
Δ log(monetary base)	-0.001	0.002	0.668
UST 10y – UST 2y	0.008	0.003	0.018
log(σ(s))	-4.417	0.121	0.000

Transition probabilities		
	s=1	s=2
s=1	0.881 (0.086)	0.118 (0.086)
s=2	0.046 (0.055)	0.953 (0.055)

Diagnostics			
Log-Likelihood	**SSR**	**Durbin-Watson**	**J-Berra (residuals)**
339.71	**0.193**	**2.072**	738.41

Note: Regimes are specified probabilistically by means of the expectations maximization algorithm, set up by Hamilton (1989).

Figure 1: Developments of ratings across time

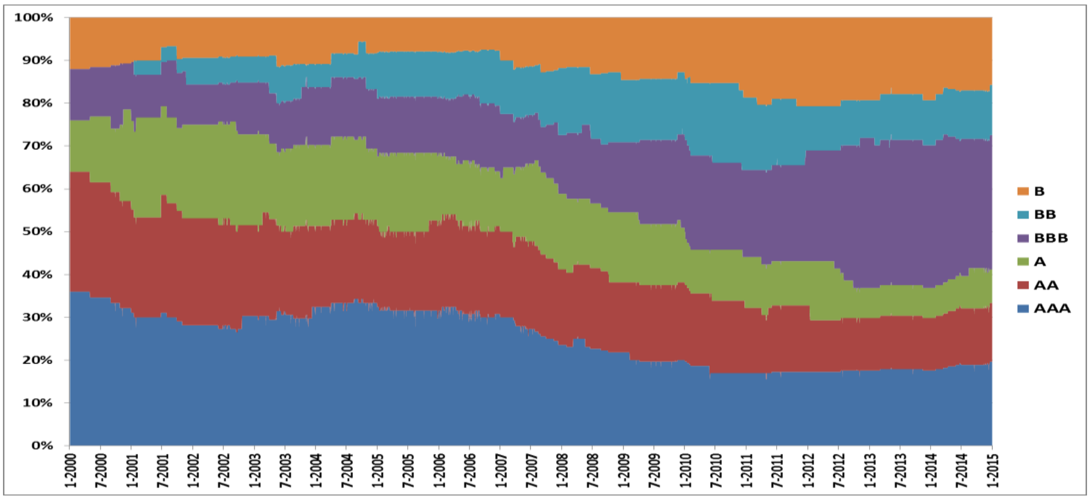


Figure 2: Observed sovereign credit yield curve

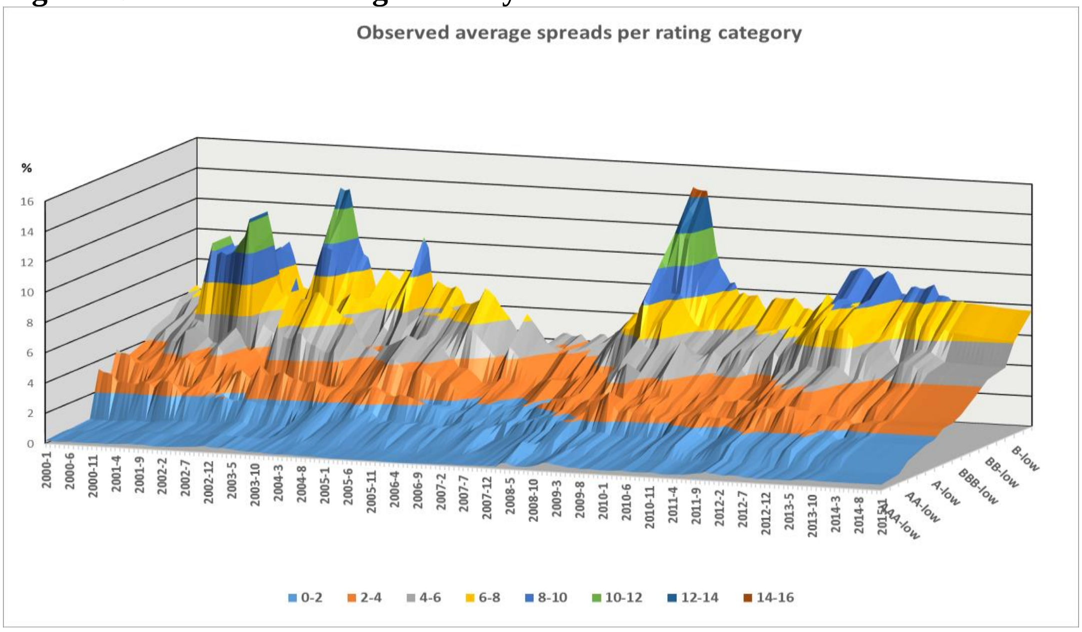
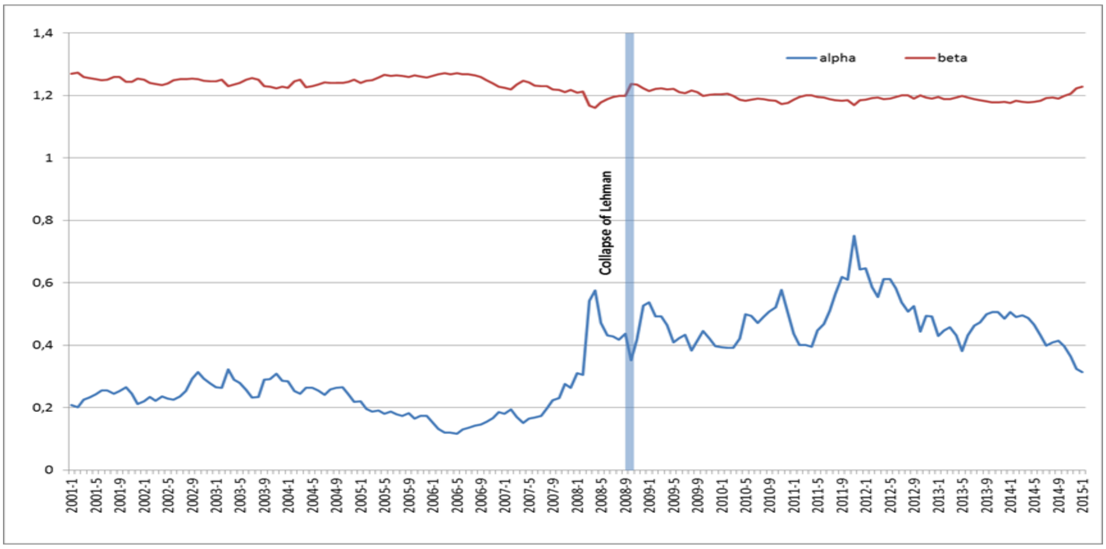
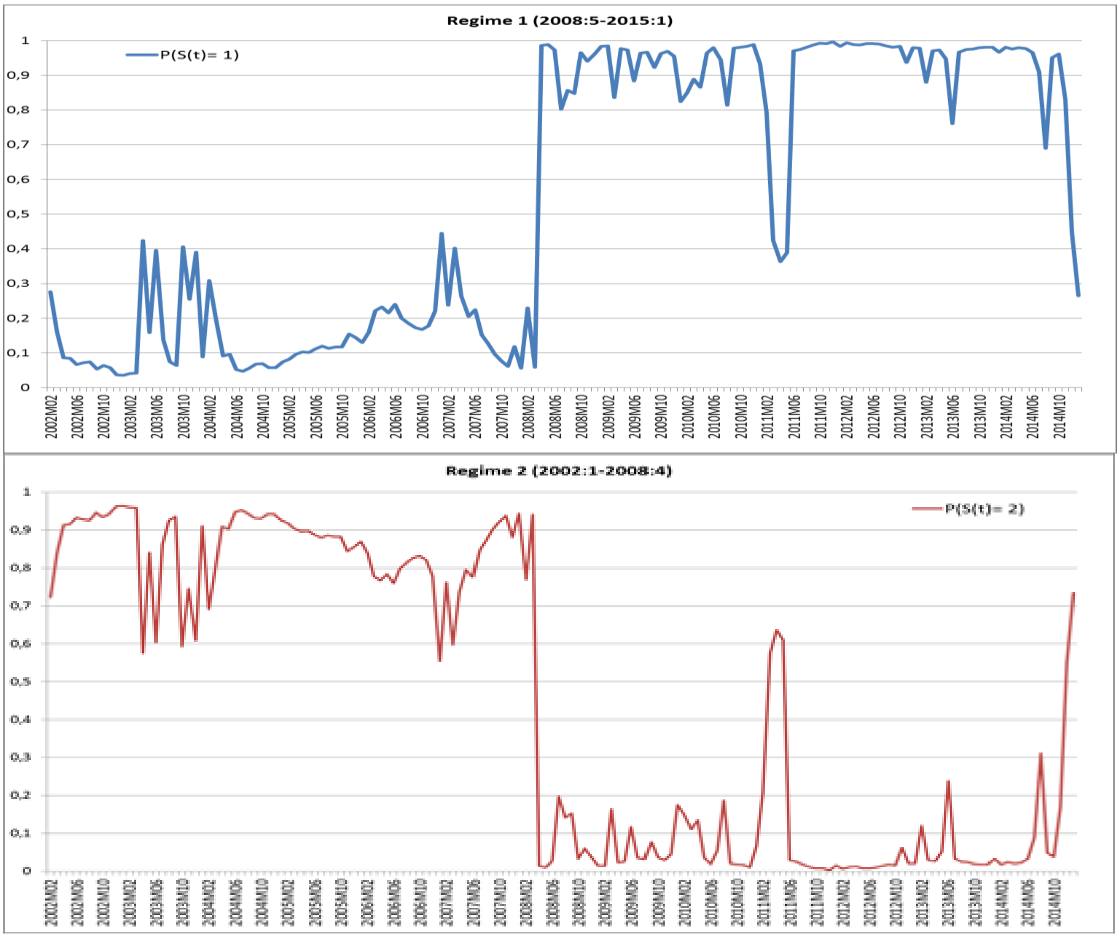


Figure 3: Estimates of time-varying parameters



Note: The Figure illustrates the variations of the exponential values of the parameters α and β of equation (4). Parameter α is the estimate of the global risk premium. Parameter β is the estimate of the market sensitivity to ratings (price of risk). The shaded area marks the period from the freeze of the money market in 9 August 2007 to the beginning of 2009.

Figure 4: Smoothed probabilities of the Markov regime-switching model of the global risk premium (alpha)



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