Commonality in Sovereign Credit Risk — A Rating-Based Approach*

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August 10, 2017

Abstract

One of the most important findings of the recent literature on sovereign credit risk is the existence of a strong commonality in sovereign CDS spreads [Pan and Singleton (2008), Longstaff, Pan, Pedersen, and Singleton (2011)]. Explicitly modeling such commonality is extremely important for capturing the joint dynamics of CDS spreads of multiple countries and consequently managing the risk of credit portfolios. In this paper, we embed this commonality in a rating-based reduced-form model, a parsimonious version of which can fully capture the commonality in sovereign credit risk and the joint dynamics of CDS spreads of multiple countries. In contrast, the common practice in the literature of estimating an one-factor model country by country achieves similar pricing performance as the rating-based model but at the expense of unreasonable model parameters. The rating-based model also generates more accurate density forecasts of sovereign CDS portfolios and is more reliable for risk management than existing models.

Keywords: Credit Rating, Sovereign Credit Risk, Credit Default Swap, Systematic Risk, Eurozone Debt Crisis, Implied Credit Rating

JEL Classification: G22, G33

*Previous versions with various titles were presented at the 2017 AFA meetings, the 2016 WFA meetings, 2014 CICF meetings, 2014 EFMA meetings, 2014 North American Winter Meeting of the Econometric Society, 2013 PKU-Tsinghua-Stanford Joint Conference in Quantitative Finance, and seminars at City University of Hong Kong, Kyoto University, Nanjing University, National University of Singapore, Shanghai Finance University, the University of Tokyo, and Xiamen University. We are grateful for comments and suggestions from Geert Bekaert, Harjoat Bhamra, Jay Cao, Jin-Chuan Duan, Peter Feldhütter, Stephen Figlewski, Shenje Hshieh, Masaaki Kijima, David Lando, Francis Longstaff, Yue Ma, Avanidhar Subrahmanyam, Dragon Yongjun Tang, Yingcong Tang, Annie Triantafillou, Sarah Wang, Yingzi Zhu, and seminar participants. The work described in this paper was substantially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China [Project No. CityU145412]. Yang received support from the National Natural Science Foundation of China (No. 71201074). We are responsible for any remaining errors.

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1 Introduction

The existence of a strong commonality in sovereign credit markets has been well documented. For example, Mauro, Sussman and Yafeh (2002) report that the comovement in sovereign bond spreads of emerging markets becomes much higher in the 1990s. Pan and Singleton (2008) and Longstaff, Pan, Pedersen and Singleton (2011) show that there exists substantial commonality in sovereign CDS spreads: time-series fluctuations of sovereign CDS spreads are mostly driven by common risk factors such as VIX and US stock index and explained by first principal component more than 60

In Ang and Longstaff (2013), the loading on the common factor is country-specific. As suggested by the regression results reported in Table 1, a country's loading on common or systematic factor is more likely to change with its credit ratings. This motivates us to use rating-based loadings on the common factor as an alternative to model commonality. By grouping borrowers into broad categories based on similar credit qualities, credit rating provides a first-order approximation of the level of default risk.[1] Moreover, as suggested by Cantor and Packer (1996) and claimed by rating agencies, important sovereign characteristics such as macroeconomic variables, political risk, repudiation risk, and foreign reserves[2] are embedded in sovereign credit ratings.

Specifically, we accommodate the commonality in sovereign credit risk through a rating-based no-arbitrage reduced-form model.[3] In the model, the credit rating of each country follows a continuous-time Markov chain characterized by a common transition matrix, and countries within a given rating category share a similar level of systematic default intensity. As in Ang and Longstaff (2013), we assume that the default risk of a sovereign borrower is a linear combination of a common systematic factor and a country-specific factor. The key difference is that, in our

[1] Empirical studies, such as Eichengreen and Mody (1998, 2000), Ismailescu and Kazemi (2010), Gärtner, Griesbach and Jung (2011), Afonso, Furceri and Gomes (2012), Kiff, Nowak and Schumacher (2012), Aizenman, Binici and Hutchison (2013), show that sovereign credit ratings and their transitions can have significant impacts on the dynamics of sovereign credit risk. However, this literature does not impose no-arbitrage restriction, and thus, has no implications on term structures of credit risk and risk premium.

[2] Eaton and Gersovitz (1981) and Duffie, Pedersen and Singleton (2003) show that these distinctive sovereign characteristics are important for pricing sovereign credit risk.

[3] A series of studies, such as Das and Hanouna (1996), Jarrow, Lando and Turnbull (1997), Lando (1998), Kijima (1998), Kijima and Komoribayashi (1998), Arvanitis, Gregory and Laurent (1999), Huge and Lando (1999), Li (2000), Lando and Mortensen (2005), Farnsworth and Li (2007), and Trueck and Rachev (2009), have considered credit rating for the pricing of corporate default risk.

model, the loading on the common factor is not country-specific, depending only on a country's credit rating.[4] The country-specific factor captures the idiosyncratic component and within-rating variation of default risk of each individual country. The number of parameters in the model does not increase with the number of countries, given that all countries share the same set of parameters for the country-specific factor.

Our rating-based model has at least three advantages over models whose parameters can only be estimated country by country. First, it incorporates the commonality in sovereign credit risk consistently in a parsimonious and unified model. Unlike the country-by-country nature of the traditional reduced-form models, the rating-based model has potential to capture credit risk of all countries simultaneously. Second, it naturally captures both continuous evolution and discrete change in sovereign credit risk due to rating transition. As shown by our study, rating transition represents a challenge to the one-factor model in which default intensity follows continuous processes. Third, it avoids over-fitting the data and improves the efficiency of model estimation. As we show, the estimated price of risk does not behave well for the one-factor country-by-country model. By contrast, the estimated price of risk behaves quite well in our rating-based model.

We apply a parsimonious rating-based model with only 17 parameters to capture the term structure of the CDS spreads of 68 countries between January 2004 and March 2012 with Standard & Poor's credit ratings. For our main estimation, we split the sample countries in half according to the number of observations of their CDS spreads during the sample period. We use the first half most observations in CDS spreads as in-sample countries and the other half as out-of-sample countries. Arguably, the CDS spreads with most observations are the most liquid ones, such that they may collectively represent the aggregate market better. Existing models for sovereign credit risk are typically estimated country by country. By contrast, we estimate the rating-based model by using the term structure of CDS spreads of the 34 in-sample countries simultaneously via maximum likelihood.

Our rating-based model captures the commonality embedded in the sovereign CDS spreads

[4] Ang and Longstaff (2013) use Germany as the systemic factor for European countries and the US for individual states. This modeling choice is perfectly sensible given the purpose of their research. We estimate the systematic factor using all in-sample countries.

well for both the in-sample and out-of-sample countries. On average, the *common*-spreads can explain more than 60% of the variations of the observed CDS spreads of the 34 in-sample and 34 out-of-sample countries. This captured commonality in the sovereign CDS spreads is consistent with that of the Principal Component Analysis (PCA) of the observed 5-year CDS spreads. However, unlike the purely data-driven principal components, our rating-based model captures the commonality much more consistently across maturities and between the in-sample and out-of-sample countries. Thus, given the systematic factor, credit rating, the key cross-sectional variable in our model, is able to capture the majority of the cross-sectional variations of the CDS spreads of most countries. Furthermore, the *common*-spreads also provides us a natural way to define model *implied* credit ratings. When we replace the observed ratings with the model implied ratings, the explanatory power of the *common*-spreads in explaining the observed CDS spreads exceeds 80% for both the in-sample and out-of-sample countries. This indicates the commonality is underestimated with the observed rating due to rating staleness.

Following existing studies, we then explore the economic forces that drive the common factor, the market price of default risk, and the credit risk premium. The common factor extracted from the model can explain a large fraction of the CDS spreads of most countries and has close connections to financial market variables. Particularly, we find that the volatility index VIX and the MSCI world stock index can explain more than 50% of the variations of the common factor and credit risk premium. The credit risk premium of the sovereign CDS spreads across all ratings and maturities increases significantly during the global financial crisis and the Eurozone debt crisis. So does the estimated price of (sovereign credit) risk, which varies between 0.1 to 0.9 most of the time during the sample period. This estimated variation of price of risk is comparable to that estimated in other financial markets, e.g., stock markets.

Overall, the rating-based model, with only 17 parameters, can capture the term structure of the CDS spreads of the 34 in-sample countries reasonably well. The model's average absolute pricing errors relative to the CDS bid-ask spreads are comparable to those of a one-factor model estimated country by country with 170 parameters (5 for each country). Furthermore, the rating-based model does not suffer from unreasonable parameter estimates that lead to extremely high Sharpe ratios, which have frequently been observed in the country-by-country setting.

In addition, our parsimonious rating-based model has comparable pricing performance for the 34 out-of-sample countries, which is impossible for models with country-by-country estimation.

This robust estimation of our rating-based model with CDS spreads of multiple countries, or a portfolio leads to a much better performance in density forecasts of sovereign CDS portfolio values. For an equal-weighted CDS portfolio of the 34 in-sample countries, the model generated conditional density (by simulations) of portfolio values describes the realized market values well. By contrast, the one-factor model performs poorly in this regard. It misses the tail distribution of the portfolio by a large margin. These results suggest that our rating-based model can be used to manage sovereign credit portfolios.

Like the one-factor model, our rating-based model also yields large pricing errors for some countries over some particular periods. Our empirical analyses show that the large model pricing errors can predict future rating changes. Finally, we examine the Eurozone debt crisis through the window of our rating-based model. Large model pricing errors and large deviations between the model implied and observed credit ratings appear before negative credit watch and rating downgrades.

The rest of the paper is organized as follows. In Section 2, we derive CDS spreads in a rating-based continuous-time model for sovereign credit risk. We discuss the data, estimation method, and report the parameter estimates in Section 3 and investigate the commonality captured by the estimated model in Section 4. Section 5 compares our rating-based model with a one-factor model, and Section 6 discusses some applications. Section 7 concludes the paper. The Appendix provides the detailed derivation of the pricing formulas. We report the results of country-by-country estimation of a one-factor model in Online Appendix A. Additional empirical results of the rating-based model and variant robustness checks are reported in Online Appendix B.

2 Credit Rating and Commonality in Sovereign Credit Risk

We assume there exists a common systematic sovereign credit risk factor z_t and the credit risk sensitivity of a sovereign on the common risk factor is based on its credit rating. Let $\bar{H}_{kk}$ ($k = 1, \cdots, K$; K is the number of all possible ratings) be the loading on the common factor z_t for a country with credit rating k, then this country's instantaneous hazard rate of default is:

$$\bar{H}_{kk}\left(\alpha + z_t\right) + y_t, \tag{1}$$

where α is constant, and y_t is a country-specific factor that captures idiosyncratic and within-rating variations of a country's default risk.

The instantaneous default risk specified in equation (1) has the potential to capture the commonality demonstrated in Table 1, but it is incomplete because credit rating of a country may change over time. Thus, we further assume that sovereign credit rating follows a continuous-time Markov chain and the transition rate matrix of credit ratings, $Q(t)$, is also proportional to the common factor z_t.[5] Since we can also express the instantaneous hazard rate in equation (1) in matrix form, the following summarizes the key setup for the rating-based model:

$$Q(t) = \bar{Q}(\alpha + z_t), \quad H(t) = \bar{H}(\alpha + z_t) + I y_t, \tag{2}$$

where $\bar{Q}$ is a constant $K \times K$ transition rate matrix and $\bar{H}$ is a constant $K \times K$ diagonal matrix and $\bar{H}_{kk}$ captures the loading on the common factor for a country with rating k. These assumptions imply that the common factor z affects both the default risk across credit ratings and the transition of credit ratings.[6] When z increases, the overall default risk increases, and credit ratings become less stable. The country-specific factor y only affects the default risk of a specific country and does not affect the transition matrix of credit ratings $Q(t)$.

We assume that the common factor z follows a CIR (see Cox, Ingersoll and Ross 1985) process under the risk-neutral measure, which is given by

$$dz_t = \kappa_z(\theta_z - z_t)\, dt + \sigma_z \sqrt{z_t}\, dW_t, \tag{3}$$

where W_t is a Brownian motion, and κ_z, θ_z, and σ_z are positive constants.[7] Following Bakshi and

[5] This is partially due to tractability and partially motivated by the data that rating transition becomes unstable when average CDS spreads are high (see Figure 1).

[6] Since the common factor z is stochastic, the rating migration follows a *nonhomogeneous* Markov chain, which, as documented in Bluhm and Overbeck (2007), can generate very rich term structure for the probability of default.

[7] In general, z_t could also be a linear function of several processes as that in the affine term structure models.

Wu (2010) and Carr and Wu (2010), we assume that the price of risk for the common factor has the following form:[8]

$$\lambda(t) = \lambda_z \sqrt{z_t}. \tag{4}$$

Thus, the dynamics of z_t under the physical measure is given by

$$dz_t = \kappa_z^P \left(\theta_z^P - z_t\right) dt + \sigma_z \sqrt{z_t}\, dW_t^P, \tag{5}$$

where W_t^P is the Brownian motion under the physical measure, and

$$\kappa_z^P = \kappa_z - \sigma_z \lambda_z, \quad \theta_z^P = \kappa_z \cdot \theta_z / \kappa_z^P. \tag{6}$$

Given this physical dynamics, it is straightforward to derive the transition probability and the likelihood of the systematic factor. Although we do not explicitly specify the price of risk for rating transitions, it is indirectly modeled through the process of z. The expected transition probability of ratings under the risk-neutral measure is $E_t\left[\exp\left(\int_t^s \bar{Q}(\alpha + z_a)\, da\right)\right]$, which is different under the physical measure because of z.

The country-specific factor y, which carries no risk premium, follows a Vasicek (1977) process[9]

$$dy_t = -\kappa_y\, y_t\, dt + \sigma_y\, dW_t^y,$$

where W^y is independent of W.

There are different ways to model the loss at default process L. Although we could allow each country to have its own loss at default or countries in the same rating category to share the same level of loss of default, for convenience, we assume that all countries share the same level of loss of default. We also assume that the risk-free interest rate r is independent of z.[10] This independence assumption enables us to separate the expectations between the risk-free

[8] This form implies equation (6). The second equality in (6) makes it easier to maintain the equivalent condition between the physical and risk-neutral probability measures.

[9] Including a Vasicek process in the credit risk may cause a potential problem since it can take negative values. However, this approach is convenient and necessary in a cross-sectional context; all country-specific factors are washed out at the aggregate level. If the country-specific factors cannot be diversified away, then the undiversified portion becomes systematic. In the cross-sectional sense, the country-specific factor y acts as "error" term.

[10] This independence assumption can be relaxed through a linear relation between r and z, such as $r(s) = X(s) + \rho z_t$, where X and z are independent, and X represents other factors that affect the default-free term structure.

rate and default risk components, thus simplifying the computation of CDS spreads. In addition, our empirical results suggest that the dependence between interest rate and z is very weak (see Table 8).

Under this specific setting, we can obtain analytical pricing formula for CDS spreads (see the Appendix for details). Notice that the common and the country-specific factors are entangled together in the CDS spreads. However, we can compute the common component of CDS spread, called z-spread, by setting $y = 0$ in the formulae. In the empirical exercise, we use the z-spread to study the explanatory power of the common factor, in conjunction with credit rating, to explain the cross-sectional and time-series variations of the sovereign CDS spreads. We will also use the z-spread to define model-implied credit ratings.

3 Data and Estimation

In this section, we first introduce the data used in our empirical analysis. These data include the term structure of CDS spreads, the corresponding bid-ask spreads, and the credit ratings of the 68 countries. We then discuss and report the estimation of the rating-based sovereign credit risk model discussed in the previous section using maximum likelihood.

3.1 Data

We obtain the sovereign CDS spreads from Credit Market Analysis Ltd (CMA), which collects OTC market data on credit derivatives. The sample consists of monthly (the last Wednesday of each month) quotes of CDS spreads with maturities of 1, 2, 3, 5, 7, and 10 years from January 2004 to March 2012.[11] The dataset includes 69 countries, which have CDS contracts traded during the sample period, from North America, Europe, Asia/Pacific, Middle East, Latin America, and Africa. We exclude Malta, which has only 6 monthly observations, from our analysis for ease of presentation. The discount bond prices $P_0(t,u)$ in the valuation formula are the US Treasury zero bonds taken from a dataset provided by Gürkaynak, Sack and Wright (2007).

[11] Although the quotes of CDS spreads with maturities of 0.5, 0.75, 4, 6, 8, and 9 years are also available, we exclude them from our analysis due to their low liquidity. The restructuring type of CDS contracts is complete restructuring (CR) for all sovereigns. In our sample, the seniority for all CDS contracts is senior. All CDS contracts are quoted based on the US dollar, except for contracts referring the United States of America, which are quoted based on the Euro.

Table 2 provides a summary of important information about the 68 countries, which includes credit rating, average 5-year CDS spread, the average bid-ask spread of 5-year CDS spreads, the number of observations, and the number of rating changes for each country. The maximum number of observations for each country is 99 months. We use the top 34 countries with the most observations of the term structure of CDS spreads to estimate the model in the sample. We then use the estimated model to price the CDS spreads of the other 34 countries with fewer observations out of sample. We split the data sample as described above with two primary considerations. First, the CDS contracts of countries with the most observations are the most liquid traded contracts and may thus reflect the underlying market conditions better. Second, using the in-sample estimated model to price the out-of-sample countries offers a substantial cross-sectional test on the validity of our model, which uses credit rating as the key cross-sectional factor in sovereign credit risk market.

All the CDS spreads are denoted in basis points based on a unit notional principal. We use Standard & Poor's credit ratings obtained from Bloomberg. Following previous literature, we ignore such minor adjustments as "+" or "-" to baseline ratings and obtain seven broad rating categories from AAA to CCC (C and CC are merged into CCC). The default state includes ratings 'SD' and 'D.' Ratings reported in Table 2 represent the rating of each country at the end of the sample period.[12] While the ratings of 25 countries (12 in-sample and 13 out-of-sample) remain constant throughout the sample, certain countries experience up to 5 rating changes during the sample period. The average 5-year CDS spreads generally increase when ratings deteriorate. Among the in-sample countries, the most common rating is BBB, whereas the least common ones are AAA (Germany) and CCC (Greece).[13] Panel A (in-sample countries) of Table 3 reports the frequency of rating changes of the 34 countries used for in-sample model estimation. In total, the 34 countries have experienced 40 rating changes (under our reclassification of ratings) during the sample period. Interestingly, rating transitions typically occur between two adjacent ratings, for example, there were 4 rating changes from A to AA for the in-sample countries. A

[12] In the empirical section, we report the complete history of the evolution of the ratings of each country.

[13] After Greece's downgrade by the S&P to Selective Default (SD) on February 27, 2012, the CDS spreads of the country became extremely high. For example, the Greece 1-year CDS spreads were 57,166 and 57,644 basis points on February 29, 2012, and March 30, 2012, respectively. Thus, we remove the last two month CDS spreads of Greece in our in-sample estimation and all subsequent analyses.

similar observation also holds for the 34 out-of-sample countries. This empirical fact motivates our parametrization of the rating transition matrix as a tridiagonal matrix in Section 3.2. The top-left panel of Figure 1 plots the numbers of quarterly rating changes, and the average 5-year CDS spreads of the 34 in-sample countries. The top-right panel of Figure 1 also reports the number of rating downgrades during the sample period. Notably, rating changes and downgrades tend to increase when the CDS spreads widen.

Panel B of Table 3 reports the average CDS spreads for countries in different rating categories and at different maturities. Panel C of Table 3 also reports the average bid-ask spreads at different maturities and credit ratings. On average, we find an upward sloping term structure of CDS spreads for ratings above BB. For the CCC rating, the term structure of CDS spreads is downward sloping. The CDS spreads increase monotonically when ratings worsen. The bottom two panels of Figure 1 provide time-series plots of the average 5-year CDS spreads at different ratings. We observe a monotonically negative relation between rating and average CDS spreads. We also see huge spikes in the CDS spreads during the global financial crisis and European debt crisis.

Note that, both the mean CDS spreads and bid-ask spreads are quite different between the in-sample and out-of-sample countries. One major reason for the large differences is the uneven sample dates during the sample period, in which the CDS spreads varied greatly as shown in Figure 1. By selection, most of the in-sample quotes cover the entire sample period, whereas most of the out-of-sample quotes occur in the late part of the sample period when the sovereign risk elevates and becomes volatile.

Many studies, including the cited references, do not distinguish whether a CDS spread quote is observed or derived.[14] For dynamic models such as ours, a full term structure of CDS spreads is preferred and is sometimes necessary for model identification. Table OA.5 reports the portions of observed data in the data sample. Following common practice in the literature, we use both observed and derived data in our main empirical studies. Finally, we also estimate the model with observed data only as a robustness check.

[14] The data provider offers the derived quotes based on observed spreads. Those quotes are used for mark-to-market purpose by the CDS traders.

3.2 Maximum Likelihood Estimation

As in Pan and Singleton (2008) and Longstaff et al. (2011), we assume that the loss rate is 75% for all countries regardless of their ratings. To capture the idiosyncratic nature of country-specific factor, we assume all countries share the same set of parameters for y_j, however, each country to have its own local factor level y_j.[15] Moreover, although the y_{jt} factor is supposed to capture the idiosyncratic component of a country's default risk, it might also capture small deviations from the average default risk for a particular sovereign credit rating due to our coarse re-classification of the observed credit ratings.

We estimate the parameters using maximum likelihood. We back out the common factor z and country-specific factor y as follows. In each month, we assume that the sum of the model z-spreads of all in-sample countries (based on their current ratings) and all maturities is equal to the sum of the corresponding market CDS spreads, such that the pricing function can be inverted to obtain the common factor z. Then, for each country, we assume that the sum of CDS spreads over all maturities implied by the model with both the common and country-specific factors is equal to the sum of the observed market quotes, such that we can back out the country-specific factor y_j given z. For the j-th country, the CDS contract with maturity M is assumed to be priced with normally distributed pricing errors with mean zero and standard error σ_{jM}. The pricing errors are assumed to be independent across countries and maturities.

To estimate the model, we have to compute the log-likelihood of the observed data and the model-implied z and y_j. To compute the likelihood of transitions of ratings and default, we have to add a default state to the transition matrix as an absorbing state. Under the setup given by (2), the transition rate matrix of ratings and default state given by (A.1) for country j becomes

$$\widetilde{Q}_j(t) = \begin{bmatrix} \bar{Q} - \bar{H} & \bar{H}\mathbf{1} \\ \mathbf{0}_{1\times K} & 0 \end{bmatrix} (\alpha + z_t) + \begin{bmatrix} -I & \mathbf{1} \\ \mathbf{0}_{1\times K} & 0 \end{bmatrix} y_{jt}. \tag{7}$$

Let ϵ_{jt} be the vector of pricing errors across maturities for the CDS contracts for country j at time t, and $R_j(t)$ be the rating for country j at time t, then the likelihood function includes the

[15] This condition may look odd at first sight. For example, the country-specific factors of Germany and Greece have the same dynamics. However, as a key point of the model that is supported by our empirical studies, the main cross-sectional differences in sovereign credit risk are captured by the common factor in conjunction with credit ratings.

following four components:

- The likelihood of the pricing error ϵ_{jt} at time t given z_t, y_{jt}, and $R_j(t)$, which is independent Gaussian by assumption, across countries;
- The likelihood of rating $R_j(t)$ or default at time t given $R_j(t-\Delta)$, $z_{t-\Delta}$, z_t, $y_{j(t-\Delta)}$, and y_{jt}, across countries;
- The likelihood of y_{jt} given $y_{j(t-\Delta)}$, which is Gaussian (see, e.g., Jamshidian 1989), across countries; and
- The likelihood of z_t given $z_{t-\Delta}$, which is non-central χ^2 (see, e.g., Cox, Ingersoll and Ross 1985).

Similar to that in Farnsworth and Li (2007), we assume that the transition rate matrix $\bar{Q}$ is 7×7 tridiagonal and has the following form:

$$\bar{Q} = \begin{pmatrix} -\bar{Q}_{12} & \bar{Q}_{12} & 0 & 0 & 0 & 0 & 0 \\ \bar{Q}_{21} & -\bar{Q}_{21}-\bar{Q}_{23} & \bar{Q}_{23} & 0 & 0 & 0 & 0 \\ 0 & \bar{Q}_{21} & -\bar{Q}_{21}-\bar{Q}_{23} & \bar{Q}_{23} & 0 & 0 & 0 \\ 0 & 0 & \bar{Q}_{21} & -\bar{Q}_{21}-\bar{Q}_{23} & \bar{Q}_{23} & 0 & 0 \\ 0 & 0 & 0 & \bar{Q}_{21} & -\bar{Q}_{21}-\bar{Q}_{23} & \bar{Q}_{23} & 0 \\ 0 & 0 & 0 & 0 & \bar{Q}_{21} & -\bar{Q}_{21}-\bar{Q}_{23} & \bar{Q}_{23} \\ 0 & 0 & 0 & 0 & 0 & \bar{Q}_{76} & -\bar{Q}_{76} \end{pmatrix},$$

where $\bar{Q}_{12} > 0$, $\bar{Q}_{23} > 0$, $\bar{Q}_{21} > 0$, and $\bar{Q}_{76} > 0$.[16] This assumption significantly reduces the parameter space and is roughly consistent with the frequency of rating transitions reported in Table 3.[17]

Note that $\widetilde{Q}_j(t)$ and $\widetilde{Q}_j(s)$ as defined by (7) are commutative and so do the two constant matrices in equation (7). These commutative properties simplify the computation of likelihood

[16] We also estimate the model with all elements of the upper and lower diagonals as independent parameters. However, there seem to be some identification problems with a full tridiagonal setup. A sensible restriction would be to require that credit ratings have a stationary distribution at the long-run mean of z. Our current setup is the easiest one, although it restricts parameter space and, hence, the model's ability to fit the data. However, our experiment with more flexible setups indicates that the current setup does not have significant effect on the model's performance.

[17] This simple setting can generate similar rating migration behaviors as those reported by rating agencies as well as that reported in literature; see, e.g., Jarrow et al. (1997) and Fuertes and Kalotychou (2007).

tremendously. Specifically, the transition probabilities of ratings and default state between $t - \Delta$ and t are given by

$$\exp\left(\int_{t-\Delta}^{t} \widetilde{Q}_j(a)\,da\right).$$

However, since we do not have a continuous observation of z_a and y_{ja}, we use the following to approximate the rating transition probabilities of country j

$$E^P\left[\exp\left(\int_{t-\Delta}^{t} \widetilde{Q}_j(a)\,da\right)\middle|\, z_{t-\Delta}, z_t, y_{jt-\Delta}, y_{jt}\right],$$

where the expectation is under the physical probability measure.[18]

Given that we reclassify the observed ratings into 7 categories, $\bar{H}$ is a 7×7 diagonal matrix. To avoid potential identification problems between $\bar{H}$ and the common factor z, we fix the value of $\bar{H}_{33}$ at 1.

3.3 Parameter Estimates

Table 4 reports the maximum likelihood estimates of the parameters of three different versions of the rating-based model. Model I is the full model as described previously. All the parameter estimates of Model I are highly significant, except for α. To examine the incremental contribution of rating transition, we consider Model II, which maintains rating-dependent default intensities but does not allow transitions between different ratings. Finally, we consider Model III, which does not permit any distinctions between ratings. Likelihood ratio tests highlight the importance of credit rating in model performance and overwhelmingly reject Model III against Model II and Model II against Model I. All subsequent analyses and discussions are solely based on the estimation results of Model I reported in Table 4.

We first highlight the cross-sectional differences in default risk for different rating categories. The loading of each rating group on the common factor $\bar{H}_{kk}$ monotonically increases from 0.59 for the AAA rating to 59.90 for the CCC rating. These estimates are consistent with the empirical results reported in Table 1. They show that rating captures the relative ranking of default risk of borrowers and show that rating is an important factor for capturing the cross-sectional variations

[18] The details of the approximation can be found in the Appendix of Farnsworth and Li (2007).

of CDS spreads.

The highly significant parameter estimates of the transition matrix $\bar{Q}$ highlight the importance of rating changes. In Table 5, we translate these estimated parameters into the transition probabilities of rating changes over a one-year horizon. We find that ratings tend to be very stable and persistent. Under normal market conditions, a country has more than 87% probability to remain in its current rating over a one-year horizon. Rating transitions become more likely when the general level of default risk measured by the common factor increases. Ratings are also more stable under the physical than the risk-neutral measure.[19]

Under our framework, systematic credit risk has two components: default risk (measured by current credit rating) and rating transition risk due to rating upgrades or downgrades. To examine the importance of rating change, Table OA.8 in Online Appendix B reports the proportions of CDS spreads caused by potential rating transitions. We find that the rating transition risk component tends to be a relatively small, but significant, percentage of the total CDS spread. On average, the portion of CDS spreads explained by rating transition risk is 19.2%, which tends to be larger at short (1-year and 2-year) maturities. Moreover, for better-rated countries, a larger fraction of CDS spreads are explained by rating transition risk. The relatively small rating transition component of CDS spreads is consistent with the fact that the ratings for sovereigns are very stable with only 40 transitions for 34 countries over 8 years. Consistent with Pan and Singleton (2008) and Longstaff et al. (2011), our parameter estimates show that $\theta_z > \theta_z^P$ and $\kappa_z < \kappa_z^P$, which suggests that the default intensity has higher mean and is more persistent under the risk-neutral measure.

4 The Common Component of CDS Spreads

We first investigate the common component of sovereign CDS spreads, and the impacts of rating staleness through model implied ratings. Sovereign credit risk consists of two components in our model: common (systematic) factor and country-specific (idiosyncratic) factor. We are interested in how much the z-spreads (computed by setting $y \equiv 0$), with the observed credit ratings or

[19] Our rating migration matrix is similar to those reported by rating agencies such as Moody's, Standard & Poor's, and Fitch Ratings. Also, many studies report similar rating transition behavior as ours; see, e.g., Hu, Kiesel and Perraudin (2002), Lando and Skodeberg (2002), Wei (2003), and Hill, Brooks and Faff (2010).

with the model implied credit ratings, explain cross-sectional and time-series variations of the observed sovereign CDS spreads.

One of the advantages of our rating-based model is that we can compute the model *implied credit ratings* based on the model estimation. The average CDS spread for a given rating is determined by the common factor z only. We call this common component of the model CDS spread z-spread, which can be computed in the model by setting the country-specific factor zero. At time t, for a country with observed rating $\widetilde{k} \in \{1 = \text{AAA}, \cdots, 7 = \text{CCC}\}$, we define the model *implied* credit rating as the nearest number $k \in \{1 = \text{AAA}, \cdots, 7 = \text{CCC}\}$ to $\widetilde{k}$ such that

$$\begin{aligned} &z\text{-spread}_t(k-1) + 0.4 \times \left(z\text{-spread}_t(k) - z\text{-spread}_t(k-1)\right) \leqslant \\ &\qquad\qquad \text{either } \textbf{bid spread quote} \text{ or } \textbf{ask spread quote} \text{ at } t \\ &\qquad\qquad\qquad < z\text{-spread}_t(k) + 0.4 \times \left(z\text{-spread}_t(k+1) - z\text{-spread}_t(k)\right), \end{aligned} \tag{8}$$

with the convention z-spread(0) = 0 and z-spread(8) = ∞.[20] Notice that we can take both quote and z-spread for a particular maturity, e.g., 5 years, or average over all observed maturities in equation (8). The reported implied ratings hereafter are based on the maturity of 5 years. The results are similar if we use the average over all observed maturities.

The mean absolute pricing errors relative to the bid-ask spreads with the implied ratings (Table OA.7 in Online Appendix B) are comparable to or smaller than that with the original ratings (Table 9) across all maturities for both the in-sample and out-of-sample countries. This indicates that the way we define the implied rating does not sacrifice the model pricing performance and that country-specific factor y mainly captures the idiosyncratic, within-rating variations of a country's credit risk.

4.1 Model Common Component vs. First Principal Component of CDS Spreads

How well does our rating-based model capture the commonality embedded in the sovereign CDS spreads? What are the potential impacts on the estimated commonality caused by rating staleness? To answer these questions, we regress the 5-year market CDS spreads on the corre-

[20] We choose 0.4 as the cutoff between ratings in considering the relatively high default intensity for worse ratings (high k, see the estimates of $\bar{H}_{kk}$ reported in Table 4).

sponding z-spreads either with the observed ratings or with the implied ratings. The left and right panels of Table 6 report the regression results for the in-sample and out-of-sample countries, respectively.

We find that the z-spread can explain, on average, approximately 65% of the variations of the CDS spreads of both the in-sample and out-of-sample countries; the mean R^2 for the in-sample (out-of-sample) countries is 66% (65%), whereas the median R^2 for the in-sample (out-of-sample) countries is 75% (68%). The mean and median R^2s with the implied ratings become 90% (83%) and 91% (88%) for the in-sample (out-of-sample) countries, respectively. The R^2s of the time-series regressions for most of the countries increases significantly after replacing the observed rating with the model-implied ratings. For example, the time-series R^2 of the Philippines jumps from 0.3% to 91%.

How well does the rating-based model capture the commonality in the Sovereign CDS market? To answer this question, we conduct a principal component analysis, following Longstaff et al. (2011), on the 5-year CDS spreads of the in-sample countries. Table 6 reports the results of regressions on the extracted first principal components for the 5-year CDS spreads of both in-sample and out-of-sample countries. On average, the first principal component explains 66% of the variations of the in-sample CDS spreads, which is comparable with the in-sample performance of our model with the *observed* ratings. However, as for the out-of-sample countries,[21] our model outperforms the simple principal component analysis by a large margin in terms of regression R^2s (65% vs. 52%, the difference is significant at the 5% level). A similar conclusion can be made based on the median R^2s. In addition to the true out-of-sample nature offered by the rating-based model, it also captures well the commonality embedded in both the in-sample and out-of-sample market CDS spreads.

To further demonstrate the advantages of our rating-based credit risk model, which yields consistent term structures of credit risk, we repeat the regression exercises in Table 6 for different maturities and report the resulting average R^2s in Table 7. The rating-based model enjoys a much consistent performance across maturities for both in-sample and out-of-sample countries and with both the observed and implied ratings. Whereas the first principal component

[21]Performing a strict out-of-sample analysis for the principal component analysis is not possible because we have to estimate the coefficients of the in-sample principal components for the out-of-sample countries.

extracted from the 5-year CDS spreads of the in-sample countries explains CDS spreads less consistently across different maturities. The rating-based model with the implied rating shows much more commonality existed in the Sovereign CDS spreads than the principal component analysis suggested, which is purely data driven without any consistent no-arbitrage restrictions.

4.2 Cross-Sectional Variations

To examine the cross-sectional explanatory power of sovereign ratings, we run a regression of 5-year data CDS spreads on the 5-year z-spreads with the observed ratings across countries for every month.[22] Figure 2 plots the resulting R^2s for the in-sample countries (top), the out-of-sample countries (middle), and then a combination of both (bottom). The average R^2 over the sample period is 56% (74%) for the in-sample (out-of-sample) countries.

The in-sample cross-sectional R^2 varies from low twenties to near 90% and peaks in early 2004, late 2006 to early 2007, late 2008 to late 2009 and early 2011 to late 2011, which correspond to the "unwinding carry trade," the "subprime mortgage crisis," the "global financial crisis" and the "Eurozone debt crisis," respectively. This observation suggests that the global sovereign risk comoves more during crisis periods. Three periods exist in between the peaks when the R^2s fall notably below the sample average. These periods are from January 2005 to January 2006, March 2008 to August 2008, and January 2010 to March 2011. After the crisis, the fundamentals of some countries may have changed dramatically, and the credit ratings of these countries may fail to reflect their credit worthiness.

To examine the effects of rating staleness,we repeat the cross-sectional regressions with the implied ratings, as defined by equation (8), and the resulting R^2s (dot-dash line in Figure 2) become much higher, reaching 90% on average, and less volatile over time.

As for the out-of-sample countries, the cross-sectional R^2s with the observed ratings dropped during the global financial crisis and the Eurozone debt crisis when the countries with stale ratings emerged. The average cross-sectional R^2 dramatically increase from 74% to 91% with the model implied ratings. The bottom panel of Figure 2 depicts the cross-sectional R^2s for the combined both the in-sample and out-of-sample countries with the observed rating and with

[22]We also redo this exercise with average CDS spreads over maturities, and obtained similar results.

the implied ratings. With the model implied ratings, the resulting cross-sectional R^2s for the pooled sample vary between 70% to almost 100% over the sample period. These different sampling results show that credit rating is the key cross-sectional variable that drives the main cross-sectional variations in the sovereign CDS spreads.

The proportion of rating staleness implied by our model is 46% (28%) for the in-sample (out-of-sample) countries. In general, the cross-sectional R^2 tends to correlate negatively with the proportion of the rating staleness. In general, the model implied ratings are relatively stable over time; thus, the improvements on the cross-sectional R^2s are not through high-frequency changes of the implied ratings.

4.3 Nature of the Common Factor and Risk Premium

Given the importance of the common factor, we study the economic forces that drive the fluctuations of z_t and the sovereign credit risk premium. For maturity τ and credit rating i, the risk premium is defined as (see Pan and Singleton 2008)

$$CRP_i(t, t+\tau) \equiv CDS_i(t, t+\tau) - CDS_i^P(t, t+\tau), \tag{9}$$

where $CDS_i(t, t+\tau)$ is the τ-year CDS spreads, and $CDS_i^P(t, t+\tau)$ is the τ-year CDS spreads obtained from (A.7) by setting the price of risk to zero [e.g., setting $\lambda_z = 0$ in (4)]. We are also interested in the risk premium fraction of CDS spread defined as

$$RPF_i(t, t+\tau) \equiv \frac{CDS_i(t, t+\tau) - CDS_i^P(t, t+\tau)}{CDS_i(t, t+\tau)}. \tag{10}$$

Table 8 reports the regressions of changes in z_t and the first principal component on six key financial market variables, namely, the volatility VIX index, the MSCI World stock index, the DAX stock index, the S&P 500 stock index, corporate credit risk index [CDX NA IG (North America, Investment Grade)], and the 5-year constant maturity Treasury yield, individually and collectively. Individually, all these market variables, except the Treasury yield, are highly significant and can explain close to or more than 30% of the variations of the common factor z. All three stock indexes are negatively correlated with the common factor and the first principal component, such that when the World economy improves, so does the World sovereign credit risk. As expected, the volatility index VIX and the corporate credit risk index CDX are positively correlated with the World sovereign credit risk.

Collectively, only the volatility index VIX and the MSCI World stock index remain highly significant in explaining the common factor z and the first principal component. Jointly, the VIX and MSCI World stock indices explain more than 50% of the variations of the common factor and the first principal component. On the other hand, the S&P 500 stock index of the US, the DAX stock index of Germany, and the corporate credit risk index CDX become insignificant, and the improvement in the regression R^2 also becomes insignificant by including these three market indexes as additional explanatory variables.

One important advantage of the rating-based model is that we can jointly use the CDS spreads of all in-sample countries to estimate the common default factor, which considerably increases estimation efficiency. Thus, the model structure and estimation method significantly improve our ability to identify the common factor.

Figure 3 plots the time series of the common factor z (top-left panel) and the average credit risk premium CRP at different ratings (middle-left panel) and maturities (bottom-left panel) during our sample period. Notably, both the common factor and the risk premium CRP for all ratings increased dramatically during the global financial crisis and the Eurozone debt crisis. The right panels in Figure 3 plot the time series of the price of risk, average fractions of credit risk premium of CDS spreads at different ratings and maturities. The price of risk varies between 0.02 to 0.92 and peaks around 0.9 during the global financial crisis and Eurozone debt crisis. Meanwhile, the fractions of risk premium are relatively stable, varying around 30% for the top 5 ratings and around 20% for the 2 bottom ratings. Whereas the average fraction of risk premium increases with maturities, varying around 10% for 1-year CDS contracts to 45% for 10-year CDS contracts. We also report the average credit risk premium and the fraction of risk premium across maturities for each country in Table OA.12 in Online Appendix B.

We also conduct some analyses about the economic forces that drive the fluctuations of the country-specific factor y_t and report the results in Online Appendix B. We find that, on average, more than half of the variations of country-specific factors can be explained by five local macro economic variables (GDP growth rate, GDP per capita, government effectiveness, the s-tock market return of the country, and the total reserve of the country). The resulting regression coefficients, reported in Table OA.13 in Online Appendix B, vary dramatically across countries in signs, magnitudes, and significance. This reflects the idiosyncratic nature of the country-specific factors.

5 Comparison with One-Factor Model

We use a one-factor model as a benchmark to assess the empirical performance of our rating-based sovereign credit risk model. We estimate one-factor model country by country for the 34 in-sample countries and then compare the pricing and forecasting performances between these two models. The estimated one-factor model is based on CIR process, similar to our common factor. The model details and full estimation results are presented in Online Appendix A. Specifically, we estimate two versions of the one-factor model: one has a more flexible setup on the price of risk with 5 model parameters; the other has 4 model parameters. The key results of relative pricing errors and Sharpe ratio ranges are reported in Table 10.

5.1 Pricing Performance

Now we turn to examine the pricing performance of the rating-based model with full spreads, including both common factor z and country-specific factor y, which can be extracted for the out-of-sample countries similarly as for the in-sample countries. The left (right) panel of Table 9 reports the mean absolute pricing error relative to the bid-ask spread for the 34 in-sample (out-of-sample) countries over the sample period. In general, the model pricing errors are quite small compared with the observed bid-ask spreads. For most countries at intermediate maturities (2 to 7 years), the average absolute pricing errors are comparable with the average bid-ask spreads. The relative pricing errors are larger for 1- and 10-year maturities. Notably, the relative pricing errors for the out-of-sample countries are generally similar to that of the in-sample countries.

We find that the pricing performance of our rating-based model reported in Table 9 is comparable to that of the country-by-country estimation of the 5-parameter model reported in Table 10. However, Table 10 also shows that the country-by-country estimation of the one-factor 5-

parameter model has some undesirable features, e.g., very large or negative price of risk (Sharpe ratio) for some countries and explosive behavior of the underlying factors under risk-neutral measure. We then reduce the flexibility of the 5-parameter one-factor model, re-estimate the 4-parameter version of the one-factor model, and report the relative pricing errors and Sharpe ratio ranges in Table 10. We find that the estimated Sharpe ratios improve, the pricing performance, however, worsens significantly.

Overall, our rating-based sovereign credit risk model does not only capture the commonality well but also performs well in capturing the term structures of CDS spreads for both in-sample and out-of-sample countries. In particular, our rating-based model achieves these good performances with a generic dynamic setup for country-specific factors. This evidence supports our assumption that country-specific factors are more or less idiosyncratic.

5.2 Conditional Distribution of CDS Portfolio Value

One potential application of our rating-based model is to use it to manage the risk of a sovereign CDS portfolio. This, however, depends on whether the model does a reasonable job in forecasting the distribution of future CDS portfolio values. To assess portfolio forecasting ability of our rating-based model, we compute the one-month forward conditional distribution of an equal-weighted (in notational amounts and \$100 in total) sovereign CDS portfolio of the 34 in-sample countries by simulations. The portfolio consists of par CDS contracts, and thus, its value is zero at month $t-1$. We then use the observed CDS spreads at month t to calculate the market value of this CDS portfolio formed at month $t-1$. If a model-based conditional distribution of this portfolio is close to reality, the resulting CDF of the portfolio value at t should form a uniform distribution on [0, 1] over observations and is identical and independent across observations (see Diebold, Gunther and Tay 1998).

The top-left panel of Figure 4 plots the histogram of the CDFs over the sample period and the bottom-left panel is a scatter plot of CDF_{t-1} and CDF_t. Both plots indicate that our rating-based model performs reasonably well, especially compared to the same plots for the one-factor model (5-parameter version) in the right-column of the same figure. Moreover, we also conduct a couple of formal tests, Kolmogorov-Smirnov and χ^2 goodness-of-fit, for the CDFs being the uniform distribution on [0, 1]. Our rating-based model passes both tests with p-values over 10%. On the other hand, the one-factor model fails these tests with p-values close to zero.

One of the reasons for the dramatically different results is that the one-factor model tends to over fit the CDS spreads of individual countries with extreme parameters (see Table OA.1). This is particularly the case for countries experienced several major downgrades. For example, Greece has several downgrades over the sample period, and the CDS spreads of Greece range from a couple of basis points in the early sample period to tens of thousand basis points just before default. It has to take extreme parameters to fit such an explosive dynamics for a one-factor model. Thus, it forecasts poorly. On the other hand, our rating-based model explicitly uses regime (credit rating) to accommodate the explosive behavior caused by rating migrations. Therefore, our rating-based sovereign credit risk model can fit a cross section of CDS spreads without resorting to extreme parameter values, which may result in poor model forecasts of credit portfolio values.

6 Applications

6.1 Density Forecasts of Sovereign CDS Portfolio Values

As discussed in Section 5.2, the conditional distribution of future CDS portfolio values generated by our rating-based model is quite consistent with the distribution of realized market values of CDS portfolio. Thus, our rating-based model can be used to manage the risk of sovereign CDS portfolios. Figure 5 illustrates several examples of such applications for both our rating-based model and the one-factor model described in Online Appendix A. The figure plots the one-month forward conditional densities (histograms) of an equal-weighted CDS portfolio generated by simulations based on both our rating-based and one-factor models, and VARs can be simply calculated from these conditional distributions.

As illustrated by the examples in Figure 5, the rating-based model yields much wider conditional distributions of the equal-weighted CDS portfolio value that spreads over both negative and positive values. On the other hand, the conditional distributions generated by the one-factor model cluster over a narrow range of positive values for all three cases. These results are consistent with the discussions in Section 5.2. The purpose of our rating-based model is not to fit individual sovereign CDS contracts perfectly but is to fit a sovereign CDS portfolio well with reasonable conditional forecasting. It is similar to the idea widely used in the asset pricing literature that it is much easier and relevant to study portfolios rather than individual stock.

6.2 Pricing Errors and Potential Future Rating Changes

As indicated by the pricing analyses, the model can well capture the CDS spreads for both in-sample and out-of-sample countries with stable ratings. However, the model tends to have larger pricing errors for countries that undergo dramatic economic developments, which may cause their ratings to change. This feature of the model, however, does not necessarily represent a shortcoming. Large pricing error provides a warning sign to investors for potential rating changes in the near future. We verify this idea formally by the predictive regressions reported in Table 11. The results presented in Table 11 indicate that pricing errors significantly predict future rating changes. For example, the reported probit regression (Panel B) suggests that the probability of near future rating changes is increased by 40% if pricing error increases by one-hundred basis points. By contrast, although existing reduced-form models might be capable of selecting the latent factors to fit individual CDS spreads well, these models may have difficulty in providing insights into whether the changes in CDS spreads are actually due to changes in the economic fundamentals of the sovereign borrower. We further illustrate this point and other model implications more concretely in the Eurozone Debt Crisis.

6.3 Eurozone Debt Crisis

The global financial crisis and the Eurozone debt crisis had clear effects on sovereign credit risk for many countries. The countries that were the most affected by these events were, of course, the Eurozone countries. The 2008 global financial crisis served as a real-time stress test, which exposed the hidden problems of some Eurozone countries inherited by these welfare states with stretched low economic growth coupled with relatively high growth in sovereign debt. Since the 2008 global financial crisis, sovereign market participants started to reassess the credit worthiness of the Eurozone countries, and the standing credit ratings did not reflect the underlying credit risk of these countries, in particular for the GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain). Greece was the first one to fall; all three major rating agencies, namely, Fitch, Moody's, and S&P, downgraded Greece to CCC in January 2011. The Eurozone debt crisis reached its peak on December 5, 2011, on which S&P placed Germany, France, and 13 other Eurozone countries (Austria, Belgium, Estonia, Finland, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovak, Slovenia, and Spain) on negative credit watch. One month later, on January 13, 2012, S&P cut the ratings of Cyprus, Italy, Spain, and Portugal by two notches and the standings of Austria, France, Malta, Slovakia, and Slovenia by one notch each.

The time-series pricing errors for the 12 Eurozone countries in our dataset well reflect the unfolding of the Eurozone debt crisis but from a different perspective, as shown in Figure 6. Before the 2008 global financial crisis, the pricing errors for both in-sample and out-of-sample countries were relatively small and stable. The pricing errors for some countries during this period were higher than the bid-ask spreads. However, parts of the relatively "large" pricing errors might be attributed to very low bid-ask spreads, usually in low single digits of basis points. The pricing errors jumped to significantly higher levels and became unstable, especially for the GIIPS[23] countries, since the 2008 global financial crisis. The in-sample countries include three GIIPS countries, Greece, Italy, and Portugal. S&P went through a series of negative watches and subsequent downgrades on the credit standing of Greece. However, these downgrades failed to catch up with the rapid deterioration of Greek economic growth, fiscal conditions, and political uncertainty caused by austerity measure. The average absolute pricing errors for Greece reached in the 2,000s in basis points before the country's default in February 2012. The countries with the second and third highest pricing errors during this period were Portugal and Italy, respectively. The relative magnitude of the pricing errors reflected the severity of the default risk of each of the three in-sample GIIPS countries. As expected, the other three in-sample countries had much smaller pricing errors due to their relatively strong underlying economies and relatively lower debt levels. However, we do see some market concerns for Austria and Belgium, which were downgraded in January 2012. Although Germany was also placed on the negative watch list by

[23]Several versions of the acronym of GIIPS emerged to refer the troubled Eurozone countries during the Eurozone debt crisis in the popular press. Other versions include GIPS (without Italy), GIIIPS (adding Iceland), and GGIIPS (adding Great Britain).

S&P in December 2011, the major concern was that Germany might have to bail out the troubled Eurozone countries, it survived this negative credit watch.

The time-series pricing errors of the six out-of-sample Eurozone countries paint a similar picture as that of the in-sample countries. Among the out-of-sample countries during the crisis period, the two out-of-sample GIIPS countries, Ireland and Spain, had the largest pricing errors, followed by France and England. Meanwhile, Finland and Netherlands did not fully participate in the crisis due to their relatively strong fiscal conditions. Although these two countries were also on the negative watch list in December 2011, their triple-A ratings survived this credit reviews.

We also plot the model-implied credit ratings in Figure 6 along with the observed ratings (S&P's). In general, the large deviations between the implied and observed ratings tend to associate with large pricing errors. Large pricing errors and lower implied ratings did appear before rating downgrades for Austria, Greece, Italy, and Italy of the in-sample countries, and France, Ireland, Spain of the out-of-sample countries. However, for the rest of the Eurozone countries in our sample, both pricing errors and model implied ratings remained relatively stable and survived the negative credit watch issued by S&P in December 2011.

7 Conclusion

In this paper, we apply a rating-based continuous-time no-arbitrage model to incorporate the commonality observed in the sovereign credit markets. Credit rating captures a country's default risk sensitivity to the common sovereign risk factor, and rating transitions capture the discrete jumps of this sensitivity. One of the advantages of our approach is that it offers a parsimonious and unified framework to capture the credit risk of multiple countries simultaneously. This, in turn, enables us to better estimate the underlying model parameters and risk factor risk premium.

Our empirical exercises show that our rating-based model captures the embedded commonality in the sovereign credit risk markets well for both the in-sample and out-of-sample countries. The estimated model produces a much reasonable price of risk and dynamics of the common factor. Thus, our rating-based sovereign credit risk model yields much more consistent conditional forecasts of sovereign CDS portfolio values than the one-factor model, which tends to overfit CDS spreads. The model pricing errors and implied credit ratings are also useful in understanding the dynamics of sovereign credit markets.

Overall, our study shows that incorporating sovereign credit rating, a key credit variable widely used in practice, into no-arbitrage models is very important to understand the global sovereign credit markets. Instead of viewing each sovereign entity as independent borrowers, credit ratings, at least partially, integrate all sovereign borrowers into a unified global sovereign credit market. This may be one of the reasons why there exists a strong commonality in the global sovereign credit market. Our rating-based no-arbitrage model captures this commonality well and offers useful insights to understand the global sovereign credit markets. We expect that credit rating plays a similar role in corporate credit markets, in which our rating-based model can be even more useful to understand corporate credit risk due to the much larger number of corporate borrowers.

Appendix Pricing Equation and Formulas

CDS Spreads in a Rating-Based Credit Risk Model

In this appendix, we first present a rating-based continuous-time sovereign credit risk model under the reduced-form framework[24] and derive rating-based CDS spreads.[25] We then consider a special version of the model with one common and one country-specific factor with closed-form solutions for our empirical study. Throughout the analysis, we assume that there exists a risk-neutral probability space $(\Omega, \mathcal{F}, \mathbf{F}, \mathcal{Q})$, under which all securities can be priced appropriately. In this paper, all expectations are taken under this risk-neutral probability measure $\mathcal{Q}$, unless otherwise stated.

Suppose all sovereign borrowers can be classified into K possible credit rating categories (excluding the default state) and that the rating for each country follows a continuous-time Markov chain characterized by a common $K \times K$ transition *rate* matrix[26]

$$Q(t) = \{q_{ik}(t)\}_{\{i,k=1,\ldots,K\}},$$

where $\sum_{k=1}^{K} q_{ik}(t) = 0$ and $q_{ik}(t) \geq 0$ for all $i \neq k$ and t. Intuitively, $q_{ik}(t)$ is the *rate* (*intensity*) of rating transition from i to $k \neq i$: over a short horizon Δt, the conditional probability for a rating change from i to $k \neq i$ is approximately $q_{ik}(t)\Delta t$, and the conditional probability of staying in i is $1 + q_{ii}(t)\Delta t$, therefore, $q_{ii}(t) = -\sum_{k=1,\, k\neq i}^{K} q_{ik}(t) < 0$.[27]

If a country is rated $i \in \{1, \cdots, K\}$, then its hazard rate of default is $h_i(t)$. Denote $H(t)$ as a $K \times K$ diagonal matrix with its diagonal element $H_{ii}(t) = h_i(t)$, which is a continuous process

[24] Unlike the *structural* approach of Merton (1974), the *reduced-form* formation of credit risk does not depend on the detailed structure of fundamentals. Thus, the idea of modeling corporate credit risk can be directly applied to modeling sovereign credit risk.

[25] Rating-based credit risk models have been studied in many papers including Jarrow and Turnbull (1995), Jarrow et al. (1997), Lando (1998), Li (2000), Farnsworth and Li (2007), among others. This paper focuses on model specifications that are tractable for sovereign CDS pricing and associated empirical studies.

[26] This is also known as intensity matrix or infinitesimal generator matrix.

[27] When $Q(t)$ is a constant matrix Q, the transition probability matrix $\widehat{Q}_t$ (over a time interval of length t) admits a simple form as

$$\widehat{Q}_t = e^{tQ} = I + \sum_{n=1}^{\infty} t^n \frac{Q^n}{n!},$$

where I is the identity matrix. We can therefore see that summation over rows of $\widehat{Q}$ being 1 is equivalent to summation over rows of Q equal to 0, e.g., $Q\mathbf{1} = \mathbf{0}$ implies $\widehat{Q}_t\mathbf{1} = \mathbf{1}$, and *vice versa*, where $\mathbf{1}$ is a vector of 1s.

and represents the default intensity of a country with rating i. If we pool the K ratings and the default-state together, then the augmented rating transition rate matrix of the $K+1$ states can be written as (default is an absorbing state)

$$\widetilde{Q}(t) = \{\widetilde{q}_{ik}(t)\}_{\{i,k=1,\ldots,K+1\}} =: \begin{bmatrix} Q(t) - H(t) & H(t)\mathbf{1} \\ \mathbf{0}_{1\times K} & 0 \end{bmatrix}, \tag{A.1}$$

where $\mathbf{1}$ is $K \times 1$ vector of ones and $\mathbf{0}_{1\times K}$ is a $1 \times K$ vector of zeros.

Let $P(t,T)$ be the $K \times 1$ price vector associated with a $K \times 1$ payoff $P(T)$ at maturity T if no default happens up to T, and a $K \times 1$ vector payoff $P^D(s)$ if default happens at $s \leqslant T$.[28]

Given a generic country with rating $i \in \{1,2,\ldots,K\}$ at time $t-$, Itô's Lemma implies that the (risk-neutral) instantaneous expected return of an associated defaultable security is (note that, for $i \in \{1,2,\ldots,K\}$, $\widetilde{q}_{i,K+1}(t) = h_i(t)$ and $\widetilde{q}_{ik}(t) = q_{ik}(t)$, $\forall\, k \leq K$, $k \neq i$)[29]

$$\frac{1}{P_i(t,T)} \left\{ E_t\left[dP_i(t,T)\right] + \sum_{k=1}^{K} q_{ik}(t)\left(P_k(t,T) - P_i(t,T)\right)dt + h_i(t)\left(P_i^D(t) - P_i(t,T)\right)dt \right\}.$$

As no-arbitrage requires the risk-neutral instantaneous expected return must be the same as the risk-free rate, thus, we have

$$E_t[dP_i(t,T)] + \sum_{k=1}^{K} q_{ik}(t)\left(P_k(t,T) - P_i(t,T)\right)dt + h_i(t)\left(P_i^D(t) - P_i(t,T)\right)dt = r(t)P_i(t,T)\,dt,$$

where r is the risk-free interest rate. Let I be the $K \times K$ identity matrix. By the fact that $\sum_{k=1}^{K} q_{ik}(t) = 0$, we can rewrite the equation in terms of vectors and matrices as

$$E_t[dP(t,T)] = [r(t)I + H(t)]P(t,T)\,dt - Q(t)P(t,T)\,dt - H(t)P^D(t)\,dt, \tag{A.2}$$

where Q, H, and P^D (a $K \times 1$ vector) are some suitable measurable stochastic processes.

[28] $P_i^D(s)$ is the payoff given that the reference country defaults directly from rating i at time $s \leqslant T$.

[29] See Farnsworth and Li (2007), Lando (1998), or Li (2000) for rigorous treatments.

It can be shown that pricing equation (A.2) is equivalent to the following pricing equation:[30]

$$P(t,T) = E_t \left[\exp\left(-\int_t^T r(s)\,ds \right) \Phi(t,T) P(T) \right.$$
$$\left. + \int_t^T \exp\left(-\int_t^s r(a) da \right) \Phi(t,s) H(s) P^D(s)\,ds \right], \quad \text{(A.3)}$$

where $\Phi(t,s)$ is defined as the solution to the following matrix differential equation[31]

$$\frac{d\Phi(t,s)}{dt} = -[Q(t) - H(t)]\Phi(t,s),\ 0 \le t < s, \quad \text{(A.4)}$$

with terminal condition $\Phi(s,s) = I$.

Pricing equation (A.3) has a natural and intuitive interpretation. Here, $\Phi(t,s)$ is the probability matrix that the security has not defaulted up to time s, $H(s)ds$ is the default probability matrix over ds, $P^D(s)$ is the cash flow vector when the security defaults, and $P(T)$ is the cash flow vector if the security does not default up to T. Thus, the summation (integration) over all expected discounted cash flows under the risk-neutral probability yields the price of the security.

A single-country CDS buyer pays a constant premium c in exchange for a one-time cash flow $\mathbf{1} - P^D(s) = L(s)\mathbf{1}$ when a reference country defaults at date s. Here $\mathbf{1}$ is a $K \times 1$ vector with all elements being 1. The protection buyer also stops paying any remaining premium after default. To compute for the value of the premium (fixed) leg of a CDS contract, we simply substitute $P(T) = c\Delta t\mathbf{1}$ and $P^D(s) = 0$ in equation (A.3) for $T = T_m$, $m = 1, \cdots, M$.[32] Thus, the value of

[30] For a coupon bond, $P(T) = \mathbf{1}$. The model can easily price credit linked notes by setting appropriate rating-dependent terminal payoff $P(T)$.

[31] For any squared matrix A, the matrix exponential is defined as $e^A = \sum_{n=0}^{\infty} \frac{A^n}{n!}$. If $Q(t) - H(t)$ is a constant matrix $Q - H$, we have $\Phi(t,s) = e^{(s-t)(Q-H)}$.

[32] Accruals can be easily accounted by setting $P^D(s) = (s - n_s\Delta t)\mathbf{1}$, where n_s is the greatest integer that is smaller than $s/\Delta t$. In this case, we have

$$P_{fx}(t,T) = \Delta t \sum_{m=1}^{M} E_t \left[\exp\left(-\int_t^{T_m} r(s)\,ds \right) \Phi(t,T_m) \right] \mathbf{1}$$
$$+ E_t \left[\int_t^T \exp\left(-\int_t^s r(a)\,da \right) \Phi(t,s) H(s) \,(s - n_s\Delta t)\, ds \right] \mathbf{1}.$$

The extra term is similar to the valuation of the floating leg of a CDS.

the fixed leg is $cP_{fx}(t,T)$, where

$$P_{fx}(t,T) = \Delta t \sum_{m=1}^{M} E_t \left[\exp\left(-\int_t^{T_m} r(s)\, ds \right) \Phi(t,T_m) \right] \mathbf{1}, \tag{A.5}$$

$\Delta t = T_{m+1} - T_m$, and $T_M = T$.

For the default (floating) leg, substituting $P(T) = 0$ and $P^D(s) = L(s)\mathbf{1}$ into equation (A.2) yields the value of the floating leg:

$$P_{fl}(t,T) = E_t \left[\int_t^T \exp\left(-\int_t^s r(a)\, da \right) \Phi(t,s) H(s) L(s)\, ds \right] \mathbf{1}. \tag{A.6}$$

If the reference country is rated i at t, then the premium c is given by

$$\mathrm{CDS}_i(t,T) = \frac{\mathbf{1}_i^\top P_{fl}(t,T)}{\mathbf{1}_i^\top P_{fx}(t,T)}, \tag{A.7}$$

where $\mathbf{1}_i$ is a $K \times 1$ vector of zeros except that its ith element equals 1.

Analytical Pricing Formulas used in Empirical Study

The key to the computation of the pricing formulae (A.5) and (A.6) is to compute $E_t[\Phi(t,s)]$ and $E_t[\Phi(t,s)H(s)]$. Since the specifications given in (2) enable that $Q(t) - H(t)$ and $Q(s) - H(s)$ are commutative for all $t \neq s$, Φ as defined by (A.4) has a closed-form solution as follows:

$$\Phi(t,s) = \Omega \exp\left(\Lambda \int_t^s (\alpha + z_a)\, da - I \int_t^s y_a\, da \right) \Omega^{-1},$$

where $\Omega \Lambda \Omega^{-1} = \bar{Q} - \bar{H}$, and Λ is a $K \times K$ diagonal matrix with its diagonal elements $\Lambda_{ii},\ i = 1, \ldots, K$, being eigenvalues of $\bar{Q} - \bar{H}$. Since Λ is a diagonal matrix, we have that

$$\exp\left(\Lambda \int_t^s (\alpha + z_a)\, da - I \int_t^s y_a\, da \right)$$

is also a diagonal matrix with its ith diagonal element being

$$\exp\left(\Lambda_{ii} \int_t^s (\alpha + z_a)\, da - \int_t^s y_a\, da \right).$$

It is straightforward to show that

$$E_t[\Phi(t,s)] = \hat{p}_1(\tau, y_t)\Omega\,\Gamma^1(\tau, z_t)\Omega^{-1}, \tag{A.8}$$

where $\tau = s - t$, and Γ^1 is a diagonal matrix with its diagonal elements equal to

$$\Gamma^1_{ii}(\tau, z_t) = p_0(\tau, \alpha\Lambda_{ii})p_1(\tau, z_t, \Lambda_{ii}),\ i = 1, \ldots, K.$$

We can also show that

$$E_t[\Phi(t,s)H(s)] = \Omega\,[\hat{p}_1(\tau, y_t)\Gamma^2(\tau, z_t) + \hat{p}_2(\tau, y_t)\Gamma^1(\tau, z_t)]\Omega^{-1}\bar{H}, \tag{A.9}$$

where Γ^2 is a diagonal matrix with its diagonal elements equal to

$$\Gamma^2_{ii}(\tau, z_t) = p_0(\tau, \alpha\Lambda_{ii})[\alpha p_1(\tau, z_t, \Lambda_{ii}) + p_2(\tau, z_t, \Lambda_{ii})],\ i = 1, \ldots, K.$$

Here, for $\tau = s - t$, p_0, p_1, and p_2 are given by

$$\begin{aligned}
p_0(\tau, \beta) &= \exp(\beta\tau), \\
p_1(\tau, z_t, \beta) &= E_t\left[\exp\left(\beta\int_t^s z_a\,da\right)\right] = A(\beta,\tau)e^{B(\beta,\tau)z_t}, \\
p_2(\tau, z_t, \beta) &= E_t\left[z_s\exp\left(\beta\int_t^s z_a\,da\right)\right] = [C(\beta,\tau) + D(\beta,\tau)z_t]e^{B(\beta,\tau)z_t},
\end{aligned}$$

and, for any β,

$$\begin{aligned}
A(\beta,\tau) &= \exp\left(\frac{\kappa_z\theta_z(\phi+\kappa_z)}{\sigma_z^2}\tau\right)\left(\frac{1-\gamma}{1-\gamma e^{\phi\tau}}\right)^{\frac{2\kappa_z\theta_z}{\sigma_z^2}}, \\
B(\beta,\tau) &= \frac{\kappa_z-\phi}{\sigma_z^2} + \frac{2\phi}{\sigma_z^2(1-\gamma e^{\phi\tau})}, \\
C(\beta,\tau) &= \frac{\kappa_z\theta_z}{\phi}(e^{\phi\tau}-1)\exp\left(\frac{\kappa_z\theta_z(\phi+\kappa_z)}{\sigma_z^2}\tau\right)\left(\frac{1-\gamma}{1-\gamma e^{\phi\tau}}\right)^{\frac{2\kappa_z\theta_z}{\sigma_z^2}+1}, \\
D(\beta,\tau) &= \exp\left(\frac{\kappa_z\theta_z(\phi+\kappa_z)+\phi\sigma_z^2}{\sigma^2}\tau\right)\left(\frac{1-\gamma}{1-\gamma e^{\phi\tau}}\right)^{\frac{2\kappa_z\theta_z}{\sigma_z^2}+2}, \\
\phi &= \sqrt{-2\beta\sigma_z^2+\kappa_z^2}, \qquad \gamma = \frac{\kappa_z+\phi}{\kappa_z-\phi}.
\end{aligned}$$

Meanwhile, $\hat{p}_1$ and $\hat{p}_2$ are given by (see, e.g., Jamshidian 1989)

$$\begin{aligned}\hat{p}_1(\tau, y_t) &= E_t\left[\exp\left(-\int_t^s y_a da\right)\right] = \hat{A}(\tau)e^{-\hat{B}(\tau)y_t},\\ \hat{p}_2(\tau, y_t) &= E_t\left[y_s \exp\left(-\int_t^s y_a da\right)\right] = \left[\hat{C}(\tau) + \hat{D}(\tau)y_t\right]e^{-\hat{B}(\tau)y_t},\end{aligned}$$

where $\tau = s - t$, and

$$\begin{aligned}\hat{A}(\tau) &= \exp\left(-\frac{\sigma_y^2}{2\kappa_y^2}(\hat{B}(\tau) - \tau) - \frac{\sigma_y^2 \hat{B}^2(\tau)}{4\kappa_y}\right),\\ \hat{B}(\tau) &= \frac{1 - e^{-\kappa_y \tau}}{\kappa_y}, \qquad \hat{C}(\tau) = -\frac{\sigma_y^2 \hat{B}^2(\tau)}{2}\hat{A}(\tau), \qquad \hat{D}(\tau) = e^{-\kappa_y \tau}\hat{A}(\tau).\end{aligned}$$

Substituting formulae (A.8) and (A.9) together with the default-free bond price

$$P_0(t, s) = E_t\left[\exp\left(-\int_t^s r_a\, da\right)\right] \tag{A.10}$$

into equations (A.5), (A.6), and (A.7) yields the CDS spreads. A numerical integration is needed to compute (A.6) for the floating leg

$$P_{fl}(t, T) = \Omega\left[\int_t^T P_0(t, s)\left[\hat{p}_1(\tau, y_t)\Gamma^2(\tau, z_t) + \hat{p}_2(\tau, y_t)\Gamma^1(\tau, z_t)\right] ds\right]\Omega^{-1}\bar{H}L\mathbf{1},$$

where $\tau = s - t$ and $P_0(t, s)$ is the price of default-free zero coupon bonds.

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Table 1: OLS Regressions of CDS Spreads on VIX and the First Principal Component by Credit Rating. We use monthly data of CDS spreads for the top 34 (out of 68) counties with the most complete observations, and group their 5-year CDS spreads into 7 classes by the corresponding observed credit ratings. Within each rating class, we then regress 5-year CDS spreads on the contemporaneous observations of VIX and on the first principal component. The first principal component is extracted from the changes of 5-year CDS spreads of the 34 selected countries. We re-scale the independent variables such that the coefficient β for rating A equals to 1. ΔCDS denotes the first order difference of CDS spreads. NoO represents the number of observations used in the regression.

	CDS on VIX				ΔCDS on First PC			
Rating	β	t-stat.	Adj-R^2	NoO	β	t-stat.	Adj-R^2	NoO
AAA	0.48	10.05	34.26	193	0.48	12.60	45.64	189
AA	0.64	12.73	28.81	399	0.51	20.56	52.15	388
A	1.00	25.97	41.63	945	1.00	32.92	53.84	929
BBB	1.94	25.01	40.18	931	1.66	45.03	69.04	910
BB	2.31	10.99	14.49	708	2.71	18.08	32.11	690
B	7.83	12.09	59.19	101	9.97	14.36	69.74	90
CCC	13.50	1.12	1.23	21	28.47	3.67	40.91	19

Table 2: General Information of Sovereign CDS Contracts of 68 Countries. This table provides general information on the 34 in-sample and 34 out-of-sample countries between January 2004 and March 2012. We have monthly observations of the term structure of CDS spreads with bid-ask spreads and credit ratings from the S&P's. MoCDS represents the monthly average of 5-year CDS spreads, MoBAS represents the monthly average of the bid-ask spreads of 5-year CDS spreads, NoO is the number of observations, and NoTR is the number of rating transitions (under our reclassification of ratings) during the sample period. The reported rating for each country is the S&P's rating in the last month of the sample period. For the case of Greece, the reported rating is the one before its default.

In-Sample Countries							Out-of-Sample Countries						
SN	Rating	Country	MoCDS	MoBAS	NoO	NoRT	SN	Rating	Country	MoCDS	MoBAS	NoO	NoRT
1	AAA	Germany	23.5	2.6	99	0	35	AAA	Australia	62.0	5.8	45	0
2	AA	Austria	47.9	3.5	97	1	36	AAA	Denmark	48.2	4.8	59	0
3	AA	Belgium	59.7	4.2	99	0	37	AAA	Finland	33.3	4.2	56	0
4	AA	China	62.4	4.8	99	2	38	AAA	Hong Kong	39.8	6.0	86	2
5	AA	Czech	57.7	6.6	99	1	39	AAA	Netherlands	41.0	4.3	65	0
6	AA	Japan	38.6	3.7	98	0	40	AAA	Norway	25.4	4.6	49	0
7	AA	Qatar	75.3	10.3	95	1	41	AAA	Sweden	41.4	4.5	58	1
8	A	Chile	66.9	10.0	94	0	42	AAA	Switzerland	55.2	9.0	39	0
9	A	Israel	89.0	10.8	95	0	43	AAA	UK	57.8	4.0	59	0
10	A	Korea	93.0	5.1	99	0	44	AA	Abu Dhabi	152.6	13.1	36	0
11	A	Malaysia	77.1	5.6	99	0	45	AA	Estonia	180.5	19.1	54	1
12	A	Poland	89.9	5.9	99	1	46	AA	France	46.7	2.9	80	1
13	A	Slovakia	60.7	7.7	94	1	47	AA	New Zealand	75.0	7.1	39	0
14	BBB	Brazil	211.2	6.2	97	2	48	AA	Saudi Arabia	136.5	19.5	33	1
15	BBB	Bulgaria	167.2	11.7	99	1	49	AA	USA	34.8	4.7	58	1
16	BBB	Colombia	207.7	9.4	99	1	50	A	Slovenia	111.8	9.8	49	2
17	BBB	Croatia	166.7	13.5	99	0	51	A	Spain	143.3	5.0	65	3
18	BBB	Iceland	213.1	24.4	96	3	52	BBB	Bahrain	276.3	31.3	45	1
19	BBB	Italy	94.0	3.8	99	2	53	BBB	Ireland	304.9	12.1	58	3
20	BBB	Mexico	121.0	4.4	98	0	54	BBB	Kazakhstan	233.5	15.4	80	1
21	BBB	Panama	165.8	11.3	99	1	55	BBB	Lithuania	253.7	19.7	62	2
22	BBB	Peru	178.2	10.5	96	1	56	BBB	Morocco	188.6	29.8	41	1
23	BBB	Russia	177.8	5.6	94	1	57	BB	Costa Rica	193.7	28.1	37	0
24	BBB	South Africa	129.6	8.2	99	0	58	BB	Cyprus	140.7	6.3	9	2
25	BBB	Thailand	92.5	6.6	99	0	59	BB	El Salvador	229.2	30.3	34	0
26	BB	Hungary	174.8	6.3	99	2	60	BB	Guatemala	177.5	33.6	23	0
27	BB	Indonesia	232.7	14.0	90	1	61	BB	Latvia	335.8	24.3	58	3
28	BB	Philippines	251.5	9.2	99	0	62	BB	Vietnam	238.7	24.6	86	0
29	BB	Portugal	201.5	8.2	99	3	63	B	Argentina	902.7	34.4	82	1
30	BB	Romania	186.7	12.4	94	2	64	B	Dominican	299.5	73.5	10	1
31	BB	Turkey	240.1	7.1	95	1	65	B	Ecuador	992.4	111.7	18	5
32	B	Ukraine	663.8	35.3	92	4	66	B	Egypt	343.3	31.8	49	1
33	B	Venezuela	765.4	25.1	95	4	67	B	Lebanon	380.8	32.9	52	2
34	CCC	Greece	597.9	28.6	97	4	68	B	Pakistan	656.5	112.8	80	2

Table 3: Summary Information of Rating Transitions, CDS Spreads, and Bid/Ask Spreads. Panel A reports the number of rating transitions (40 times for the 34 in-sample countries and 37 times for the 34 out-of-sample countries) and defaults between January 2004 and March 2012. The left column represents the rating before rating transitions, and the upper row represents the rating after transitions. Panels B and C report the average monthly CDS spreads and bid-ask spreads by rating and maturity, respectively. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. NoO is the number of observations for each rating.

In-Sample Countries

Panel A: Number of Rating Transitions	AAA	AA	A	BBB	BB	B	CCC	D/SD
AAA	0	1	0	0	0	0	0	0
AA	0	0	3	0	0	0	0	0
A	0	4	0	5	0	0	0	0
BBB	0	0	3	0	4	0	0	0
BB	0	0	0	7	0	3	0	0
B	0	0	0	0	5	0	3	0
CCC	0	0	0	0	0	2	0	2
Panel B: Mean of CDS Spreads	AAA	AA	A	BBB	BB	B	CCC	D/SD
1	20.4	32.1	50.1	115.9	190.3	426.1	4399.4	—
2	24.7	40.1	59.8	132.7	226.5	501.7	3614.9	—
3	28.7	47.4	67.8	143.3	253.6	547.3	3189.9	—
5	33.5	51.5	79.2	160.6	299.5	574.8	2767.3	—
7	39.5	65.2	86.5	168.6	320.6	615.7	2528.0	—
10	41.7	70.5	91.9	175.8	337.4	630.1	2350.1	—
Slope	21.3	38.4	41.7	60.0	147.0	204.0	-2049.3	—
Panel C: Mean of Bid-Ask Spreads	AAA	AA	A	BBB	BB	B	CCC	D/SD
1	3.3	6.9	10.6	20.7	23.6	46.2	403.0	—
2	3.3	6.4	9.4	16.6	19.3	38.7	265.1	—
3	3.2	6.1	8.7	13.9	17.6	36.2	207.8	—
5	2.9	4.6	7.0	9.4	12.2	29.8	154.2	—
7	3.3	5.2	7.3	10.0	14.4	31.8	141.6	—
10	3.5	5.3	7.3	10.1	13.7	30.8	133.4	—
NoO	193	399	945	931	708	101	23	0

Out-of-Sample Countries

Panel A: Number of Rating Transitions	AAA	AA	A	BBB	BB	B	CCC	D/SD
AAA	0	4	0	0	0	0	0	0
AA	3	0	3	0	0	0	0	0
A	0	4	0	5	0	0	0	0
BBB	0	0	2	0	2	0	0	0
BB	0	0	0	2	0	1	0	0
B	0	0	0	0	0	0	4	0
CCC	0	0	0	0	0	7	0	2
Panel B: Mean of CDS Spreads	AAA	AA	A	BBB	BB	B	CCC	D/SD
1	25.7	81.4	134.3	255.0	191.3	512.4	1818.5	—
2	31.1	93.5	150.6	277.5	215.3	558.6	1715.9	—
3	35.9	102.6	163.2	290.1	234.7	586.6	1655.8	—
5	44.5	114.9	179.4	299.4	259.7	625.7	1537.4	—
7	48.2	119.6	180.7	302.5	276.5	641.1	1512.4	—
10	51.1	123.6	179.4	300.5	285.9	653.6	1472.8	—
Slope	25.5	42.2	45.1	45.5	94.6	141.3	-345.7	—
Panel C: Mean of Bid-Ask Spreads	AAA	AA	A	BBB	BB	B	CCC	D/SD
1	6.1	15.8	34.5	46.6	46.7	86.0	469.4	—
2	5.7	13.8	28.7	36.9	39.3	69.0	385.1	—
3	5.3	11.9	24.4	30.0	33.1	57.2	323.5	—
5	4.7	9.5	18.3	21.1	28.8	49.3	298.8	—
7	4.9	9.1	17.7	21.6	25.1	44.5	309.2	—
10	5.1	8.9	16.6	20.4	22.8	42.3	283.0	—
NoO	621	289	133	185	279	230	17	0

Table 4: Parameter Estimates of Rating-Based Sovereign Credit Risk Models. Model I is the full model, Model II allows dependence of default risk on rating but no transitions between ratings, and Model III allows neither. $\bar{H}_{33}$ is fixed at 1 for all models. Likelihood ratio test between Model I and Model II (III) has a χ^2 distribution with 4 (10) degrees of freedom, with critical value at the 99.99 percentile of 23.51 (35.56). There is overwhelming evidence that both $\bar{Q}$ and $\bar{H}$ are important factors for CDS pricing.

parameter	estimate	std. error	parameter	estimate	std. error
Model I: full model					
$\bar{Q}_{12}$	7.6538	0.3460	$\bar{H}_{77}$	59.8975	0.6609
$\bar{Q}_{21}$	37.5411	0.6019	α	1e-06	1e-05
$\bar{Q}_{23}$	28.0941	0.6496	κ_z^p	0.2017	0.0936
$\bar{Q}_{76}$	74.4700	2.8453	$\kappa_z^p\theta_z^p$	0.0007	6e-06
$\bar{H}_{11}$	0.5851	0.0084	σ_z	0.0286	0.0004
$\bar{H}_{22}$	0.6445	0.0108	λ_z	-7.0456	3.2837
$\bar{H}_{44}$	3.2012	0.0308	κ_y	0.0475	0.0023
$\bar{H}_{55}$	3.5085	0.0464	σ_y	0.0076	5e-05
$\bar{H}_{66}$	27.7768	0.5426	LogLikeli	1103.65	—
Model II: $\bar{Q} = 0$					
$\bar{H}_{11}$	0.4006	2e-05	κ_z^p	0.1522	1e-05
$\bar{H}_{22}$	0.7177	0.0001	$\kappa_z^p\theta_z^p$	0.0009	9e-07
$\bar{H}_{44}$	2.0774	0.0001	σ_z	0.0303	3e-06
$\bar{H}_{55}$	4.6256	0.0003	λ_z	-5.0210	0.0006
$\bar{H}_{66}$	10.8648	2e-05	κ_y	0.0033	0.0003
$\bar{H}_{77}$	17.1201	0.0984	σ_y	0.0076	1e-05
α	1e-06	3e-07	LogLikeli	1057.67	—
Model III: $\bar{H} = I$ ($\bar{Q} = 0$)					
α	1e-07	2e-07	λ_z	-3.1569	0.0001
κ_z^p	0.1308	6e-06	κ_y	0.0949	0.0001
$\kappa_z^p\theta_z^p$	0.0020	3e-07	σ_y	0.0300	1e-05
σ_z	0.0414	7e-07	LogLikeli	954.13	—
Likelihood Ratio Test:					
$p_{99\%}$ of $\chi^2(4)$		13.28	Model I vs. Model II: tested value		
$p_{99.99\%}$ of $\chi^2(4)$		23.51	$2 \times (1103.65 - 1057.67) = 91.96$		
$p_{99\%}$ of $\chi^2(10)$		23.21	Model I vs. Model III: tested value		
$p_{99.99\%}$ of $\chi^2(10)$		35.56	$2 \times (1103.65 - 954.13) = 299.03$		

Table 5: One-Year Rating Transition Probabilities. Expected (conditional) rating transition probabilities are computed under the physical measure and the risk-neutral measure with the estimated model parameters, that is, $E_t^P\left[e^{\int_t^{t+1}\widetilde{Q}(u)du}|y_t=0\right]$ and $E_t\left[e^{\int_t^{t+1}\widetilde{Q}(u)du}|y_t=0\right]$. This table reports results (in percent) when z_t is the 10th percentile, the median, and the 90th percentile of the estimated time series for the common factor z.

	Under Physical Measure								Under Risk-Neutral Measure							
Ratings	AAA	AA	A	BBB	BB	B	CCC	D/SD	AAA	AA	A	BBB	BB	B	CCC	D/SD
	Normal Period: $z_t = 0.0027$								Normal Period: $z_t = 0.0027$							
AAA	97.85	1.91	0.08	0.00	0.00	0.00	0.00	0.16	97.65	2.07	0.09	0.00	0.00	0.00	0.00	0.18
AA	9.35	83.78	6.42	0.27	0.01	0.00	0.00	0.18	10.17	82.37	6.92	0.32	0.01	0.00	0.00	0.20
A	0.51	8.57	83.95	6.40	0.27	0.01	0.00	0.30	0.60	9.25	82.59	6.91	0.31	0.01	0.00	0.33
BBB	0.02	0.47	8.55	83.45	6.37	0.26	0.01	0.86	0.03	0.56	9.23	82.04	6.88	0.31	0.01	0.95
BB	0.00	0.02	0.47	8.52	83.37	6.16	0.24	1.22	0.00	0.02	0.56	9.19	81.96	6.62	0.28	1.36
B	0.00	0.00	0.02	0.46	8.23	78.35	5.59	7.36	0.00	0.00	0.02	0.55	8.85	76.58	5.95	8.05
CCC	0.00	0.00	0.00	0.03	0.85	14.81	69.88	14.42	0.00	0.00	0.00	0.04	1.00	15.78	67.52	15.65
	Tranquil Period: $z_t = 0.0004$								Tranquil Period: $z_t = 0.0004$							
AAA	99.46	0.50	0.01	0.00	0.00	0.00	0.00	0.04	99.41	0.54	0.01	0.00	0.00	0.00	0.00	0.04
AA	2.43	95.73	1.78	0.02	0.00	0.00	0.00	0.04	2.64	95.37	1.92	0.02	0.00	0.00	0.00	0.05
A	0.04	2.37	95.72	1.77	0.02	0.00	0.00	0.07	0.05	2.57	95.37	1.92	0.02	0.00	0.00	0.07
BBB	0.00	0.04	2.37	95.59	1.77	0.02	0.00	0.21	0.00	0.04	2.56	95.22	1.92	0.02	0.00	0.23
BB	0.00	0.00	0.04	2.37	95.57	1.75	0.02	0.25	0.00	0.00	0.04	2.56	95.20	1.90	0.02	0.28
B	0.00	0.00	0.00	0.04	2.34	94.08	1.71	1.83	0.00	0.00	0.00	0.04	2.53	93.59	1.84	1.99
CCC	0.00	0.00	0.00	0.00	0.07	4.52	91.56	3.84	0.00	0.00	0.00	0.00	0.09	4.88	90.88	4.16
	Turbulent Period: $z_t = 0.0114$								Turbulent Period: $z_t = 0.0114$							
AAA	92.86	5.67	0.77	0.07	0.01	0.00	0.00	0.63	92.27	6.05	0.89	0.09	0.01	0.00	0.00	0.69
AA	27.80	53.65	15.31	2.26	0.23	0.02	0.00	0.74	29.66	50.79	15.85	2.57	0.29	0.02	0.00	0.82
A	5.03	20.45	55.45	15.31	2.25	0.21	0.01	1.28	5.85	21.18	52.83	15.87	2.56	0.27	0.02	1.43
BBB	0.65	4.04	20.46	54.24	15.09	2.06	0.18	3.29	0.83	4.59	21.21	51.57	15.62	2.33	0.22	3.65
BB	0.07	0.55	4.02	20.16	53.82	13.47	1.63	6.29	0.09	0.68	4.57	20.87	51.09	13.80	1.79	7.10
B	0.01	0.05	0.51	3.68	18.00	43.74	9.45	24.55	0.01	0.07	0.64	4.15	18.44	40.81	9.35	26.53
CCC	0.00	0.01	0.09	0.84	5.76	25.06	27.79	40.45	0.00	0.01	0.12	1.03	6.35	24.78	24.78	42.92

Table 6: R^2s of Time Series Regressions of CDS Spreads on Principal Components and Model z-Spreads. This table reports adjusted R-squares from the time series regressions of 5-year market CDS spreads on their first principal component (the column PC1), on common-factor model spreads with observed ratings (the column Observed), and on common-factor model spreads with implied ratings (the column Implied). We obtain the principal components by conducting the principal components analysis of the correlation matrix of the changes of 5-year CDS spreads for in-sample countries. The average for each rating is computed according to the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

In-Sample Countries					Out-of-Sample Countries				
Rating	Country	PC1	Observed	Implied	Rating	Country	PC1	Observed	Implied
AAA	Germany	52.0	67.0	84.7	AAA	Australia	74.4	80.6	92.2
AA	Austria	56.2	83.2	96.5	AAA	Denmark	46.0	75.3	91.7
AA	Belgium	30.8	47.9	91.7	AAA	Finland	60.7	71.0	79.2
AA	China	85.9	71.2	94.4	AAA	Hong Kong	71.7	84.4	93.1
AA	Czech	83.7	85.8	92.8	AAA	Netherlands	55.8	74.9	91.6
AA	Japan	60.2	52.8	91.3	AAA	Norway	64.6	71.7	71.7
AA	Qatar	74.3	79.3	92.0	AAA	Sweden	48.2	80.0	93.9
A	Chile	77.5	89.7	95.6	AAA	Switzerland	73.9	65.7	90.0
A	Israel	78.3	82.4	87.7	AAA	UK	46.7	67.8	88.0
A	Korea	82.4	81.3	92.1	AA	Abu Dhabi	64.4	47.3	83.8
A	Malaysia	87.7	84.8	91.8	AA	Estonia	85.6	84.8	97.0
A	Poland	79.3	71.1	89.4	AA	France	36.8	51.3	94.8
A	Slovakia	77.9	67.7	91.9	AA	New Zealand	73.3	78.9	79.9
BBB	Brazil	45.8	50.6	89.3	AA	Saudi Arabia	79.3	68.5	88.6
BBB	Bulgaria	80.9	90.2	91.9	AA	USA	37.0	48.3	76.8
BBB	Colombia	54.3	5.7	89.5	A	Slovenia	42.8	59.7	94.2
BBB	Croatia	82.6	88.1	91.3	A	Spain	19.1	40.8	93.4
BBB	Iceland	61.2	73.4	94.8	BBB	Bahrain	63.5	48.5	80.5
BBB	Italy	34.8	63.1	94.5	BBB	Ireland	9.2	64.5	82.9
BBB	Mexico	89.9	73.8	90.1	BBB	Kazakhstan	64.6	62.2	92.3
BBB	Panama	58.3	45.3	73.5	BBB	Lithuania	83.7	78.9	92.3
BBB	Peru	62.1	21.2	78.6	BBB	Morocco	54.2	52.4	67.6
BBB	Russia	84.5	75.5	94.0	BB	Costa Rica	47.2	76.9	73.1
BBB	South Africa	90.0	80.5	92.3	BB	Cyprus	20.6	99.1	100.0
BBB	Thailand	83.8	88.6	87.0	BB	El Salvador	28.9	90.2	74.2
BB	Hungary	74.7	85.9	90.3	BB	Guatemala	49.3	9.1	66.2
BB	Indonesia	76.4	50.3	74.7	BB	Latvia	73.5	45.6	86.5
BB	Philippines	72.4	0.3	91.5	BB	Vietnam	70.3	81.8	83.1
BB	Portugal	4.9	79.7	91.2	B	Argentina	48.0	62.5	94.2
BB	Romania	84.2	92.5	89.4	B	Dominican	0.1	0.2	10.7
BB	Turkey	70.2	35.1	71.8	B	Ecuador	0.0	92.5	93.7
B	Ukraine	71.2	75.4	94.3	B	Egypt	64.7	57.8	79.7
B	Venezuela	42.0	19.9	92.9	B	Lebanon	44.0	32.8	55.8
CCC	Greece	6.1	93.8	86.6	B	Pakistan	68.2	87.5	91.9
Average	AAA	52.0	67.0	84.7	Average	AAA	60.2	74.6	87.9
Average	AA	65.2	70.0	93.1	Average	AA	62.7	63.2	86.8
Average	A	80.5	79.5	91.4	Average	A	31.0	50.2	93.8
Average	BBB	69.0	63.0	88.9	Average	BBB	55.0	61.3	83.1
Average	BB	63.8	57.3	84.8	Average	BB	48.3	67.1	80.5
Average	B	56.6	47.7	93.6	Average	B	37.5	55.6	71.0
Overall	Mean	66.4	66.3	89.5	Overall	Mean	52.1	64.5	83.1
Overall	SD	22.1	25.2	6.1	Overall	SD	22.8	22.0	16.3
Overall	Min	4.9	0.3	71.8	Overall	Min	0.0	0.2	10.7
Overall	Med	74.5	74.6	91.4	Overall	Med	55.0	68.2	88.3
Overall	Max	90.0	93.8	96.5	Overall	Max	85.6	99.1	100.0

Table 7: R^2s of Time Series Regressions of CDS Spreads on Model z-Spreads and the First Principal Component across Maturities. This table reports the results from OLS regression the time series of market quotes for CDS spreads on the common-factor model spread with observed ratings (the row Observed), on the common-factor model spread with implied ratings (the row Implied), and on the first principal component of 5-year CDS spreads for in-sample countries (the row PC1). We conduct regression for each individual country and for each maturity. Reported are the averages (across countries) of adjusted-R^2 for each maturity.

	In-Sample Countries						Out-of-Sample Countries					
Independent Var.	1y	2y	3y	5y	7y	10y	1y	2y	3y	5y	7y	10y
PC1	51.8	59.1	63.8	66.4	65.2	61.9	40.3	45.7	49.6	52.1	51.6	49.2
Observed	70.0	70.4	68.5	66.3	63.9	62.4	58.5	62.0	64.3	64.5	64.0	63.8
Implied	77.7	84.4	87.9	89.5	87.7	85.7	76.3	79.6	82.0	83.1	81.9	80.2

Table 8: Regression Results of the Common Factor z and The First Principle Component on Financial Variables. The table reports the regressions of changes in the estimated common factor z (in percent) and the first principle component (from PCA of 5-year CDS spreads of in-sample countries) on changes in the CBOE VIX index, the CDX NA IG index, the 5-Year US Treasury rate, as well as the returns in the MSCI World stock market index, the S&P 500 Index, and the DAX index. t-statistics are reported in square brackets. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively. The correlation coefficient between Δz and the first principle component is: 0.903.

Common Factor z								The First Principal Component							
Intercept	VIX	MSCI	DAX	S&P 500	CDX	Treasury	R^2(%)	Intercept	VIX	MSCI	DAX	S&P 500	CDX	Treasury	R^2(%)
0.00	1.83***						40.58	0.01	59.69***						55.04
[0.31]	[8.10]							[0.03]	[10.84]						
0.01		-2.27***					45.63	0.16		-71.58***					57.65
[0.71]		[-8.98]						[0.52]		[-11.43]					
0.01			-1.57***				28.38	0.29			-52.27***				40.05
[0.86]			[-6.17]					[0.77]			[-8.01]				
0.01				-2.34***			40.60	0.17				-75.68***			53.97
[0.69]				[-8.10]				[0.52]				[-10.61]			
0.00					0.73***		32.85	-0.08					23.76***		44.43
[0.10]					[6.85]			[-0.22]					[8.76]		
0.00						-0.08	1.61	-0.03						-1.39	0.66
[0.13]						[-1.25]		[-0.06]						[-0.80]	
0.01	0.93***	-1.51***					51.00	0.11	33.27***	-44.40***					66.44
[0.62]	[3.23]	[-4.49]						[0.38]	[4.99]	[-5.68]					
0.01	0.91***	-1.91***	0.40				51.49	0.10	33.20***	-46.27***	1.87				66.45
[0.51]	[3.17]	[-3.62]	[0.98]					[0.35]	[4.94]	[-3.75]	[0.20]				
0.01	0.89***	-2.57**	0.37	0.76			51.73	0.10	33.39***	-39.17	2.20	-8.19			66.49
[0.50]	[3.09]	[-2.33]	[0.89]	[0.68]				[0.35]	[4.93]	[-1.52]	[0.23]	[-0.31]			
0.01	0.85***	-2.46**	0.40	0.83	0.12		52.05	0.06	31.71***	-34.77	3.39	-5.44	4.60		67.14
[0.42]	[2.89]	[-2.21]	[0.96]	[0.74]	[0.79]			[0.22]	[4.62]	[-1.34]	[0.35]	[-0.21]	[1.35]		
0.01	0.84***	-2.46**	0.34	0.86	0.13	0.02	52.16	0.13	30.36***	-34.43	-1.90	-1.81	5.99*	2.28**	68.60
[0.46]	[2.82]	[-2.19]	[0.80]	[0.76]	[0.86]	[0.46]		[0.45]	[4.48]	[-1.35]	[-0.19]	[-0.07]	[1.75]	[2.06]	

Table 9: Mean Absolute Pricing Error Relative to Bid-Ask Spread. We also report the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

In-Sample Countries								Out-of-Sample Countries							
Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	3.7	2.6	1.3	1.3	2.2	3.2	AAA	Australia	1.5	0.8	0.2	1.3	1.3	0.6
AA	Austria	2.0	1.4	0.9	1.2	1.6	2.4	AAA	Denmark	2.1	1.0	0.6	1.0	1.2	1.6
AA	Belgium	1.7	0.9	1.1	0.8	1.2	2.7	AAA	Finland	3.0	1.2	0.5	1.1	1.1	1.4
AA	China	2.1	1.6	1.0	1.2	1.5	2.7	AAA	Hong Kong	0.7	0.6	0.5	0.3	0.8	1.5
AA	Czech	1.0	0.8	0.8	0.5	1.1	2.8	AAA	Netherlands	1.9	1.2	0.6	1.0	1.3	1.8
AA	Japan	4.9	2.4	1.2	1.4	2.1	3.0	AAA	Norway	1.3	1.1	0.7	0.8	0.9	1.3
AA	Qatar	1.2	0.6	0.3	0.8	0.8	1.0	AAA	Sweden	2.4	1.4	0.5	1.2	1.2	1.5
A	Chile	0.7	0.5	0.3	0.6	0.5	0.9	AAA	Switzerland	1.2	1.0	0.5	0.9	1.1	0.8
A	Israel	1.1	0.4	0.3	0.8	0.6	0.7	AAA	UK	5.3	3.2	1.4	2.2	2.3	2.2
A	Korea	1.3	0.9	0.6	1.2	1.2	1.9	AA	Abu Dhabi	2.2	1.4	0.7	1.1	1.2	2.1
A	Malaysia	1.8	1.1	0.5	1.2	1.0	1.5	AA	Estonia	1.6	0.7	0.6	0.8	1.1	1.6
A	Poland	2.1	1.1	0.9	1.1	1.9	3.5	AA	France	3.3	2.2	1.0	1.7	2.0	2.6
A	Slovakia	0.8	0.8	0.8	0.5	1.2	2.8	AA	New Zealand	0.3	0.7	1.0	0.6	0.8	2.4
BBB	Brazil	3.9	2.4	1.1	2.6	2.6	4.0	AA	Saudi Arabia	0.4	0.4	0.2	0.5	0.4	0.8
BBB	Bulgaria	1.6	0.9	0.7	0.7	1.3	2.5	AA	USA	0.9	0.7	0.6	0.6	1.1	1.7
BBB	Colombia	3.2	1.8	0.9	1.7	2.0	2.8	A	Slovenia	1.6	0.8	0.5	1.0	1.1	1.2
BBB	Croatia	1.1	0.8	0.7	0.5	1.1	2.1	A	Spain	2.1	1.5	1.4	1.8	1.9	2.6
BBB	Iceland	0.8	0.8	0.4	0.5	1.3	2.2	BBB	Bahrain	0.5	0.4	0.5	0.6	0.6	1.6
BBB	Italy	1.5	1.2	1.1	1.2	1.5	2.7	BBB	Ireland	1.3	1.4	1.2	1.5	2.5	3.5
BBB	Mexico	2.8	1.5	0.8	1.7	1.7	2.8	BBB	Kazakhstan	2.1	0.6	0.5	1.4	1.1	1.7
BBB	Panama	1.5	0.9	0.6	0.7	1.1	1.9	BBB	Lithuania	1.4	1.0	0.6	0.7	1.6	2.7
BBB	Peru	2.0	1.0	0.6	1.0	1.2	2.1	BBB	Morocco	0.7	0.6	0.4	0.3	0.9	1.5
BBB	Russia	3.4	1.2	0.9	2.4	2.0	2.9	BB	Costa Rica	0.9	1.0	0.9	0.3	1.1	1.9
BBB	South Africa	2.6	1.2	0.6	1.5	1.3	2.0	BB	Cyprus	1.0	1.1	0.9	0.6	1.8	3.1
BBB	Thailand	1.3	1.0	0.8	0.7	1.0	2.1	BB	El Salvador	0.7	0.5	0.5	0.4	0.7	1.3
BB	Hungary	2.1	1.1	0.8	1.6	1.8	2.9	BB	Guatemala	0.7	0.5	0.3	0.3	0.7	0.7
BB	Indonesia	1.5	1.4	1.5	1.1	1.4	2.5	BB	Latvia	1.7	1.3	0.7	1.4	2.1	2.8
BB	Philippines	2.3	1.9	1.5	1.9	1.8	2.8	BB	Vietnam	1.2	0.9	0.8	0.9	1.4	1.9
BB	Portugal	1.3	1.3	1.0	1.1	2.3	3.3	B	Argentina	5.4	3.1	1.6	2.9	4.2	7.4
BB	Romania	1.8	1.3	0.8	1.1	2.1	3.4	B	Dominican	0.9	0.5	0.3	0.4	0.6	1.0
BB	Turkey	3.4	2.5	1.4	2.7	2.8	4.8	B	Ecuador	2.4	1.2	0.8	1.7	2.8	3.2
B	Ukraine	2.5	1.5	0.8	1.8	2.2	3.6	B	Egypt	1.4	0.9	0.7	1.0	1.6	2.1
B	Venezuela	3.2	2.0	0.9	2.8	3.5	4.4	B	Lebanon	1.1	1.2	1.2	0.5	1.4	2.9
CCC	Greece	1.6	1.2	0.7	1.7	2.8	4.1	B	Pakistan	1.5	0.9	0.7	0.6	1.2	1.6
—	AAA	2.8	2.0	1.1	1.2	1.9	2.8	—	AAA	2.3	1.4	0.7	1.2	1.4	1.6
—	AA	2.7	1.4	0.9	1.0	1.5	2.3	—	AA	1.3	0.9	0.8	1.0	1.1	1.9
—	A	1.2	0.8	0.7	0.9	1.1	2.1	—	A	1.3	1.0	0.7	0.7	1.4	2.3
—	BBB	2.1	1.1	0.8	1.3	1.6	2.8	—	BBB	1.6	0.8	0.6	1.1	1.4	2.1
—	BB	2.4	1.8	1.1	2.0	2.2	3.2	—	BB	1.1	0.8	0.6	0.8	1.3	1.8
—	B	4.2	2.3	1.1	2.0	3.6	5.4	—	B	2.8	1.8	1.1	1.4	2.4	4.1
—	CCC	1.0	0.5	0.5	1.1	1.4	1.7	—	CCC	2.2	1.1	0.5	1.7	2.4	2.8
—	Overall	2.1	1.3	0.8	1.3	1.6	2.7	—	Overall	1.9	1.2	0.7	1.1	1.5	2.1

Table 10: Relative Pricing Error and Range of Estimated Price of Risk of One-Factor Models. The estimated parameters are reported in Table OA.1. Reported in this table are the mean absolute pricing errors relative to bid-ask spread, and the range of estimated price of risk. The first column reports the last-month rating for each country. The average pricing error for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The column Max (resp. Min) reports the maximum (resp. minimum) of $-\lambda(t)$ for each country. The column NoRN reports the number of rating notches changed over the sample period. The sample consists of monthly observations between January 2004 and March 2012.

		5-Parameter Model								4-Parameter Model								
		Pricing Error						Price of Risk		Pricing Error						Price of Risk		NoRN
Rating	Country	1y	2y	3y	5y	7y	10y	Max	Min	1y	2y	3y	5y	7y	10y	Max	Min	
AAA	Germany	2.8	1.5	1.1	1.5	1.8	2.9	-0.066	-7.0e+06	16.3	6.1	7.0	10.2	12.9	15.5	1.913	3.7e-08	0
AA	Austria	1.7	0.9	0.6	1.2	1.0	1.4	0.114	-7.4e+06	11.0	6.6	7.1	10.2	10.2	15.0	0.091	2.3e-09	1
AA	Belgium	2.1	1.0	0.9	1.5	1.2	1.5	0.074	-8.2e+06	8.1	6.1	6.5	11.4	7.6	12.3	0.011	5.0e-11	0
AA	China	1.6	1.1	0.7	1.8	1.4	2.3	0.211	-2.2e+06	1.4	1.2	1.0	2.7	2.6	4.3	0.177	7.9e-09	4
AA	Czech	1.0	0.4	0.3	0.8	0.8	1.2	0.507	-2.9e+06	1.2	1.3	1.7	3.9	4.8	7.8	0.051	1.4e-09	2
AA	Japan	3.4	1.4	0.7	1.9	1.8	2.1	0.075	-6.5e+06	5.8	3.3	4.0	6.7	7.8	10.1	0.780	5.5e-08	1
AA	Qatar	1.0	0.5	0.4	0.9	0.8	1.6	0.410	-2.1e+06	0.7	0.8	0.9	1.7	2.1	3.8	0.103	1.2e-09	1
A	Chile	1.1	0.6	0.3	0.8	1.0	1.2	0.290	-2.2e+06	0.9	0.5	0.4	1.2	1.5	2.0	0.035	1.0e-09	0
A	Israel	1.2	0.5	0.4	1.2	1.0	1.4	0.109	-8.6e+05	1.1	0.6	0.6	1.7	1.8	2.5	0.049	1.7e-09	1
A	Korea	1.8	1.2	0.8	1.5	2.0	2.6	0.072	-2.2e+06	1.5	1.2	1.2	3.1	3.4	4.5	-0.000	-5.6e-02	0
A	Malaysia	2.0	1.4	0.7	1.7	1.8	2.7	0.117	-2.5e+06	1.3	1.7	2.1	4.7	4.6	6.2	-0.000	-6.0e-02	0
A	Poland	2.5	0.7	0.5	1.8	1.9	2.4	0.184	-7.9e+06	2.3	1.1	1.3	3.7	4.1	5.8	0.065	2.0e-09	0
A	Slovakia	0.8	0.4	0.3	0.8	0.9	1.2	0.112	-3.8e+06	0.9	1.5	2.2	4.4	5.5	8.5	0.053	2.0e-09	3
BBB	Brazil	3.2	2.7	1.8	1.9	3.4	4.7	0.154	-1.4e+00	4.8	5.4	6.6	18.3	15.2	18.4	-0.000	-4.1e-01	4
BBB	Bulgaria	1.8	0.8	0.5	1.6	1.9	2.8	1.328	-1.3e+07	1.7	1.6	2.1	4.7	5.6	7.2	-0.000	-1.4e-01	2
BBB	Colombia	2.6	2.3	1.3	1.1	2.6	3.7	0.437	-3.5e+00	3.5	3.4	4.0	7.9	8.1	10.2	8.361	2.3e-07	1
BBB	Croatia	1.2	0.5	0.5	1.0	1.0	1.5	0.120	-1.9e+06	1.0	0.6	0.8	1.7	2.0	3.3	0.059	2.2e-10	1
BBB	Iceland	0.7	0.4	0.3	0.6	0.6	0.9	-0.283	-2.8e+06	1.9	0.9	1.1	4.1	2.6	3.3	-0.000	-5.9e-01	6
BBB	Italy	2.0	1.0	0.7	2.3	1.7	1.6	0.022	-1.3e+07	2.0	1.6	2.0	6.0	4.6	5.1	3.895	6.2e-08	1
BBB	Mexico	2.2	1.0	0.8	2.8	1.8	3.3	0.912	-9.3e+06	1.8	1.2	1.4	3.9	2.9	5.5	8.183	1.7e-07	1
BBB	Panama	1.6	1.2	1.0	1.5	1.3	2.9	0.010	-1.4e+00	2.0	1.7	1.6	3.1	4.2	6.4	2.342	5.0e-08	1
BBB	Peru	1.5	1.5	1.0	0.8	1.8	2.5	5.071	-5.9e+00	3.1	5.1	6.5	10.5	8.6	9.4	13.246	3.2e-08	3
BBB	Russia	4.5	1.8	0.9	3.5	3.6	4.3	-0.100	-3.1e+06	4.1	1.7	1.2	5.2	5.0	5.7	-0.000	-1.0e-01	2
BBB	South Africa	2.3	1.1	0.8	2.5	2.0	2.8	1.158	-2.6e+06	1.8	1.5	1.8	4.3	3.7	5.1	-0.000	-1.8e-01	0
BBB	Thailand	1.3	0.9	0.6	1.1	1.1	2.2	-0.084	-3.7e+06	2.2	3.5	3.8	6.1	5.1	6.0	6.164	4.5e-08	0
BB	Hungary	2.3	1.1	0.7	2.1	2.3	3.0	-0.004	-5.5e+06	2.3	2.0	2.5	6.4	6.9	9.8	-0.000	-1.1e-01	3
BB	Indonesia	1.6	1.1	0.9	1.7	1.4	3.4	0.064	-4.0e+06	2.0	1.4	1.0	1.7	2.1	4.6	4.699	6.2e-08	3
BB	Philippines	2.0	1.5	0.9	1.6	1.8	3.2	3.379	-3.7e+00	3.7	4.9	6.0	11.9	9.7	12.4	7.519	1.0e-07	1
BB	Portugal	2.1	1.5	1.0	2.8	2.8	3.2	0.107	-1.8e+07	1.8	2.0	2.6	9.4	6.7	8.1	-0.000	-1.3e+00	8
BB	Romania	1.5	0.7	0.4	1.4	1.6	2.2	0.543	-1.8e+06	1.4	1.2	1.4	3.4	4.1	6.0	2.094	6.1e-08	1
BB	Turkey	2.7	3.0	1.9	1.8	3.6	5.7	7.137	-2.3e+01	11.2	13.6	11.9	16.0	9.6	8.8	13.909	1.2e-07	1
B	Ukraine	2.1	1.2	0.5	1.6	1.9	2.3	0.010	-8.7e+05	1.8	1.2	1.3	2.9	2.7	4.0	-0.000	-2.8e-01	4
B	Venezuela	2.6	1.5	0.7	1.7	2.4	3.5	0.299	-3.4e+06	2.1	2.1	2.8	6.0	5.0	6.8	-0.000	-2.1e-01	8
CCC	Greece	2.2	1.4	1.0	2.9	2.9	3.5	-0.349	-1.8e+06	2.7	1.9	2.0	6.6	5.7	6.3	-0.000	-3.2e+00	15
—	Mean	2.0	1.2	0.8	1.6	1.8	2.6	0.651	-4.1e+06	3.3	2.7	2.9	6.0	5.6	7.4	2.171	-1.9e-01	0
—	Std	0.8	0.6	0.4	0.7	0.8	1.1	1.548	4.3e+06	3.5	2.6	2.6	4.1	3.2	3.8	3.860	5.8e-01	0
—	Min	0.7	0.4	0.3	0.6	0.6	0.9	-0.349	-1.8e+07	0.7	0.5	0.4	1.2	1.5	2.0	-0.000	-3.2e+00	0
—	Median	2.0	1.1	0.7	1.6	1.8	2.6	0.116	-2.7e+06	2.0	1.6	2.0	4.7	4.9	6.2	0.056	1.6e-09	1
—	Max	4.5	3.0	1.9	3.5	3.6	5.7	7.137	-1.4e+00	16.3	13.6	11.9	18.3	15.2	18.4	13.909	2.3e-07	15

Table 11: Pricing Error and Rating Changes. Panel A: We regress the aggregated (across all 68 countries) number of rating changes (NoRCs) in each month on lagged average (across all 68 countries) absolute pricing errors (AAPE) of our rating-based model. The pricing errors are measured in percent (100 basis points). z_t is the estimated systematic factor (measured in percent), and VIX is the CBOE S&P 500 volatility index. Panel B: We do probit regression where the dependent variable equals one when there is a rating change and 0 otherwise. We line up each variable (country by country) into a single column. In Panel B, AAPE denotes the averaged absolute pricing errors across maturities for each country. t-statistics are reported in square brackets. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Intercept	AAPE_{t-1}	AAPE_{t-2}	AAPE_{t-3}	z_{t-1}	VIX_{t-1}	Adj-R^2(%)
Panel A: OLS regression of aggregated NoRCs						
1.07***	5.14***					13.44
[3.69]	[3.97]					
1.42***		3.26**				4.73
[4.71]		[2.39]				
1.78***			1.36			0.00
[5.63]			[0.92]			
1.18***	8.78***	−4.27*				15.21
[4.01]	[3.55]	[−1.72]				
1.02*	10.11***	−3.87		−0.58	0.36	13.61
[1.96]	[2.83]	[−1.47]		[−0.51]	[0.14]	
Panel B: Probit regression of rating changes on AAPEs						
−1.95***	0.34***					1.04
[−48.59]	[6.63]					
−1.93***		0.32***				0.63
[−48.42]		[5.75]				
−1.91***			0.27***			0.38
[−48.18]			[4.49]			
−1.94***	0.40***	0.00	−0.10			1.06
[−47.24]	[3.96]	[0.01]	[−0.84]			
−1.95***	0.39***	0.00	−0.11	0.06	−0.09	1.07
[−21.50]	[3.84]	[0.01]	[−0.87]	[0.50]	[−0.18]	

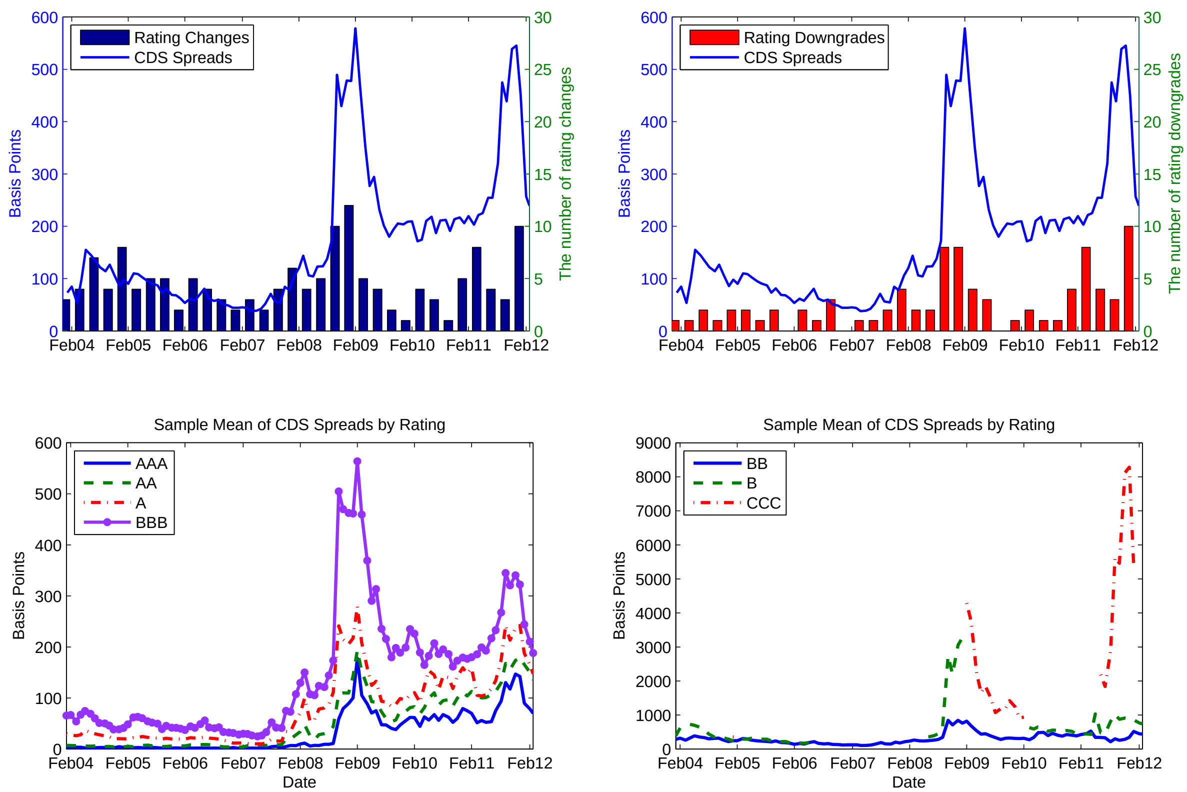

Figure 1: Time Series of Average CDS Spreads and Numbers of Rating Changes for In-Sample Countries. Top Left (Right) Panel: time series of 5-Year CDS Spreads averaged across countries and maturities and quarterly rating changes (downgrades) by one notch or more. Numbers of rating changes here include those with minor changes (e.g., "+" and "-") within each broad rating category. Bottom Panels: time series of 5-Year CDS spreads averaged across countries at seven different ratings.

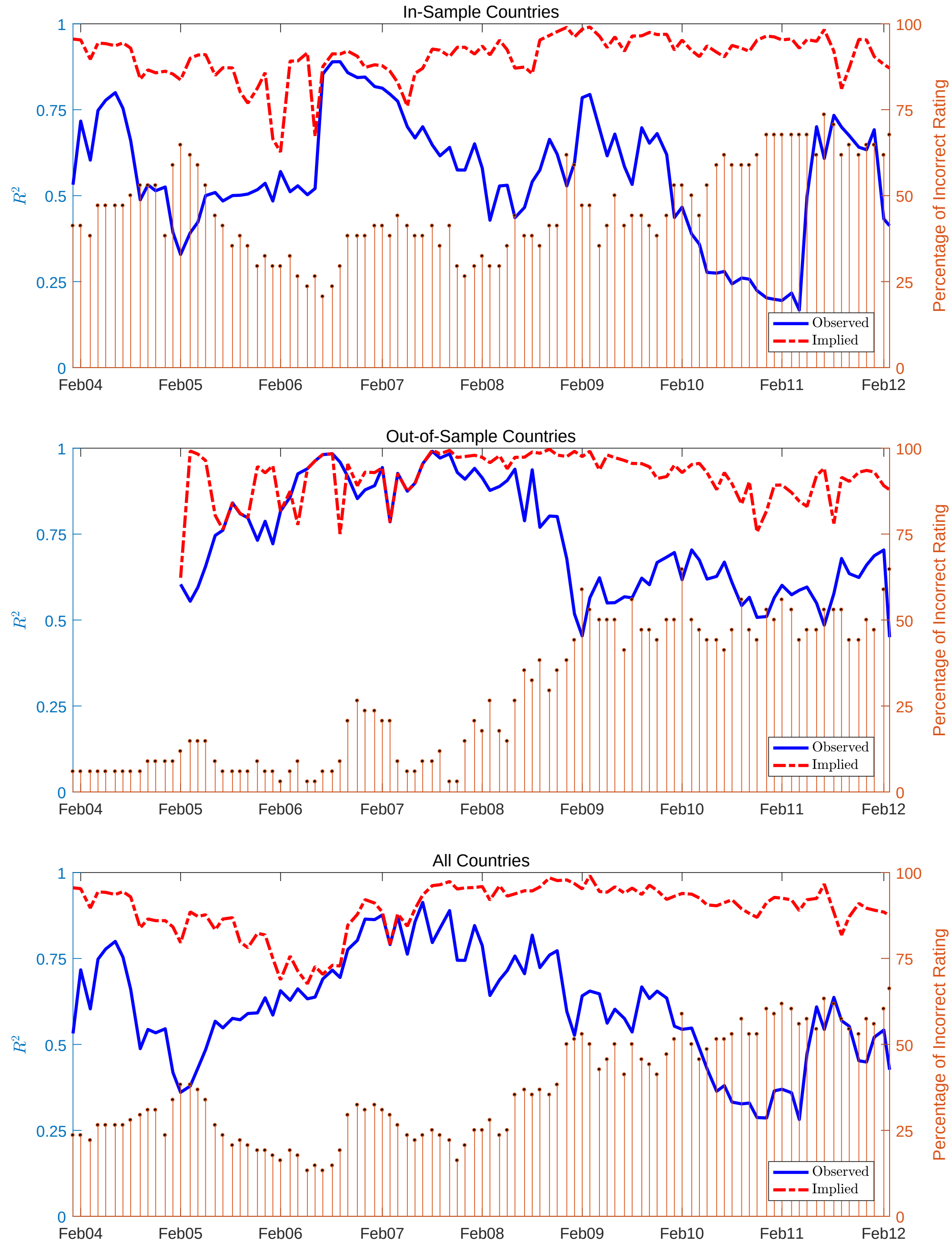

Figure 2: Cross Sectional Regressions. We regress the 5-year market CDS spreads on 5-year model z-spread for each month and plot the resulting R^2s with observed (implied) ratings. For the in-sample countries, the mean R^2 is 56.1% (90.4%) for the observed (implied) ratings. For the out-of-sample countries, the mean of R^2 is 73.6% (91.6%) for the observed (implied) ratings. For the full sample, the mean R^2 is 60.9% (89.3%) for the observed (implied) ratings. The time-series average of the proportion of stale ratings for the in-sample countries is 46.3%, that for the out-of-sample countries is 27.5%, and that for all countries is 36.9%.

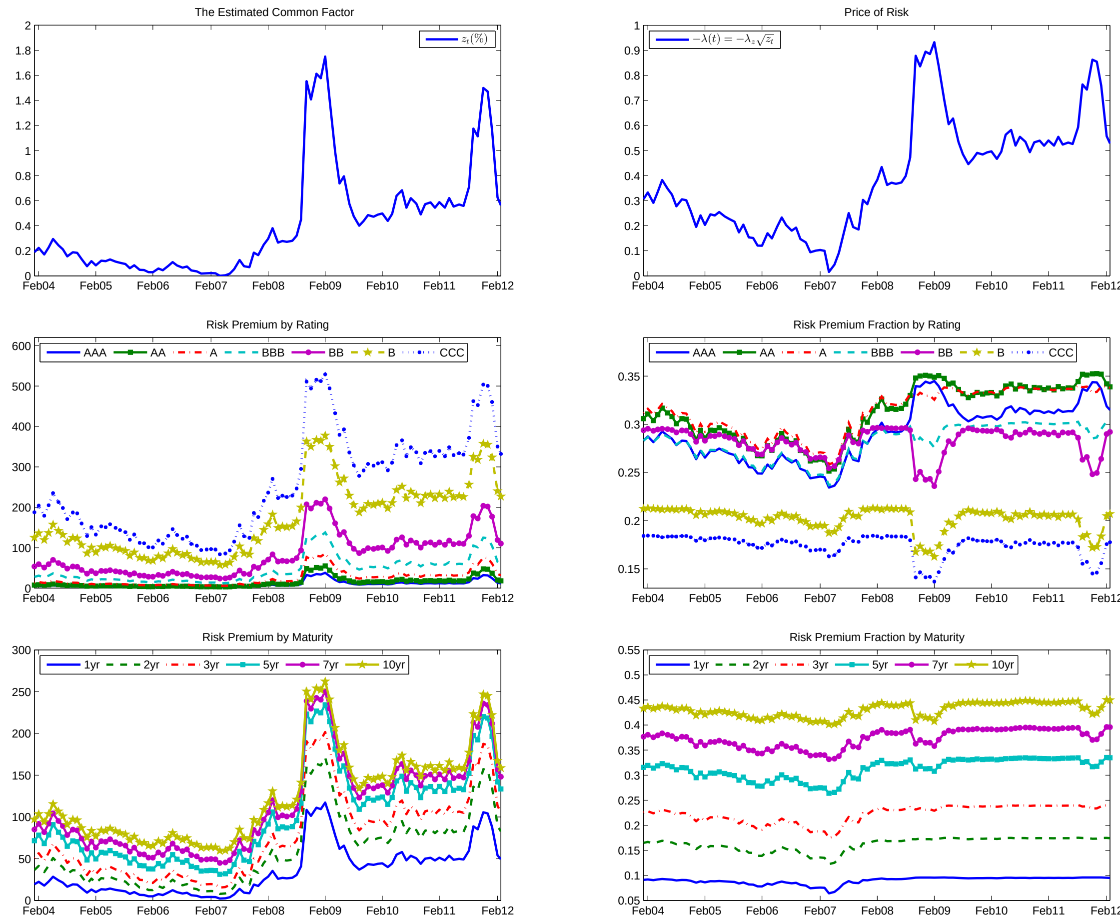

Figure 3: Common Factor, Price of Risk, the Average Risk Premium $CDS(M) - CDS^P(M)$, and the Average Risk Premium Fraction for Different Ratings and Maturities. The risk premium is measured in basis point, and the risk premium fraction is computed by (9). The average for each rating is taken over all 6 maturities (1y, 2y, 3y, 5y, 7y, 10y), and the average for each maturity is taken across all 7 ratings. All calculations are based on the estimation of Model I reported in Table 4 with zero country-specific factor.

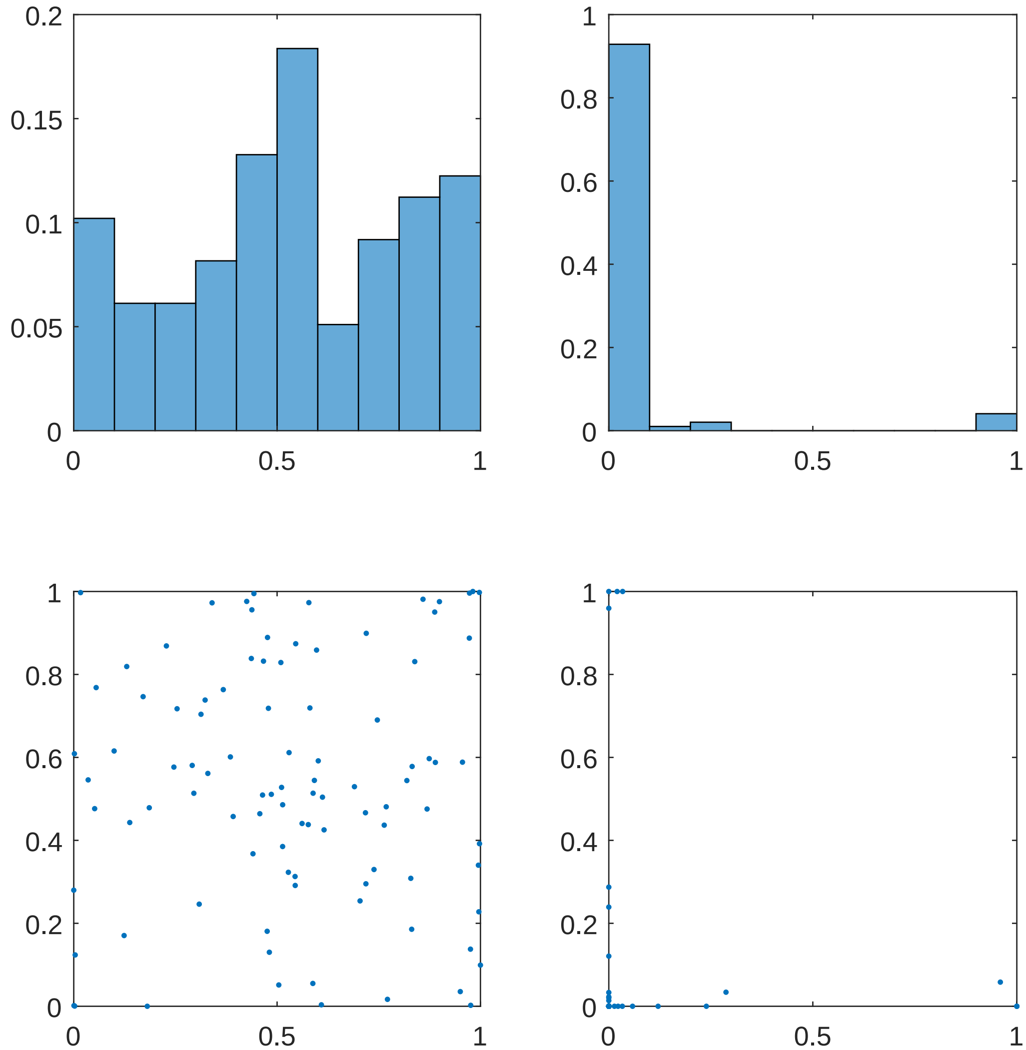

Figure 4: Histogram of $U_t = \text{CDF}(V_t|V_{t-1} = 0)$ and Scatter Plot of (U_{t-1}, U_t). Here CDF is the cumulative distribution function generated by a pricing model, and V_t is the market value of an equally notional-weighted CDS portfolio in month t. The portfolio consists of **fresh** 5-year CDS contracts of all in-sample countries in month $t-1$, so that the market value of this portfolio is zero at time $t-1$. Based on observed rating $R_{i,t-1}$ and the estimated values of z_{t-1} and $y_{i,t-1}$ in month $t-1$, we simulate 10 thousand samples for each of z_t, $y_{i,t}$, and $R_{i,t}$ in month t. We then compute the portfolio value in each scenario and obtain the model-predicted $\text{CDF}(\cdot|V_{t-1} = 0)$ for V_t by kernel smoothing. For each country i, the market value $V_{i,t}$ is estimated by $\frac{1}{2}\sum_{m=1}^{M}(CDS_{i,t} - CDS_{i,t-1})B^D(t, T_m)$, where $CDS_{i,t}$ is the market quote of 5-year CDS spread for country i at time t, T_m-s are premium payment dates, and $B^D(t, T_m)$ is the time-t value of the associated defaultable bond maturing at time T_m with unit face value. Plots on the left column are based on for rating-based model, and those on the right column are based on the one-factor model estimated country by country. For our rating-based model, the p-values for testing the null hypothesis that $\{U_t\}$ comes from a uniform distribution on $[0, 1]$ are 0.1078 (One-sample Kolmogorov-Smirnov test) and 0.1139 (χ^2 goodness-of-fit test). While the p-values for the country-by-country model are less than 0.0001. For both models, the autocorrelation coefficients of $\{U_t\}$ are very close to zero with p-values (for testing the hypothesis of no correlation) higher than 0.5.

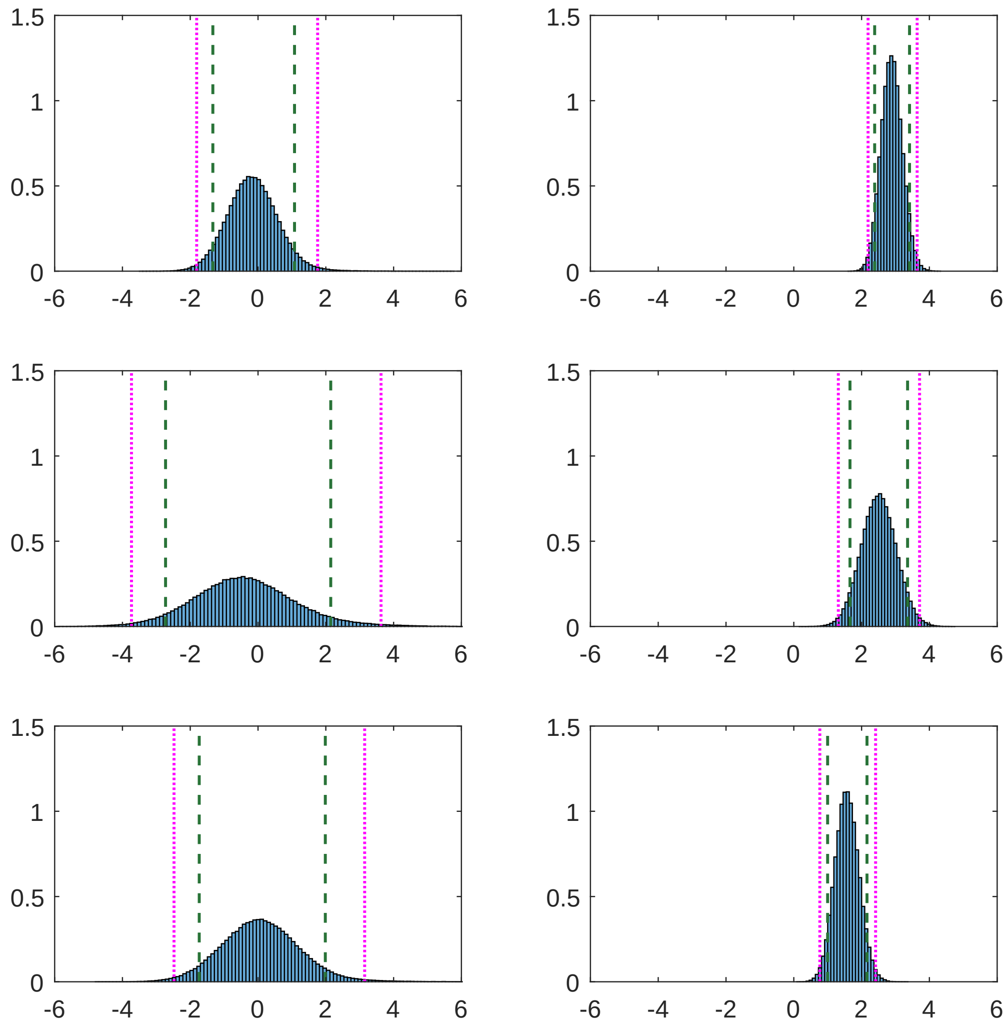

Figure 5: Histogram of Simulated One-Month Forward CDS Portfolio Values and Value-at-Risk. The portfolio's overall notional value is $100. We pick up three representative cases which are based on the estimated factor levels on 28-Apr-2004 (top row), 29-Oct-2008 (middle row), and 26-Aug-2009 (bottom row), respectively. In each month, we build up an equally notional-weighted portfolio consisting of fresh 5-year CDS contracts of all in-sample countries, so that the market value of the portfolio is zero. Then based on observed rating $R_{i,t}$ and the estimated values of z_t and $y_{i,t}$ in month t, we simulate 1 million samples for each of z_{t+1}, $y_{i,t+1}$, and $R_{i,t+1}$ in month $t+1$. For each scenario, we then calculate the corresponding values of the CDS portfolio. The left column shows results for our rating-based model, and the right column shows those for the one-factor model. The dashed lines indicate the 5th (95th) percentiles of the portfolio, and the dotted lines indicate the 1st (99th) percentiles.

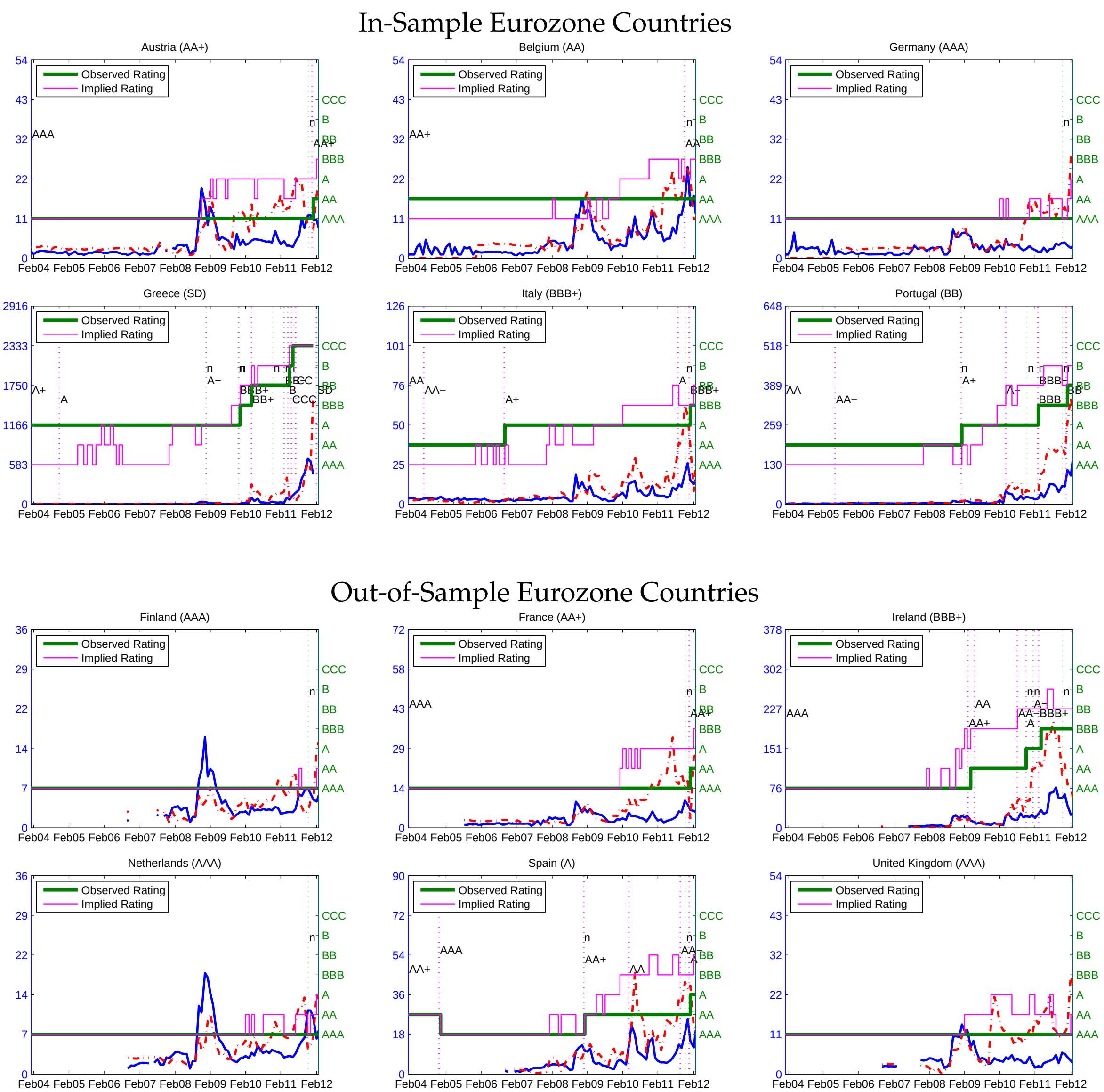

Figure 6: Pricing Errors of the Eurozone Countries. This figure plots the time series of the absolute pricing errors (dash-dot lines) and the Bid-Ask spreads (solid lines) for each country, both series are averaged across maturities. "SD" is for Selective Default, "n" is for negative Credit Watch, and "p" is for positive Credit Watch. Vertical lines represent the dates of either credit rating changes or announcements of Credit Watch.

Online Appendix for
"Commonality in Sovereign Credit Risk
— A Rating-Based Approach"

Online Appendix A One-Factor Model

In this section, we present a one-factor model and estimate the model country by country for all the in-sample countries. These country-by-country estimations provide an important benchmark for our rating-based model.

We assume that, under the risk-neutral measure, the default intensity of each country follows a CIR process given by

$$dz_t = \kappa(\theta - z_t)\, dt + \sigma\sqrt{z_t}\, dW_t, \tag{OA.1}$$

where W_t is a Brownian motion, and κ, θ, and σ are positive constants. We assume that the price of risk for the common factor has the following form:

$$\lambda(t) = \lambda_z\sqrt{z_t} + \varrho/\sqrt{z_t}. \tag{OA.2}$$

This setup has 5 model parameters, it is the most flexible model with analytical solutions in both pricing and likelihood. We also estimate a less flexible model with 4 model parameters with the price of risk taking the following form:

$$\lambda(t) = \lambda_z\sqrt{z_t}. \tag{OA.3}$$

This is what we used for the systematic factor in our rating-based model.

We estimate this classical one-factor model by maximum likelihood estimation. The likelihood function consists of two components: the likelihood of the dynamics of default intensity under the physical measure and the likelihood of CDS spreads under the risk-neutral measure. Here the CDS pricing errors of each maturity are assumed to be i.i.d. normal. The estimated parameters and the absolute pricing errors for the 5-parameter model are reported in Table OA.1. These absolute pricing errors are in general comparable to those reported in Longstaff, Pan, Pedersen and Singleton (2011).[1] The relative (to bid-ask spreads) pricing errors are reported in Table OA.2, which are comparable to those of our rating-based model reported in Table 9 in the main paper. Given that the country-by-country one-factor estimation has 170 parameters in total and our rating-based model has only 17 parameters, our rating-based model performs quite well in

[1] Unlike ours, Longstaff et al. (2011) use a lognormal process to model default intensity. Their sample period and sample countries are also different from ours.

terms of pricing. We also report the ranges of $-\lambda(t)$ in Table OA.2. The resulting price of risk of the one-factor model has wrong signs, and its level can reach in the order of 10^6, which is unreasonable high. In contrast, the price of risk in our rating-based model ranges roughly from 0.1 to 0.9 (see Figure 3 in the main paper), which is much reasonable.

Of course, one may wonder whether these adversaries of the one-factor model can be mitigated by limiting the flexibility of price of risk. To address this concern, we also estimate 4-parameter one-factor model and the results are reported in Tables OA.3 and OA.4. As we can see the range and level of the price of risk are improved, however, the relative pricing errors become much worse than those of the 5-parameter model (and our rating-based model).

These results seem to indicate that sovereign credit rating is important and captures a major systematic component of sovereign credit risk embedded in cross-sectional sovereign CDS contracts. In the following, we illustrate why credit rating or its transition is the key reason for the poor overall performance of the one-factor model.

Intuitively, the more volatile the rating (and thus the more volatile the CDS spreads), the more difficult for a model to fit the data. To show this more visually, Figure OA.1 plots the point (NoRN, LogLikeli) for each country. Here NoRN (number of rating notches changed over the sample period) and LogLikeli are those numbers reported in Table OA.2. We fit a linear model to the data and plot the fitted lines in the same figure. The results presented in Figure OA.1 show that the estimated likelihood is negatively correlated with rating changes, and the negative relation is very significant. Rating changes may induce large discrete changes in CDS spreads, thus making it very difficult for a one-factor model to fit the data with reasonable factor dynamics.

For example, the rating of Greece had changed to A+ from SD, a total of 15 notches had changed over the sample period. This makes Greece the most difficult country to be fitted. The top plot in Figure OA.2 shows the rating variations and the fitted default intensity of Greece in the one factor CIR model. Table OA.2 shows that it is very difficult to fit CDS spreads in such a volatile period: the log-likelihood of the estimated default intensity is -9.24. While our rating-based model can resolve this problem by allowing the default intensity to depend on credit ratings. The bottom plot in Figure OA.2 shows the estimated global factor and Greece's idiosyncratic factor in our rating-based model. The estimated log-likelihood for global factor is 4.24, and that for Greece's idiosyncratic factor is 3.59.

Figure OA.3 shows that a linear model can easily be destroyed by only a few jumps in default intensity. The correlation coefficients are lower than one. Moreover, the R^2-s from linear regressions (see below) are much lower than one. If we allow loadings of the common factor depend on ratings, then we can achieve full linear correlation. For one particular country, this will need more parameters. But if the number of countries is far more than the number of ratings, this will reduce the parameter space significantly.

$$s_t^{(2)} = \underset{(11.0551)}{1.7478} \times z_t - \underset{(-1.0574)}{0.0010} + \epsilon_1, \qquad \text{Adj-}R^2\text{=55.30\%}$$

$$\Delta s_t^{(2)} = \underset{(9.9512)}{1.4217} \times \Delta z_t + \underset{(0.5660)}{0.0001} + \epsilon_2, \qquad \text{Adj-}R^2\text{=50.26\%}$$

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Pan, J. and K. Singleton, 2008, "Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads," *Journal of Finance*, 63 (5), 2345–2384.

Table OA.1: Estimated Parameters and Mean Absolute Pricing Errors (5-Parameter One-Factor Model). This table reports the estimated parameters and mean absolute pricing errors from country-by-country estimation of the classical one-factor CIR model. Given equations (OA.1) and (OA.2), the dynamics of z_t under the physical measure is given by $dz_t = \kappa^P(\theta^P - z_t)dt + \sigma\sqrt{z_t}dW_t^P$, where W_t^P is a standard Wiener process under the physical measure. Here we assume the price of risk has the form $\lambda(t) = \lambda_z\sqrt{z_t} + \varrho/\sqrt{z_t}$. We thus have $\kappa = \kappa^P + \sigma * \lambda_z$ and $\kappa^P * \theta^P = \kappa * \theta + \sigma * \varrho$. The first column reports the last-month rating for each country. The last column reports the logarithm of the likelihood. The mean absolute pricing errors are in basis points. The sample consists of monthly observations between January 2004 and March 2012.

		Estimated Parameters					Mean Absolute Pricing Errors						
Rating	Country	κ^P	$\kappa^P * \theta^P$	σ	λ_z	$\kappa * \theta$	1y	2y	3y	5y	7y	10y	Likeli
AAA	Germany	0.0059	0.0019	0.0614	-3.0385	0.0001	3.5	3.2	2.7	3.9	4.1	7.6	37.48
AA	Austria	0.0062	0.0019	0.0611	-1.8855	0.0001	5.9	3.6	2.3	5.3	4.3	5.7	40.37
AA	Belgium	0.0050	0.0019	0.0613	-1.2243	0.0002	10.8	4.6	4.6	6.0	5.6	6.2	33.16
AA	China	0.0050	0.0015	0.0553	-2.1388	0.0007	6.5	5.1	4.2	7.1	6.0	11.6	38.91
AA	Czech	0.1457	0.0019	0.0614	-3.9870	0.0003	7.9	3.2	2.3	5.4	4.8	6.2	40.87
AA	Japan	0.0053	0.0017	0.0579	-3.3763	0.0002	7.2	4.2	2.7	6.1	6.4	8.7	40.58
AA	Qatar	0.0868	0.0020	0.0625	-2.9919	0.0007	9.7	5.1	3.4	6.6	6.1	10.4	36.93
A	Chile	0.1022	0.0023	0.0674	-2.2655	0.0011	9.6	5.4	2.4	6.0	7.5	8.5	37.64
A	Israel	0.0057	0.0020	0.0635	-1.0002	0.0014	11.6	4.8	3.8	9.1	7.4	10.2	36.36
A	Korea	0.0050	0.0023	0.0676	-0.5042	0.0013	9.6	6.8	4.6	5.8	8.7	12.6	36.73
A	Malaysia	0.0296	0.0031	0.0782	-1.3450	0.0013	9.8	6.8	4.5	7.9	8.5	14.9	37.02
A	Poland	0.0161	0.0019	0.0614	-1.3137	0.0008	14.5	4.9	3.7	8.2	9.0	11.5	37.80
A	Slovakia	0.0050	0.0020	0.0627	-1.4641	0.0004	6.6	3.5	2.4	5.3	5.2	7.2	39.00
BBB	Brazil	0.0050	0.0142	0.1683	-2.6917	0.0001	32.2	21.2	14.6	10.2	21.6	30.4	29.42
BBB	Bulgaria	0.4938	0.0051	0.1015	-5.2355	0.0018	22.4	9.5	5.6	11.5	14.2	20.1	34.49
BBB	Colombia	1.2062	0.0314	0.2243	-7.6494	0.0014	30.7	24.3	11.8	9.8	23.1	33.0	30.42
BBB	Croatia	0.0050	0.0024	0.0693	-0.7496	0.0012	19.0	7.9	6.5	10.5	10.4	14.2	34.38
BBB	Iceland	0.0051	0.0019	0.0613	0.8740	0.0005	27.7	16.5	6.3	8.4	14.4	20.8	23.72
BBB	Italy	0.0050	0.0019	0.0614	-0.4207	0.0006	12.9	4.9	3.5	7.6	7.3	7.4	38.64
BBB	Mexico	0.4634	0.0057	0.1068	-4.9134	0.0026	12.6	6.1	5.0	9.4	9.2	15.6	36.52
BBB	Panama	0.0050	0.0092	0.1360	-1.8601	0.0014	24.1	16.5	10.9	14.5	16.1	26.9	32.66
BBB	Peru	7.2919	0.0545	0.2030	-38.1442	0.0011	22.8	19.4	10.1	8.3	18.1	25.0	31.78
BBB	Russia	0.0056	0.0077	0.1240	-0.0363	0.0030	35.6	14.6	6.8	14.6	19.8	22.7	29.62
BBB	South Africa	0.6206	0.0069	0.1176	-5.6650	0.0027	17.3	9.1	6.6	11.3	13.2	19.0	35.39
BBB	Thailand	0.0483	0.0086	0.1311	-1.1120	0.0017	10.6	6.9	5.2	6.7	7.7	14.4	37.92
BB	Hungary	0.0050	0.0041	0.0905	-0.4010	0.0013	24.4	11.2	6.3	11.6	15.2	18.3	33.53
BB	Indonesia	0.0152	0.0111	0.1489	-0.5506	0.0058	25.4	15.5	10.6	14.2	16.4	27.7	28.07
BB	Philippines	4.3249	0.0505	0.2180	-21.6489	0.0021	33.2	21.4	10.5	12.9	21.4	34.4	30.90
BB	Portugal	0.1661	0.0024	0.0698	-0.2938	0.0008	39.2	24.5	14.4	11.9	20.3	25.0	26.06
BB	Romania	0.1723	0.0045	0.0951	-2.1453	0.0016	22.0	10.6	5.3	10.7	13.5	16.8	30.95
BB	Turkey	10.7617	0.0914	0.3088	-35.7383	0.0056	29.7	21.9	12.0	9.7	21.6	32.8	29.45
B	Ukraine	0.0834	0.0125	0.1559	-0.0484	0.0089	73.2	28.4	11.0	22.5	34.6	46.4	22.13
B	Venezuela	0.0318	0.0313	0.2485	-0.7265	0.0061	86.6	38.7	14.5	28.6	43.7	58.9	24.20
CCC	Greece	0.0050	0.0019	0.0612	2.1668	0.0010	261.4	92.7	13.8	80.9	124.3	155.0	2.77

Table OA.2: Relative Pricing Error and Range of Estimated Price of Risk (5-Parameter One-Factor Model). The estimated parameters are reported in Table OA.1. Reported in this table are the mean absolute pricing errors relative to bid-ask spread, range of estimated price of risk, as well as the maximized values of likelihood. The first column reports the last-month rating for each country. The average pricing error for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. Likeli_z is the logarithm of the likelihood of z dynamics under the physical measure, Likeli_{cds} is the likelihood of pricing errors, and $\text{Likeli}=\text{Likeli}_z+\text{Likeli}_{cds}$. The column Max (resp. Min) reports the maximum (resp. minimum) of $-\lambda(t)$ for each country. The column NoRN reports the number of rating notches changed over the sample period. The sample consists of monthly observations between January 2004 and March 2012.

		Pricing Error							Log-Likelihood			Price of Risk		NoRN
Rating	Country	1y	2y	3y	5y	7y	10y		Likeli	Likeli_z	Likeli_{cds}	Max	Min	
AAA	Germany	2.8	1.5	1.1	1.5	1.8	2.9		37.48	7.07	30.42	-0.066	-7.0e+06	0
AA	Austria	1.7	0.9	0.6	1.2	1.0	1.4		40.37	6.13	34.24	0.114	-7.4e+06	1
AA	Belgium	2.1	1.0	0.9	1.5	1.2	1.5		33.16	6.41	26.75	0.074	-8.2e+06	0
AA	China	1.6	1.1	0.7	1.8	1.4	2.3		38.91	5.52	33.39	0.211	-2.2e+06	4
AA	Czech	1.0	0.4	0.3	0.8	0.8	1.2		40.87	6.04	34.82	0.507	-2.9e+06	2
AA	Japan	3.4	1.4	0.7	1.9	1.8	2.1		40.58	6.61	33.97	0.075	-6.5e+06	1
AA	Qatar	1.0	0.5	0.4	0.9	0.8	1.6		36.93	5.20	31.73	0.410	-2.1e+06	1
A	Chile	1.1	0.6	0.3	0.8	1.0	1.2		37.64	5.42	32.22	0.290	-2.2e+06	0
A	Israel	1.2	0.5	0.4	1.2	1.0	1.4		36.36	5.29	31.07	0.109	-8.6e+05	1
A	Korea	1.8	1.2	0.8	1.5	2.0	2.6		36.73	4.03	32.70	0.072	-2.2e+06	0
A	Malaysia	2.0	1.4	0.7	1.7	1.8	2.7		37.02	5.48	31.54	0.117	-2.5e+06	0
A	Poland	2.5	0.7	0.5	1.8	1.9	2.4		37.80	5.57	32.23	0.184	-7.9e+06	0
A	Slovakia	0.8	0.4	0.3	0.8	0.9	1.2		39.00	5.65	33.34	0.112	-3.8e+06	3
BBB	Brazil	3.2	2.7	1.8	1.9	3.4	4.7		29.42	4.19	25.23	0.154	-1.4e+00	4
BBB	Bulgaria	1.8	0.8	0.5	1.6	1.9	2.8		34.49	4.63	29.87	1.328	-1.3e+07	2
BBB	Colombia	2.6	2.3	1.3	1.1	2.6	3.7		30.42	4.32	26.10	0.437	-3.5e+00	1
BBB	Croatia	1.2	0.5	0.5	1.0	1.0	1.5		34.38	4.23	30.15	0.120	-1.9e+06	1
BBB	Iceland	0.7	0.4	0.3	0.6	0.6	0.9		23.72	2.39	21.33	-0.283	-2.8e+06	6
BBB	Italy	2.0	1.0	0.7	2.3	1.7	1.6		38.64	5.79	32.85	0.022	-1.3e+07	1
BBB	Mexico	2.2	1.0	0.8	2.8	1.8	3.3		36.52	4.78	31.73	0.912	-9.3e+06	1
BBB	Panama	1.6	1.2	1.0	1.5	1.3	2.9		32.66	4.49	28.16	0.010	-1.4e+00	1
BBB	Peru	1.5	1.5	1.0	0.8	1.8	2.5		31.78	4.35	27.43	5.071	-5.9e+00	3
BBB	Russia	4.5	1.8	0.9	3.5	3.6	4.3		29.62	3.72	25.89	-0.100	-3.1e+06	2
BBB	South Africa	2.3	1.1	0.8	2.5	2.0	2.8		35.39	4.99	30.40	1.158	-2.6e+06	0
BBB	Thailand	1.3	0.9	0.6	1.1	1.1	2.2		37.92	5.29	32.63	-0.084	-3.7e+06	0
BB	Hungary	2.3	1.1	0.7	2.1	2.3	3.0		33.53	4.88	28.65	-0.004	-5.5e+06	3
BB	Indonesia	1.6	1.1	0.9	1.7	1.4	3.4		28.07	3.55	24.52	0.064	-4.0e+06	3
BB	Philippines	2.0	1.5	0.9	1.6	1.8	3.2		30.90	4.15	26.75	3.379	-3.7e+00	1
BB	Portugal	2.1	1.5	1.0	2.8	2.8	3.2		26.06	4.59	21.48	0.107	-1.8e+07	8
BB	Romania	1.5	0.7	0.4	1.4	1.6	2.2		30.95	3.83	27.11	0.543	-1.8e+06	1
BB	Turkey	2.7	3.0	1.9	1.8	3.6	5.7		29.45	3.71	25.75	7.137	-2.3e+01	1
B	Ukraine	2.1	1.2	0.5	1.6	1.9	2.3		22.13	1.08	21.06	0.010	-8.7e+05	4
B	Venezuela	2.6	1.5	0.7	1.7	2.4	3.5		24.20	2.52	21.69	0.299	-3.4e+06	8
CCC	Greece	2.2	1.4	1.0	2.9	2.9	3.5		2.77	-9.24	12.01	-0.349	-1.8e+06	15
—	AAA	2.2	1.1	0.8	1.4	1.4	2.1		—	—	—	—	—	—
—	AA	2.2	1.1	0.8	1.9	1.7	2.0		—	—	—	—	—	—
—	A	1.7	0.9	0.6	1.5	1.5	2.0	Min	2.77	-9.24	12.01	-0.349	-1.8e+07	0.0
—	BBB	1.9	1.1	0.8	1.8	2.0	2.7	Median	34.44	4.70	30.01	0.116	-2.7e+06	1.0
—	BB	2.1	1.6	1.0	1.5	1.9	3.4	Max	40.87	7.07	34.82	7.137	-1.4e+00	15.0
—	B	3.7	1.7	0.7	1.9	2.6	3.2	Mean	32.82	4.31	28.51	0.651	-4.1e+06	2.3
—	CCC	1.7	0.9	0.2	1.7	2.8	3.5	Std	7.31	2.70	4.96	1.548	4.3e+06	3.1
—	Overall	2.0	1.2	0.8	1.6	1.8	2.6	Sum	1115.87	146.64	969.23	—	—	—

Table OA.3: Estimated Parameters and Mean Absolute Pricing Errors (4-Parameter One-Factor Model). This table reports the estimated parameters and mean absolute pricing errors from country-by-country estimation of the classical one-factor CIR model. Given equations (OA.1) and (OA.3), the dynamics of z_t under the physical measure is given by $dz_t = \kappa^P(\theta^P - z_t)dt + \sigma\sqrt{z_t}dW_t^P$, where W_t^P is a standard Wiener process under the physical measure. Here we assume the price of risk has the form $\lambda(t) = \lambda_z\sqrt{z_t}$. We thus have $\kappa = \kappa^P + \sigma * \lambda_z$ and $\kappa^P * \theta^P = \kappa * \theta$. The first column reports the last-month rating for each country. The last column reports the logarithm of the likelihood. The mean absolute pricing errors are in basis points. The sample consists of monthly observations between January 2004 and March 2012.

		Estimated Parameters				Mean Absolute Pricing Errors						
Rating	Country	κ^P	$\kappa^P * \theta^P$	σ	λ_z	1y	2y	3y	5y	7y	10y	Likeli
AAA	Germany	1.2032	0.0018	0.0602	-18.4045	7.4	9.1	10.2	16.7	19.9	26.4	32.27
AA	Austria	0.0001	0.0014	0.0532	-0.5562	6.7	7.8	10.1	17.7	21.5	32.0	35.34
AA	Belgium	1.0e-06	0.0019	0.0612	-0.0606	12.1	9.0	12.5	20.9	20.5	31.3	29.37
AA	China	3.1e-09	0.0015	0.0541	-1.1864	6.3	5.7	5.6	8.8	10.7	20.3	38.09
AA	Czech	1.3e-08	0.0017	0.0587	-0.2946	7.6	6.8	8.6	15.5	19.1	28.6	36.18
AA	Japan	0.3799	0.0016	0.0573	-7.2904	9.9	9.1	10.6	17.6	25.1	34.6	35.69
AA	Qatar	2.3e-09	0.0019	0.0614	-0.5615	8.2	6.1	5.8	10.3	12.5	21.8	35.48
A	Chile	2.2e-07	0.0016	0.0566	-0.1987	8.3	4.4	3.3	8.4	10.2	12.9	36.62
A	Israel	3.5e-09	0.0020	0.0632	-0.2824	11.4	5.2	4.4	10.9	11.3	15.6	35.63
A	Korea	1.3e-06	0.0023	0.0673	0.2095	9.0	7.0	6.2	9.4	13.9	20.9	35.62
A	Malaysia	6.6e-07	0.0030	0.0777	0.3137	8.4	8.5	9.4	16.4	20.5	30.6	34.42
A	Poland	3.6e-08	0.0019	0.0611	-0.3131	13.3	6.6	7.4	14.8	18.0	25.6	35.62
A	Slovakia	1.0e-09	0.0019	0.0618	-0.2942	6.3	7.6	10.0	17.3	22.1	34.9	34.12
BBB	Brazil	3.7e-09	0.0140	0.1676	1.2041	53.0	37.4	33.8	54.1	74.8	90.4	25.22
BBB	Bulgaria	0.0006	0.0045	0.0947	0.4666	20.1	13.3	14.3	24.7	31.0	42.2	31.25
BBB	Colombia	5.1967	0.0149	0.1724	-28.7735	42.7	35.5	30.5	43.6	60.3	73.9	26.42
BBB	Croatia	1.1e-09	0.0023	0.0684	-0.2295	17.3	8.1	7.9	13.1	14.8	23.5	33.83
BBB	Iceland	3.8e-06	0.0019	0.0614	1.4690	25.5	18.6	9.4	17.9	20.6	25.2	23.08
BBB	Italy	0.7949	0.0013	0.0511	-15.5175	12.3	6.6	7.2	12.9	14.1	17.1	36.37
BBB	Mexico	3.4499	0.0045	0.0945	-36.1659	11.4	6.9	7.2	12.3	14.3	23.4	34.65
BBB	Panama	1.5140	0.0090	0.1339	-10.7153	27.9	20.2	15.8	23.7	36.6	53.9	30.39
BBB	Peru	10.1968	0.0239	0.2186	-44.0439	45.9	54.7	55.1	60.9	69.8	74.9	25.12
BBB	Russia	0.0618	0.0047	0.0970	0.2846	32.8	13.7	8.3	17.2	22.9	26.5	29.40
BBB	South Africa	0.0002	0.0054	0.1038	0.7379	13.8	11.3	12.8	20.0	23.1	31.6	33.16
BBB	Thailand	3.6103	0.0081	0.1274	-25.5120	22.1	23.3	21.9	29.5	36.0	40.5	30.47
BB	Hungary	3.9e-05	0.0037	0.0865	0.3961	24.2	14.8	15.3	26.8	34.3	44.3	30.95
BB	Indonesia	1.7679	0.0078	0.1249	-14.1087	27.5	17.2	11.6	13.8	20.4	34.0	27.48
BB	Philippines	5.3538	0.0193	0.1964	-26.0639	52.5	44.8	41.2	58.5	75.7	91.9	26.11
BB	Portugal	1.6e-07	0.0024	0.0699	2.3990	36.6	23.7	19.0	21.5	25.8	31.5	25.61
BB	Romania	0.6239	0.0039	0.0882	-6.7390	20.5	11.7	10.4	18.6	25.3	35.4	29.22
BB	Turkey	10.1771	0.0589	0.3434	-25.1635	82.9	78.9	65.1	49.6	49.9	51.6	23.19
B	Ukraine	0.0560	0.0133	0.1631	0.3384	63.9	26.6	16.5	24.2	35.9	52.1	22.37
B	Venezuela	4.4e-06	0.0193	0.1964	0.3095	70.8	36.7	36.8	56.2	60.6	73.7	22.25
CCC	Greece	1.7e-08	0.0019	0.0612	2.5893	258.3	92.2	16.5	85.2	128.0	159.1	2.61

Table OA.4: Relative Pricing Error and Range of Estimated Price of Risk (4-Parameter One-Factor Model). The estimated parameters are reported in Table OA.3. Reported in this table are the mean absolute pricing errors relative to bid-ask spread, range of estimated price of risk, as well as the maximized values of likelihood. The first column reports the last-month rating for each country. The average pricing error for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. Likeli_z is the logarithm of the likelihood of z dynamics under the physical measure, Likeli_{cds} is the likelihood of pricing errors, and $\text{Likeli}=\text{Likeli}_z+\text{Likeli}_{cds}$. The column Max (resp. Min) reports the maximum (resp. minimum) of $-\lambda(t)$ for each country. The column NoRN reports the number of rating notches changed over the sample period. The sample consists of monthly observations between January 2004 and March 2012.

		Pricing Error							Log-Likelihood			Price of Risk		NoRN
Rating	Country	1y	2y	3y	5y	7y	10y		Likeli	Likeli_z	Likeli_{cds}	Max	Min	
AAA	Germany	16.3	6.1	7.0	10.2	12.9	15.5		32.27	7.03	25.23	1.913	3.7e-08	0
AA	Austria	11.0	6.6	7.1	10.2	10.2	15.0		35.34	5.80	29.53	0.091	2.3e-09	1
AA	Belgium	8.1	6.1	6.5	11.4	7.6	12.3		29.37	6.37	23.01	0.011	5.0e-11	0
AA	China	1.4	1.2	1.0	2.7	2.6	4.3		38.09	5.76	32.33	0.177	7.9e-09	4
AA	Czech	1.2	1.3	1.7	3.9	4.8	7.8		36.18	5.99	30.19	0.051	1.4e-09	2
AA	Japan	5.8	3.3	4.0	6.7	7.8	10.1		35.69	6.59	29.11	0.780	5.5e-08	1
AA	Qatar	0.7	0.8	0.9	1.7	2.1	3.8		35.48	5.62	29.85	0.103	1.2e-09	1
A	Chile	0.9	0.5	0.4	1.2	1.5	2.0		36.62	5.23	31.39	0.035	1.0e-09	0
A	Israel	1.1	0.6	0.6	1.7	1.8	2.5		35.63	5.47	30.16	0.049	1.7e-09	1
A	Korea	1.5	1.2	1.2	3.1	3.4	4.5		35.62	4.16	31.46	-0.000	-5.6e-02	0
A	Malaysia	1.3	1.7	2.1	4.7	4.6	6.2		34.42	5.75	28.67	-0.000	-6.0e-02	0
A	Poland	2.3	1.1	1.3	3.7	4.1	5.8		35.62	5.49	30.13	0.065	2.0e-09	0
A	Slovakia	0.9	1.5	2.2	4.4	5.5	8.5		34.12	5.73	28.38	0.053	2.0e-09	3
BBB	Brazil	4.8	5.4	6.6	18.3	15.2	18.4		25.22	4.82	20.40	-0.000	-4.1e-01	4
BBB	Bulgaria	1.7	1.6	2.1	4.7	5.6	7.2		31.25	4.56	26.70	-0.000	-1.4e-01	2
BBB	Colombia	3.5	3.4	4.0	7.9	8.1	10.2		26.42	4.92	21.49	8.361	2.3e-07	1
BBB	Croatia	1.0	0.6	0.8	1.7	2.0	3.3		33.83	4.53	29.30	0.059	2.2e-10	1
BBB	Iceland	1.9	0.9	1.1	4.1	2.6	3.3		23.08	2.33	20.75	-0.000	-5.9e-01	6
BBB	Italy	2.0	1.6	2.0	6.0	4.6	5.1		36.37	5.32	31.05	3.895	6.2e-08	1
BBB	Mexico	1.8	1.2	1.4	3.9	2.9	5.5		34.65	4.65	30.00	8.183	1.7e-07	1
BBB	Panama	2.0	1.7	1.6	3.1	4.2	6.4		30.39	4.93	25.45	2.342	5.0e-08	1
BBB	Peru	3.1	5.1	6.5	10.5	8.6	9.4		25.12	4.78	20.34	13.246	3.2e-08	3
BBB	Russia	4.1	1.7	1.2	5.2	5.0	5.7		29.40	3.23	26.17	-0.000	-1.0e-01	2
BBB	South Africa	1.8	1.5	1.8	4.3	3.7	5.1		33.16	5.14	28.02	-0.000	-1.8e-01	0
BBB	Thailand	2.2	3.5	3.8	6.1	5.1	6.0		30.47	5.00	25.48	6.164	4.5e-08	0
BB	Hungary	2.3	2.0	2.5	6.4	6.9	9.8		30.95	5.04	25.91	-0.000	-1.1e-01	3
BB	Indonesia	2.0	1.4	1.0	1.7	2.1	4.6		27.48	3.41	24.07	4.699	6.2e-08	3
BB	Philippines	3.7	4.9	6.0	11.9	9.7	12.4		26.11	4.77	21.34	7.519	1.0e-07	1
BB	Portugal	1.8	2.0	2.6	9.4	6.7	8.1		25.61	4.54	21.07	-0.000	-1.3e+00	8
BB	Romania	1.4	1.2	1.4	3.4	4.1	6.0		29.22	4.04	25.18	2.094	6.1e-08	1
BB	Turkey	11.2	13.6	11.9	16.0	9.6	8.8		23.19	3.63	19.56	13.909	1.2e-07	1
B	Ukraine	1.8	1.2	1.3	2.9	2.7	4.0		22.37	1.41	20.96	-0.000	-2.8e-01	4
B	Venezuela	2.1	2.1	2.8	6.0	5.0	6.8		22.25	2.47	19.77	-0.000	-2.1e-01	8
CCC	Greece	2.7	1.9	2.0	6.6	5.7	6.3		2.61	-9.49	12.11	-0.000	-3.2e+00	15
—	AAA	13.6	6.4	7.2	10.4	11.6	15.5		—	—	—	—	—	—
—	AA	4.2	3.2	3.7	8.3	6.7	9.1		—	—	—	—	—	—
—	A	1.6	1.2	1.5	3.9	3.9	5.4	Min	2.61	-9.49	12.11	-0.000	-3.2e+00	0.0
—	BBB	2.0	1.8	2.3	5.5	5.5	7.2	Median	31.10	4.93	26.04	0.056	1.6e-09	1.0
—	BB	3.9	4.5	4.6	8.1	6.1	7.8	Max	38.09	7.03	32.33	13.909	2.3e-07	15.0
—	B	2.9	1.3	0.9	2.2	2.4	2.8	Mean	30.11	4.38	25.72	2.171	-1.9e-01	2.3
—	CCC	1.6	0.9	0.2	1.6	2.7	3.4	Std	6.81	2.73	4.69	3.860	5.8e-01	3.1
—	Overall	3.2	2.6	2.9	6.1	5.5	7.3	Sum	1023.58	149.04	874.54	—	—	—

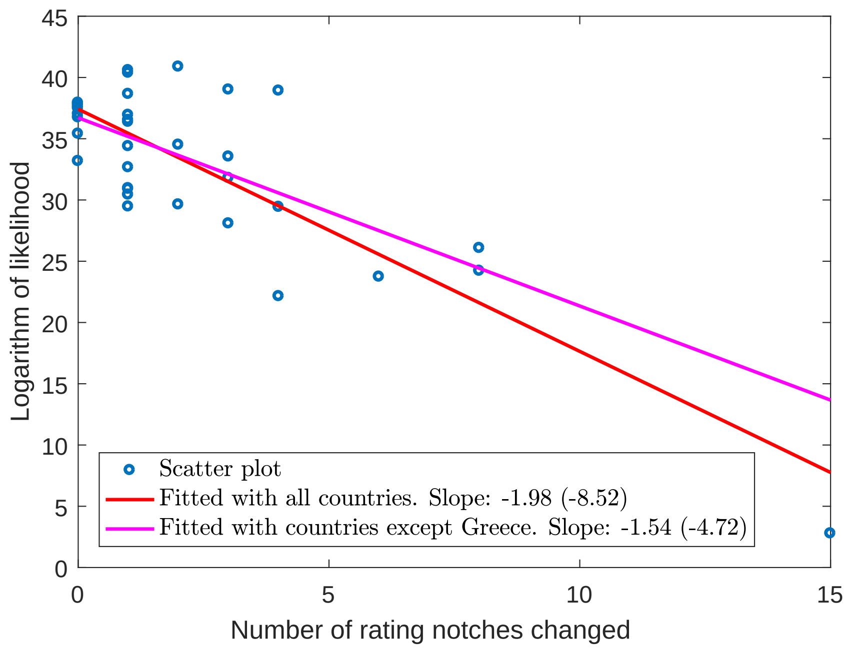

Figure OA.1: The log-likelihood versus the number of rating notches changed during the sample period. The log-likelihoods are reported in Table OA.2. We fit the two series by linear regression. In consideration of the particularity of Greece (the rightmost point), we also rerun the regression without Greece. t-statistics are corresponding to the estimated slopes are reported in parentheses.

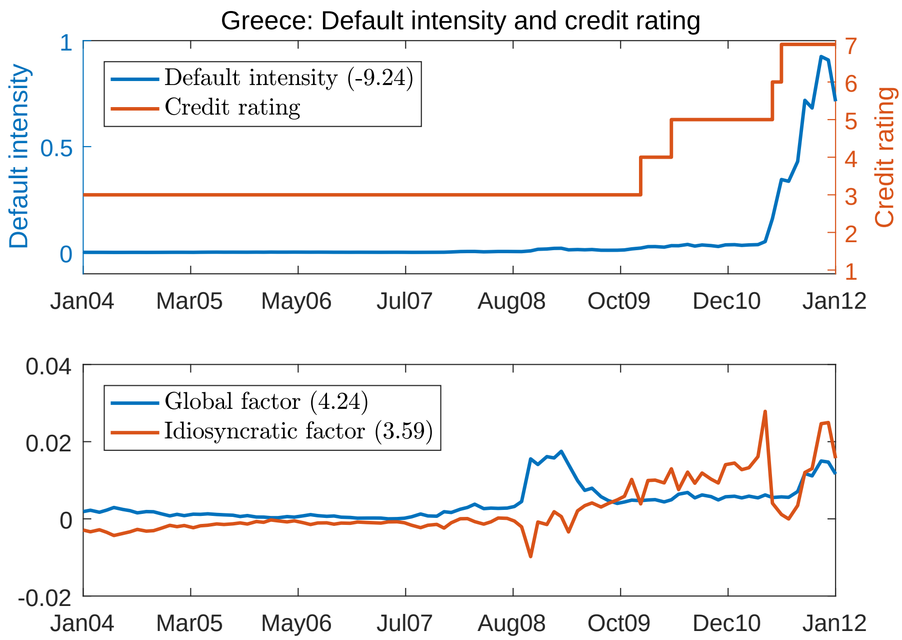

Figure OA.2: Top plot: The rating variations and the fitted default intensity of Greece in the one factor CIR model under the setting of Table OA.2. The log-likelihood of this default intensity is -9.24, and the log-likelihood of pricing errors for Greece's CDS spreads is 12.01. Thus the overall log-likelihood is 2.77. Bottom plot: The fitted global factor and Greece's idiosyncratic factor in our rating-based model. The estimated log-likelihood for global factor is 4.24, and that for Greece's idiosyncratic factor is 3.59. The log-likelihood of pricing errors for Greece's CDS spreads is 15.35. Thus the overall log-likelihood for Greece is higher than 18.94.

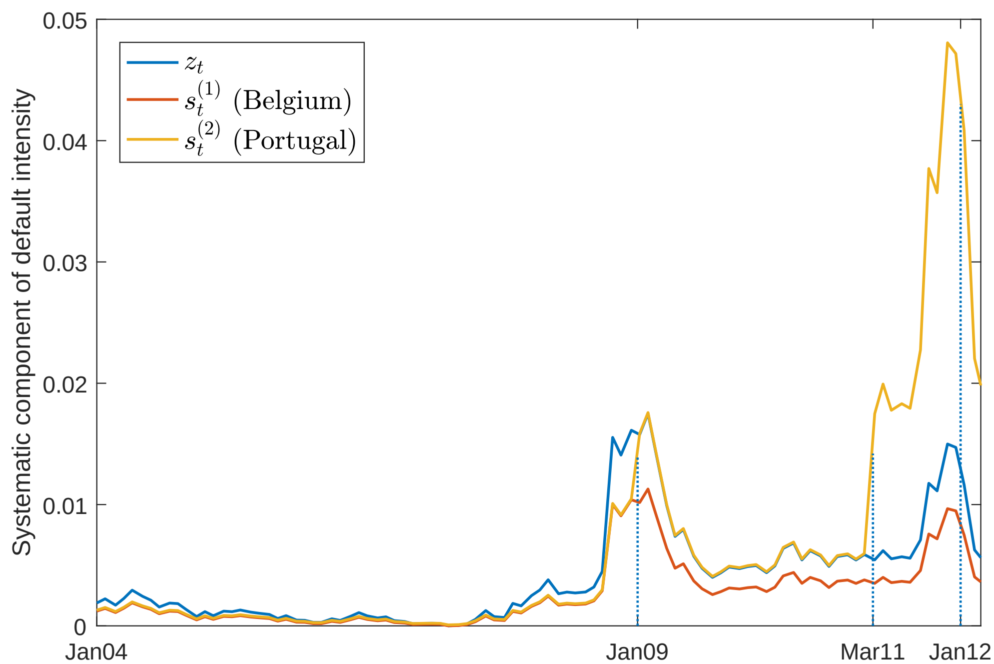

Figure OA.3: Systematic component of default intensity and rating changes. z_t is the estimated global factor. $s_t^{(1)}$ and $s_t^{(2)}$ are the systematic component of default intensities for Belgium and Portugal respectively. The rating of Belgium remains in the category AA during our sample period. While the rating for Portugal changed three times on Jan-21-2009, Mar-24-2011, and Jan-13-2012 respectively. $\text{Corr}\left(z_t, s_t^{(2)}\right) = 74.67\%$, and $\text{Corr}\left(\Delta z_t, \Delta s_t^{(2)}\right) = 71.26\%$.

Online Appendix B Additional Empirical Results

We report additional empirical results (tables) that are discussed but not included in the main paper.

Online Appendix B.1 Time Series Variations

We also find that the z-spreads can well capture the average level of the CDS spreads of both the in-sample and out-of-sample countries. The estimated values of β in Table OA.9 are close to 1, suggesting that rating is correctly priced on average. For example, the mean β for the in-sample (out-of-sample) countries is 0.99 (1.06), whereas the median β for the in-sample (out-of-sample) countries is 0.92 (1.13). However, for some specific countries, the ratings seem to be mismatched with their credit quality measured by their CDS spreads. Table OA.9 shows that most Eurozone countries, such as Austria, Belgium, Iceland, Portugal, France, Greece, Italy, Spain and Ireland, are significantly overrated because their βs are significantly higher than 1. This observation is consistent with the fact that most of these countries have inherent problems and are downgraded or placed on negative credit watch during the financial crisis, as previously discussed. Meanwhile, countries with low time-series R^2s in Table OA.9, such as Colombia, Panama and the Philippines, seem to be underrated. These observations are supported by the time-series regressions after removing data with stale ratings (with the implied ratings); all the corresponding regression coefficients $\widetilde{\beta}$ ($\hat{\beta}$) move to the right directions and the standard deviations of the regression coefficients are significantly reduced.

Overall, credit ratings, in conjunction with the common factor, capture the majority of both cross-sectional and time-series variations of sovereign CDS spreads of both in-sample and out-of-sample countries in the dataset. The existence of strong commonality in sovereign CDS spreads is consistent with Pan and Singleton (2008) and Longstaff et al. (2011). However, we use credit ratings as the only cross-sectional variable, and the method that is used to model and estimate the common factor is different from that used in the existing sovereign credit risk models.[2]

Online Appendix B.2 Alternative Estimations and Robustness

Several potential concerns of the main estimation regarding the selection of in-sample countries and the use of the S&P ratings may arise. As for the ratings, we repeat the estimations with either Moody's ratings or Fitch ratings, both of which are almost identical to the main estimation

[2]For example, Ang and Longstaff (2013) take Germany and the US as the systemic factor for the European countries and individual US states, respectively. We extend their analysis by allowing the possibility that each country has its own idiosyncratic default component. As shown in Table OA.9, the R^2s for Germany and the US are 67% and 48%, respectively, suggesting that the CDS spreads of even the highest-rated countries contain significant idiosyncratic components.

with the S&P ratings. As for the in-sample data selection, we re-estimate the model with (1) all CDS spreads of all 68 countries in the data set (Full Sample), (2) 34 in-sample countries with most observations rating-by-rating (Even Sample), and (3) only the observed CDS spreads of all 68 countries (Observed Sample). We then compare the pricing performance of these alternative estimations with that of our main estimation. The overall pricing errors of the full-sample estimation reported in Table OA.14 are comparable with that of the main estimation; the pricing errors of the 34 in-sample countries in the main estimation are slightly worsened, whereas those of the out-of-sample countries in the main estimation are slightly improved. Overall, the pricing errors of the full-sample estimation are similar to those in our main estimation.

Recall that we split data into in-sample and out-of-sample countries by the number of observations, i.e., the top half countries with the most observations of CDS spreads for in-sample. While this approach can pick up the countries with the most observations, it also leads to uneven distribution countries in each rating class between in-sample and out-of-sample countries (see Table 2). Moreover, as reported in Table 3, the averages of CDS spreads in some rating categories for in-sample countries are much lower than those for out-of-sample countries. To address this concern, we re-estimate the model with an alternative selection of in-sample and out-of-sample countries as follows. Within each rating class, the top half countries with the most observations belong to the in-sample group. Table OA.15 reports the mean absolute pricing error relative to bid-ask spread for this alternative in-sample selection. We find that these results are similar to those reported in Table 9. The results (not reported) about time-series regressions of market CDS spread on the common-factor model spreads are also quite similar to those reported in Table OA.9.

As shown in Table OA.5, large portions of the data are derived by the data provider, especially for the out-of-sample countries. Thus, an estimation with the observed data only may offer a better assessment on our main estimation. Table OA.16 reports the pricing errors of the estimation with the observed CDS spreads of all countries. As can be seen, the pricing errors of 5-year contracts for both in-sample and out-of-sample countries in the main estimation are significantly improved. Such improvements are attributed to the fact that 5-year contracts dominate in the observed data and, in particular, these contracts can be perfectly priced in the absence of other term CDS spreads. The pricing errors of other terms are basically the same as those in the main estimation, except for the countries with extremely few observations. The estimated parameters (not reported) are close to those in the main estimation. All results related to these robustness checks are available upon request. Overall, these alternative estimations show that our main estimation is robust to alternative selections of data sample and credit ratings.

Table OA.5: Proportion (%) of Observed Data. The proportion is calculated by using the formula $\frac{\text{N. of Observed Data}}{\text{N. of Observed Data + N. of Derived Data}} \times 100$. We also report the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

In-Sample Countries								Out-of-Sample Countries							
Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	0.0	0.0	1.3	62.6	8.8	50.0	AAA	Australia	0.0	0.0	0.0	77.8	0.0	0.0
AA	Austria	0.0	0.0	2.1	60.8	0.0	43.3	AAA	Denmark	0.0	0.0	1.7	62.7	0.0	47.5
AA	Belgium	0.0	0.0	2.7	67.7	0.0	58.7	AAA	Finland	0.0	0.0	1.8	78.6	0.0	62.5
AA	China	15.2	11.1	6.1	93.9	15.2	28.3	AAA	Hong Kong	0.0	0.0	1.2	46.5	4.7	10.5
AA	Czech	0.0	0.0	0.0	54.5	2.0	17.2	AAA	Netherlands	0.0	0.0	3.1	67.7	0.0	52.3
AA	Japan	0.0	0.0	1.0	61.2	1.0	9.2	AAA	Norway	0.0	0.0	2.0	81.6	0.0	42.9
AA	Qatar	7.4	4.2	1.1	64.2	4.2	10.5	AAA	Sweden	0.0	0.0	0.0	75.9	0.0	58.6
A	Chile	11.7	6.4	4.3	50.0	8.5	17.0	AAA	Switzerland	0.0	0.0	0.0	17.9	0.0	15.4
A	Israel	7.5	4.3	2.2	61.1	1.1	20.4	AAA	UK	0.0	0.0	3.4	78.0	0.0	61.0
A	Korea	16.2	9.1	8.1	92.9	20.2	35.4	AA	Abu Dhabi	0.0	0.0	0.0	86.1	0.0	0.0
A	Malaysia	17.9	9.5	10.5	91.9	15.8	30.5	AA	Estonia	0.0	1.9	0.0	79.6	0.0	3.7
A	Poland	17.2	14.1	9.1	78.8	6.1	41.4	AA	France	0.0	0.0	2.5	76.3	5.0	57.5
A	Slovakia	10.6	11.7	6.4	66.0	4.3	22.3	AA	New Zealand	0.0	0.0	0.0	82.1	0.0	0.0
BBB	Brazil	54.3	53.2	47.9	92.8	29.8	64.9	AA	Saudi Arabia	0.0	0.0	0.0	81.8	0.0	0.0
BBB	Bulgaria	28.3	23.2	13.1	88.9	17.2	44.4	AA	USA	1.7	0.0	1.7	72.4	0.0	41.4
BBB	Colombia	38.3	42.6	46.8	87.9	23.4	55.3	A	Slovenia	0.0	0.0	0.0	67.3	0.0	2.0
BBB	Croatia	23.2	19.2	9.1	78.8	14.1	44.4	A	Spain	1.5	1.5	3.1	78.5	0.0	84.6
BBB	Iceland	4.3	0.0	0.0	32.3	0.0	24.6	BBB	Bahrain	0.0	0.0	0.0	84.4	0.0	0.0
BBB	Italy	2.0	1.0	7.1	66.7	5.1	50.5	BBB	Ireland	1.7	1.7	0.0	82.8	1.7	79.3
BBB	Mexico	34.7	35.7	32.7	89.8	19.4	63.3	BBB	Kazakhstan	7.7	5.1	1.3	90.0	12.8	33.3
BBB	Panama	16.2	21.2	20.2	80.8	10.1	26.3	BBB	Lithuania	0.0	0.0	1.6	54.8	0.0	3.2
BBB	Peru	35.4	39.6	39.6	84.4	13.5	45.8	BBB	Morocco	0.0	0.0	0.0	61.0	0.0	0.0
BBB	Russia	21.3	25.5	26.6	94.7	18.1	58.5	BB	Costa Rica	0.0	0.0	0.0	2.7	0.0	0.0
BBB	South Africa	33.3	30.3	24.2	88.9	16.2	56.6	BB	Cyprus	0.0	0.0	11.1	22.2	0.0	22.2
BBB	Thailand	22.2	12.1	8.1	93.9	13.1	28.3	BB	El Salvador	0.0	0.0	0.0	2.9	0.0	0.0
BB	Hungary	29.6	29.6	21.4	81.8	9.2	58.2	BB	Guatemala	0.0	0.0	0.0	0.0	0.0	0.0
BB	Indonesia	23.3	14.0	26.7	88.9	22.1	39.5	BB	Latvia	3.4	0.0	1.7	75.9	0.0	8.6
BB	Philippines	30.3	31.3	36.4	91.9	35.4	45.5	BB	Vietnam	8.5	0.0	2.8	83.7	4.2	11.3
BB	Portugal	3.8	3.8	8.8	63.6	10.0	61.3	B	Argentina	50.0	53.7	53.7	92.7	28.0	50.0
BB	Romania	23.6	22.5	7.9	87.2	20.2	48.3	B	Dominican	0.0	0.0	0.0	0.0	0.0	0.0
BB	Turkey	50.5	60.4	57.1	92.6	20.9	62.6	B	Ecuador	0.0	11.1	11.1	11.1	0.0	11.1
B	Ukraine	35.2	38.6	37.5	82.6	15.9	38.6	B	Egypt	0.0	0.0	0.0	59.2	0.0	0.0
B	Venezuela	47.9	53.2	53.2	91.6	23.4	46.8	B	Lebanon	0.0	0.0	0.0	57.7	0.0	0.0
CCC	Greece	9.4	9.4	12.5	66.3	15.6	54.2	B	Pakistan	0.0	0.0	1.3	32.5	0.0	6.3
—	AAA	0.0	0.0	0.6	61.1	4.0	45.4	—	AAA	0.2	0.0	1.1	67.1	0.6	47.8
—	AA	1.2	0.3	4.1	61.2	3.8	22.5	—	AA	0.3	0.3	1.7	77.2	1.4	21.8
—	A	10.6	7.2	5.3	69.8	8.5	33.5	—	A	0.0	0.8	0.8	67.7	0.0	7.5
—	BBB	24.1	22.1	17.1	87.2	13.4	46.9	—	BBB	3.8	2.7	1.1	81.1	6.0	20.8
—	BB	38.5	42.0	41.9	88.3	23.7	51.1	—	BB	3.0	0.0	1.5	49.8	1.1	4.5
—	B	37.2	36.0	39.5	75.2	25.6	45.3	—	B	17.9	19.2	19.7	59.1	10.0	20.1
—	CCC	41.7	29.2	37.5	87.5	25.0	33.3	—	CCC	0.0	11.8	11.8	11.8	0.0	11.8
—	Overall	20.0	19.0	17.6	77.4	13.1	41.1	—	Overall	3.3	3.1	3.8	66.0	2.6	27.0

Table OA.6: Estimated Standard Deviations of Pricing Errors σ_{jM} Across Countries and Maturities. The first column reports the last-month rating for each country. The average for each rating is computed according to the last-month rating for each country. The standard deviations are in basis points. The sample consists of monthly observations between January 2004 and March 2012.

Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	11.2	8.3	4.7	5.8	8.5	10.2
AA	Austria	13.9	8.1	4.7	8.8	8.8	9.6
AA	Belgium	16.1	8.9	9.3	7.9	9.0	13.6
AA	China	12.6	9.2	6.1	5.7	9.5	14.9
AA	Czech	11.3	7.0	4.8	5.0	7.0	13.2
AA	Japan	15.6	9.5	4.9	7.2	10.6	13.0
AA	Qatar	16.1	8.1	3.3	6.8	8.5	11.9
A	Chile	13.3	7.8	3.3	8.0	8.2	9.3
A	Israel	15.0	6.8	4.2	8.2	7.7	9.9
A	Korea	21.2	12.4	5.3	10.9	13.8	14.8
A	Malaysia	12.7	7.9	4.5	6.7	7.9	12.2
A	Poland	22.3	11.2	6.9	7.8	12.5	19.4
A	Slovakia	14.1	8.9	5.9	5.3	9.0	16.5
BBB	Brazil	71.4	30.1	10.3	25.1	35.7	46.8
BBB	Bulgaria	30.3	13.8	11.5	12.7	14.9	24.5
BBB	Colombia	49.6	29.8	14.4	21.4	28.7	37.4
BBB	Croatia	28.1	14.7	12.8	10.4	15.6	27.5
BBB	Iceland	101.6	52.2	16.4	28.8	53.0	67.2
BBB	Italy	26.7	13.2	8.6	11.9	15.3	17.9
BBB	Mexico	21.4	12.2	8.1	8.4	12.8	21.0
BBB	Panama	32.0	21.4	14.1	11.5	20.9	34.2
BBB	Peru	36.7	23.4	10.8	15.8	22.8	31.0
BBB	Russia	62.7	22.0	11.6	29.4	30.8	24.4
BBB	South Africa	25.8	13.2	7.9	10.9	13.3	21.3
BBB	Thailand	13.5	10.0	6.9	6.0	9.7	17.1
BB	Hungary	37.2	17.2	11.4	16.3	19.8	26.0
BB	Indonesia	36.2	34.1	23.1	13.2	28.6	48.8
BB	Philippines	47.1	30.2	19.0	21.0	27.4	41.8
BB	Portugal	120.6	100.9	42.9	52.6	88.7	103.7
BB	Romania	41.4	23.8	19.4	17.8	24.1	37.1
BB	Turkey	35.1	20.0	14.1	14.2	18.8	29.0
B	Ukraine	257.0	129.0	42.4	77.0	140.0	204.0
B	Venezuela	169.1	87.9	56.7	63.1	88.2	118.6
CCC	Greece	496.6	119.4	87.2	159.5	192.3	209.4
Average	AAA	11.2	8.3	4.7	5.8	8.5	10.2
Average	AA	14.3	8.5	5.5	6.9	8.9	12.7
Average	A	16.4	9.2	5.0	7.8	9.9	13.7
Average	BBB	41.7	21.3	11.1	16.0	22.8	30.9
Average	BB	52.9	37.7	21.6	22.5	34.6	47.7
Average	B	213.0	108.4	49.5	70.0	114.1	161.3
Overall	Mean	56.9	27.4	15.2	21.2	30.1	39.9
Overall	SD	92.8	32.4	17.5	29.5	40.3	49.0
Overall	Min	11.2	6.8	3.3	5.0	7.0	9.3
Overall	Med	27.4	13.5	9.8	11.2	15.1	22.8
Overall	Max	496.6	129.0	87.2	159.5	192.3	209.4

Table OA.7: Mean Absolute Pricing Error (with Implied Ratings) Relative to Bid-Ask Spread. This table recalculates the model implied CDS spreads by using the implied ratings obtained as per equation (8). Reported are the averaged absolute pricing error relative to bid-ask spread. The first column of each panel reports the last-month rating for each country. The average for each rating is computed according to the *implied* rating when the price is quoted. The sample consists of monthly observations between January 2004 and March 2012.

In-Sample Countries								Out-of-Sample Countries							
Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	2.7	2.0	1.2	1.2	1.9	3.0	AAA	Australia	0.4	0.3	0.7	1.0	0.3	1.7
AA	Austria	1.1	1.0	1.0	0.8	1.2	2.7	AAA	Denmark	1.8	0.8	0.6	0.8	1.0	1.7
AA	Belgium	1.1	0.7	1.1	0.7	0.9	2.0	AAA	Finland	2.7	1.0	0.5	1.1	1.0	1.5
AA	China	1.5	1.1	0.7	1.2	1.0	1.7	AAA	Hong Kong	0.6	0.5	0.4	0.3	0.8	1.3
AA	Czech	0.7	0.3	0.4	0.5	0.4	1.1	AAA	Netherlands	1.4	0.9	0.6	0.9	1.0	1.8
AA	Japan	3.9	1.8	0.8	1.2	1.5	1.9	AAA	Norway	1.2	1.0	0.7	0.8	0.9	1.5
AA	Qatar	0.8	0.5	0.4	0.6	0.6	1.3	AAA	Sweden	1.9	1.2	0.6	1.1	1.1	1.6
A	Chile	0.8	0.5	0.3	0.6	0.5	0.8	AAA	Switzerland	0.9	0.8	0.4	0.8	0.9	0.8
A	Israel	1.2	0.5	0.3	0.7	0.6	0.7	AAA	UK	3.1	2.1	1.3	1.8	1.4	1.9
A	Korea	1.3	0.9	0.6	1.2	1.2	1.7	AA	Abu Dhabi	1.8	1.5	0.8	0.7	1.3	2.6
A	Malaysia	1.9	1.2	0.5	1.1	1.1	1.5	AA	Estonia	1.5	0.6	0.5	0.8	0.8	1.1
A	Poland	2.0	0.6	0.5	0.9	1.0	1.6	AA	France	1.5	1.2	1.0	1.1	1.2	2.4
A	Slovakia	0.5	0.4	0.3	0.5	0.4	1.0	AA	New Zealand	0.4	0.7	1.0	0.7	0.7	2.5
BBB	Brazil	4.2	2.5	1.3	2.9	2.7	4.2	AA	Saudi Arabia	0.6	0.6	0.3	0.4	0.8	1.7
BBB	Bulgaria	1.6	0.7	0.4	1.0	1.1	1.7	AA	USA	0.7	0.8	0.7	0.5	1.0	2.0
BBB	Colombia	3.2	1.7	0.8	1.7	1.9	2.7	A	Slovenia	1.0	0.5	0.6	0.9	0.6	1.6
BBB	Croatia	0.9	0.5	0.5	0.6	0.8	1.4	A	Spain	1.8	1.4	1.2	1.7	1.9	2.3
BBB	Iceland	1.1	0.8	0.3	0.7	1.4	2.0	BBB	Bahrain	0.6	0.4	0.4	0.6	0.7	1.3
BBB	Italy	1.5	1.0	1.0	1.2	1.2	1.7	BBB	Ireland	1.6	1.4	0.9	1.7	2.9	3.5
BBB	Mexico	3.3	1.6	0.7	2.1	1.9	2.6	BBB	Kazakhstan	1.8	0.6	0.4	1.0	1.0	1.4
BBB	Panama	2.1	1.0	0.5	1.1	1.3	1.8	BBB	Lithuania	1.5	0.9	0.4	0.9	1.6	2.4
BBB	Peru	2.5	1.2	0.5	1.3	1.5	2.1	BBB	Morocco	0.5	0.3	0.3	0.3	0.5	0.8
BBB	Russia	3.5	1.2	0.8	2.5	2.1	2.5	BB	Costa Rica	1.8	1.2	0.7	0.6	1.2	1.8
BBB	South Africa	2.7	1.3	0.5	1.6	1.5	1.9	BB	Cyprus	0.5	0.4	0.3	0.2	0.7	1.6
BBB	Thailand	1.3	0.8	0.5	1.0	0.9	1.5	BB	El Salvador	1.1	0.5	0.4	0.6	0.7	1.3
BB	Hungary	2.0	1.1	0.6	1.9	2.0	2.3	BB	Guatemala	0.7	0.3	0.2	0.5	0.4	0.6
BB	Indonesia	3.2	2.2	1.2	1.6	2.1	3.3	BB	Latvia	1.8	1.0	0.5	1.2	1.7	2.4
BB	Philippines	3.5	2.5	1.4	2.0	2.3	3.7	BB	Vietnam	0.9	0.6	0.5	0.6	1.0	1.5
BB	Portugal	1.1	0.9	0.8	1.0	1.6	2.1	B	Argentina	3.7	2.4	1.6	2.0	3.0	6.0
BB	Romania	1.3	0.6	0.4	0.9	1.2	1.7	B	Dominican	0.7	0.2	0.1	0.4	0.3	0.5
BB	Turkey	5.9	2.9	1.3	3.8	3.3	5.4	B	Ecuador	2.2	1.1	0.8	1.6	2.6	3.1
B	Ukraine	2.1	1.2	0.6	1.8	1.8	2.6	B	Egypt	1.1	0.7	0.6	0.8	1.1	1.7
B	Venezuela	3.5	2.2	1.1	2.5	3.8	5.8	B	Lebanon	1.2	0.9	0.8	0.7	1.2	1.8
CCC	Greece	1.2	0.6	0.5	1.2	1.6	2.0	B	Pakistan	1.2	0.7	0.7	0.5	1.0	1.4
—	AAA	1.8	1.5	1.1	0.9	1.5	2.9	—	AAA	1.5	1.0	0.7	1.0	1.0	1.7
—	AA	2.0	1.1	0.8	0.8	1.1	1.7	—	AA	1.1	0.9	0.8	0.8	1.1	2.1
—	A	1.2	0.7	0.5	0.9	0.9	1.4	—	A	1.3	0.7	0.4	0.8	1.1	1.4
—	BBB	2.2	1.0	0.5	1.5	1.5	2.0	—	BBB	1.5	0.8	0.5	1.1	1.4	2.0
—	BB	3.2	2.0	1.0	2.0	2.3	3.6	—	BB	1.2	0.7	0.5	0.7	1.1	1.6
—	B	3.3	1.8	0.8	1.7	2.7	3.9	—	B	2.1	1.3	1.0	1.1	1.8	3.2
—	CCC	1.2	0.5	0.4	1.3	1.8	1.9	—	CCC	2.0	1.0	0.5	1.5	2.3	2.6
—	Overall	2.1	1.2	0.7	1.3	1.5	2.2	—	Overall	1.5	0.9	0.7	0.9	1.2	2.0

Table OA.8: Proportion of Model Implied CDS Spread Attributed to Rating Transition Risk. For each country and at each maturity, we report the time series average of the ratio $|CDS^0 - CDS|/CDS$, where CDS is the model implied CDS spread and CDS^0 is obtained by setting $\bar{Q} \equiv 0$ in the CDS pricing formula, given the in-sample estimated values of z and y_i. The first column reports the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country.

Rating	Country	1y	2y	3y	5y	7y	10y	Mean
AAA	Germany	0.131	0.115	0.138	0.035	0.034	0.104	0.093
AA	Austria	0.090	0.101	0.136	0.050	0.030	0.097	0.084
AA	Belgium	0.332	0.237	0.148	0.076	0.116	0.227	0.189
AA	China	0.563	0.385	0.206	0.047	0.127	0.209	0.256
AA	Czech	0.504	0.373	0.454	0.084	0.165	0.269	0.308
AA	Japan	0.458	0.393	0.407	0.079	0.117	0.239	0.282
AA	Qatar	0.365	0.250	0.150	0.033	0.117	0.220	0.189
A	Chile	0.581	0.359	0.194	0.052	0.145	0.238	0.262
A	Israel	0.416	0.265	0.147	0.046	0.136	0.224	0.206
A	Korea	0.448	0.283	0.157	0.047	0.137	0.227	0.216
A	Malaysia	0.482	0.302	0.166	0.047	0.140	0.231	0.228
A	Poland	0.426	0.327	0.348	0.059	0.112	0.167	0.240
A	Slovakia	0.547	0.372	0.423	0.082	0.153	0.241	0.303
BBB	Brazil	0.409	0.259	0.118	0.061	0.121	0.145	0.186
BBB	Bulgaria	0.228	0.143	0.117	0.046	0.055	0.075	0.111
BBB	Colombia	0.627	0.295	0.115	0.091	0.152	0.170	0.242
BBB	Croatia	0.150	0.128	0.094	0.039	0.048	0.067	0.088
BBB	Iceland	0.185	0.159	0.133	0.046	0.079	0.133	0.122
BBB	Italy	0.486	0.413	0.307	0.069	0.128	0.225	0.271
BBB	Mexico	0.094	0.075	0.055	0.037	0.044	0.061	0.061
BBB	Panama	0.611	0.333	0.134	0.087	0.151	0.171	0.248
BBB	Peru	0.470	0.290	0.125	0.072	0.132	0.153	0.207
BBB	Russia	0.137	0.090	0.055	0.044	0.056	0.072	0.076
BBB	South Africa	0.113	0.082	0.060	0.038	0.045	0.063	0.067
BBB	Thailand	0.242	0.129	0.081	0.041	0.049	0.065	0.101
BB	Hungary	0.357	0.268	0.156	0.042	0.076	0.125	0.170
BB	Indonesia	0.615	0.238	0.095	0.082	0.127	0.152	0.218
BB	Philippines	0.586	0.254	0.097	0.100	0.152	0.172	0.227
BB	Portugal	0.442	0.359	0.214	0.054	0.102	0.186	0.226
BB	Romania	0.322	0.277	0.145	0.073	0.096	0.118	0.172
BB	Turkey	0.552	0.248	0.099	0.095	0.150	0.171	0.219
B	Ukraine	0.403	0.235	0.105	0.070	0.175	0.256	0.207
B	Venezuela	0.367	0.184	0.083	0.069	0.129	0.172	0.167
CCC	Greece	0.456	0.409	0.396	0.077	0.150	0.243	0.288
—	AAA	0.105	0.106	0.138	0.043	0.030	0.098	0.087
—	AA	0.401	0.347	0.258	0.061	0.110	0.224	0.234
—	A	0.505	0.351	0.267	0.060	0.147	0.242	0.262
—	BBB	0.149	0.108	0.097	0.042	0.049	0.063	0.085
—	BB	0.611	0.313	0.127	0.093	0.160	0.185	0.248
—	B	0.325	0.164	0.082	0.036	0.126	0.224	0.160
—	CCC	0.231	0.122	0.035	0.094	0.188	0.294	0.161
—	Overall	0.393	0.252	0.171	0.061	0.110	0.167	0.192

Table OA.9: Results of Time Series Regressions. This table reports the time series regressions of 5-year market CDS spreads on 5-year z-spreads. We obtain the z-spreads by setting the country-specific factors to zero in estimated Model I based on the 34 in-sample countries. The sample consists of monthly observations between January 2004 and March 2012. We also report $\widetilde{\beta}$ and $\widetilde{R}^2$ of regressions without the observations with "stale rating", and $\hat{\beta}$ and $\hat{R}^2$ of regressions using "implied rating". t-statistics of regression β-s are also reported. Column N reports the number of observations with "stale rating".

In-Sample Countries											
Rating	Country	β	t_{stat}	$\widetilde{\beta}$	t_{stat}	$\hat{\beta}$	t_{stat}	R^2	$\widetilde{R}^2$	$\hat{R}^2$	N
AAA	Germany	1.00	14.0	0.84	17.8	0.93	23.2	67.0	80.1	84.7	18
AA	Austria	2.28	21.7	0.96	25.6	0.94	51.2	83.2	92.4	96.5	41
AA	Belgium	1.58	9.4	0.84	15.1	0.95	32.8	47.9	94.6	91.7	84
AA	China	0.77	15.5	0.82	32.9	0.83	40.6	71.2	94.6	94.4	35
AA	Czech	1.01	24.2	0.83	14.2	0.93	35.5	85.8	83.5	92.8	57
AA	Japan	0.81	10.4	1.06	13.9	0.98	31.8	52.8	93.2	91.3	82
AA	Qatar	1.71	18.9	1.00	35.4	1.00	32.7	79.3	96.7	92.0	50
A	Chile	0.85	28.4	0.97	44.5	0.97	44.9	89.7	95.8	95.6	5
A	Israel	0.90	20.9	0.92	29.2	0.82	25.8	82.4	91.6	87.7	15
A	Korea	1.32	20.6	1.13	38.2	0.88	33.5	81.3	95.0	92.1	20
A	Malaysia	0.94	23.3	1.03	34.4	1.01	33.0	84.8	93.1	91.8	9
A	Poland	1.33	15.4	1.10	14.7	0.83	28.7	71.1	90.4	89.4	74
A	Slovakia	0.95	13.9	1.05	13.5	1.00	32.3	67.7	83.8	91.9	57
BBB	Brazil	0.69	9.9	0.90	25.3	0.77	28.1	50.6	92.8	89.3	45
BBB	Bulgaria	1.14	30.0	1.09	30.9	1.00	33.2	90.2	93.4	91.9	30
BBB	Colombia	0.14	2.4	0.47	2.9	0.60	28.8	5.7	21.1	89.5	65
BBB	Croatia	1.17	26.8	1.11	28.0	1.03	31.9	88.1	91.5	91.3	24
BBB	Iceland	1.63	16.1	0.72	8.2	1.09	41.5	73.4	76.2	94.8	73
BBB	Italy	1.30	12.9	1.13	23.1	0.96	41.0	63.1	95.3	94.5	71
BBB	Mexico	0.54	16.4	0.78	34.4	0.79	29.5	73.8	94.5	90.1	27
BBB	Panama	0.28	9.0	1.31	8.6	0.80	16.4	45.3	60.9	73.5	49
BBB	Peru	0.43	5.0	0.65	9.7	0.60	18.6	21.2	60.4	78.6	32
BBB	Russia	1.17	16.8	0.98	20.2	0.84	38.1	75.5	84.7	94.0	18
BBB	South Africa	0.68	20.0	0.84	35.7	0.83	34.1	80.5	94.0	92.3	16
BBB	Thailand	0.52	27.4	0.71	35.8	0.79	25.5	88.6	96.7	87.0	53
BB	Hungary	1.02	24.3	1.02	24.8	0.91	30.0	85.9	91.8	90.3	42
BB	Indonesia	0.46	9.4	0.67	14.3	0.69	16.1	50.3	83.3	74.7	47
BB	Philippines	0.03	0.5	0.60	17.8	0.66	32.2	0.3	91.4	91.5	67
BB	Portugal	2.57	19.5	0.74	7.8	0.87	31.8	79.7	85.9	91.2	87
BB	Romania	0.63	33.6	0.73	39.3	0.86	27.9	92.5	97.4	89.4	50
BB	Turkey	0.24	7.1	0.59	15.4	0.55	15.4	35.1	84.0	71.8	48
B	Ukraine	0.86	16.6	0.97	27.7	0.94	38.5	75.4	93.5	94.3	37
B	Venezuela	0.65	4.8	0.65	21.6	1.00	34.5	19.9	93.4	92.9	60
CCC	Greece	2.00	37.8	2.05	19.7	1.78	24.8	93.8	93.3	86.6	69
Overall	Mean	0.99	17.1	0.92	23.0	0.90	31.3	66.3	87.1	89.5	46
Overall	SD	0.58	8.9	0.28	10.7	0.20	8.0	25.2	14.6	6.1	23
Overall	Min	0.03	0.5	0.47	2.9	0.55	15.4	0.3	21.1	71.8	5
Overall	Med	0.92	16.5	0.91	22.4	0.90	32.1	74.6	92.6	91.4	48
Overall	Max	2.57	37.8	2.05	44.5	1.78	51.2	93.8	97.4	96.5	87

Out-of-Sample Countries											
Rating	Country	β	t_{stat}	$\widetilde{\beta}$	t_{stat}	$\hat{\beta}$	t_{stat}	R^2	$\widetilde{R}^2$	$\hat{R}^2$	N
AAA	Australia	1.17	13.4	1.09	13.1	0.95	22.6	80.6	93.5	92.2	31
AAA	Denmark	1.50	13.2	1.25	21.3	1.02	25.0	75.3	92.3	91.7	19
AAA	Finland	0.80	11.5	0.81	15.0	0.84	14.3	71.0	81.9	79.2	4
AAA	Hong Kong	1.01	21.3	0.93	20.9	0.97	33.6	84.4	92.7	93.1	50
AAA	Netherlands	1.24	13.7	1.13	18.8	1.09	26.2	74.9	89.2	91.6	20
AAA	Norway	0.47	10.9	0.47	10.9	0.47	10.9	71.7	—	—	0
AAA	Sweden	1.24	15.0	1.00	22.5	0.96	29.3	80.0	93.3	93.9	20
AAA	Switzerland	1.18	8.4	0.54	6.5	0.93	18.3	65.7	70.3	90.0	19
AAA	UK	1.25	11.0	1.15	18.3	0.99	20.4	67.8	94.1	88.0	36
AA	Abu Dhabi	1.34	5.5	0.34	1.5	0.81	13.3	47.3	53.5	83.8	74
AA	Estonia	2.40	17.1	1.32	7.2	1.24	41.0	84.8	77.7	97.0	37
AA	France	1.58	9.1	0.78	23.1	0.94	37.7	51.3	91.3	94.8	27
AA	New Zealand	0.84	11.8	1.01	16.8	0.87	12.1	78.9	91.3	79.9	10
AA	Saudi Arabia	1.16	8.2	0.41	2.1	0.82	15.5	68.5	69.0	88.6	29
AA	USA	0.47	7.2	0.80	13.4	0.76	13.6	48.3	83.7	76.8	21
A	Slovenia	1.89	8.3	1.13	10.9	0.87	27.6	59.7	89.4	94.2	33
A	Spain	2.09	6.6	1.04	26.9	0.89	30.0	40.8	97.4	93.4	44
BBB	Bahrain	0.76	6.4	0.66	9.6	0.84	13.3	48.5	92.1	80.5	35
BBB	Ireland	2.00	10.1	1.36	36.7	0.95	16.5	64.5	99.3	82.9	46
BBB	Kazakhstan	1.50	11.3	1.00	18.4	0.81	30.5	62.2	86.6	92.3	26
BBB	Lithuania	1.10	15.0	0.89	10.4	0.87	26.8	78.9	79.5	92.3	32
BBB	Morocco	0.22	6.6	0.53	4.2	0.67	9.0	52.4	55.7	67.6	25
BB	Costa Rica	0.29	10.8	NaN	NaN	0.57	9.8	76.9	NaN	73.1	35
BB	Cyprus	3.03	27.6	NaN	NaN	1.05	160.4	99.1	NaN	100.0	8
BB	El Salvador	0.50	17.2	0.70	16.9	0.74	9.6	90.2	93.8	74.2	13
BB	Guatemala	-0.16	-1.5	0.54	5.2	0.54	6.4	9.1	79.3	66.2	14
BB	Latvia	0.71	6.9	1.06	8.9	0.99	18.9	45.6	80.0	86.5	36
BB	Vietnam	0.51	19.5	0.74	17.9	0.83	20.4	81.8	84.9	83.1	27
B	Argentina	1.36	11.6	0.90	17.4	1.05	36.1	62.5	84.8	94.2	43
B	Dominican	-0.03	-0.1	NaN	NaN	0.21	1.0	0.2	NaN	10.7	14
B	Ecuador	1.31	14.0	1.29	14.1	1.28	15.5	92.5	93.4	93.7	8
B	Egypt	0.30	8.0	0.72	17.5	0.70	13.6	57.8	92.1	79.7	21
B	Lebanon	0.12	4.9	1.10	1.8	0.64	7.9	32.8	34.6	55.8	44
B	Pakistan	0.85	23.4	0.98	38.8	0.92	29.7	87.5	96.6	91.9	25
Overall	Mean	1.06	11.3	0.89	15.1	0.85	24.0	64.5	83.4	83.1	27
Overall	SD	0.71	6.1	0.28	9.0	0.21	26.0	22.0	14.5	16.3	15
Overall	Min	-0.16	-1.5	0.34	1.5	0.21	1.0	0.2	34.6	10.7	0
Overall	Med	1.13	10.9	0.93	15.0	0.87	18.6	68.2	89.2	88.3	27
Overall	Max	3.03	27.6	1.36	38.8	1.28	160.4	99.1	99.3	100.0	74

Table OA.10: Results of Time Series Regressions on Principal Components. This table reports the time series regressions of 5-year market CDS spreads on their principal components. We obtain the principal components by conducting the principal components analysis of the correlation matrix of the changes of CDS spreads for in-sample countries. The average for each rating is computed according to the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012. $\hat{\beta}_i$ is the loading on the i-th principal component in the two-PC regression. The column t_i reports t-statistics of $\hat{\beta}_i$. R_1^2 (R_2^2) denotes the adjusted R-square for the regression using the first (first two) principal component(s). Column N reports the number of rating transitions (under our reclassification of ratings) during the sample period.

In-Sample Countries									Out-of-Sample Countries								
Rating	Country	$\hat{\beta}_1$	t_1	$\hat{\beta}_2$	t_2	R_1^2	R_2^2	N	Rating	Country	$\hat{\beta}_1$	t_1	$\hat{\beta}_2$	t_2	R_1^2	R_2^2	N
AAA	Germany	0.15	17.4	0.34	13.6	52.0	83.6	0	AAA	Australia	0.13	11.3	0.06	1.7	74.4	75.5	0
AA	Austria	0.16	16.3	0.30	10.9	56.2	80.8	1	AAA	Denmark	0.11	8.2	0.21	5.4	46.0	64.1	0
AA	Belgium	0.12	9.4	0.36	10.2	30.8	66.6	0	AAA	Finland	0.12	11.6	0.20	6.4	60.7	78.0	0
AA	China	0.20	24.2	-0.00	-0.2	85.9	85.8	2	AAA	Hong Kong	0.17	14.3	-0.02	-0.7	71.7	71.5	2
AA	Czech	0.19	25.2	0.12	5.3	83.7	87.3	1	AAA	Netherlands	0.12	12.2	0.24	8.0	55.8	78.2	0
AA	Japan	0.16	12.2	0.07	1.8	60.2	61.2	0	AAA	Norway	0.12	10.0	0.13	3.7	64.6	72.6	0
AA	Qatar	0.18	16.3	-0.02	-0.6	74.3	74.1	1	AAA	Sweden	0.11	7.9	0.18	4.2	48.2	60.8	1
A	Chile	0.18	18.2	-0.06	-2.0	77.5	78.3	0	AAA	Switzerland	0.18	7.6	-0.03	-0.5	73.9	73.4	0
A	Israel	0.19	18.3	-0.02	-0.8	78.3	78.3	0	AAA	UK	0.11	8.9	0.24	6.6	46.7	69.9	0
A	Korea	0.19	27.7	-0.16	-8.1	82.4	89.5	0	AA	Abu Dhabi	0.10	7.8	0.05	1.1	64.4	64.6	0
A	Malaysia	0.20	31.1	-0.11	-6.2	87.7	91.1	0	AA	Estonia	0.14	17.0	-0.03	-1.2	85.6	85.7	1
A	Poland	0.19	28.1	0.20	10.5	79.3	90.4	1	AA	France	0.11	9.8	0.34	9.9	36.8	72.2	1
A	Slovakia	0.18	22.8	0.18	7.4	77.9	86.2	1	AA	New Zealand	0.20	8.4	-0.09	-1.6	73.3	74.3	0
BBB	Brazil	0.14	10.0	-0.20	-4.8	45.8	56.2	2	AA	Saudi Arabia	0.11	10.6	-0.00	-0.1	79.3	78.5	1
BBB	Bulgaria	0.19	22.2	0.11	4.5	80.9	84.1	1	AA	USA	0.10	6.1	0.17	3.6	37.0	48.2	1
BBB	Colombia	0.16	11.6	-0.15	-4.0	54.3	60.4	1	A	Slovenia	0.09	6.7	0.20	4.6	42.8	61.8	2
BBB	Croatia	0.19	23.1	0.10	4.1	82.6	85.1	0	A	Spain	0.07	4.3	0.23	4.5	19.1	38.5	3
BBB	Iceland	0.16	12.3	-0.07	-1.7	61.2	62.0	3	BBB	Bahrain	0.12	8.6	-0.01	-0.3	63.5	62.7	1
BBB	Italy	0.13	9.7	0.33	8.9	34.8	64.1	2	BBB	Ireland	0.05	2.5	0.14	2.4	9.2	16.5	3
BBB	Mexico	0.20	34.4	-0.10	-6.1	89.9	92.7	0	BBB	Kazakhstan	0.15	11.9	0.04	1.0	64.6	64.6	1
BBB	Panama	0.16	13.0	-0.17	-4.8	58.3	66.1	1	BBB	Lithuania	0.15	17.1	0.03	1.0	83.7	83.6	2
BBB	Peru	0.17	13.9	-0.16	-4.8	62.1	69.3	1	BBB	Morocco	0.10	6.9	0.10	2.3	54.2	58.9	1
BBB	Russia	0.19	26.7	-0.13	-6.1	84.5	88.9	1	BB	Costa Rica	0.24	4.5	-0.07	-0.8	47.2	46.6	0
BBB	South Africa	0.20	32.0	-0.07	-4.1	90.0	91.4	0	BB	Cyprus	1.26	0.3	-2.91	-0.4	20.6	0.0	2
BBB	Thailand	0.20	24.2	-0.09	-4.1	83.8	86.1	0	BB	El Salvador	0.18	3.1	-0.07	-0.5	28.9	26.8	0
BB	Hungary	0.18	20.4	0.17	6.7	74.7	82.6	2	BB	Guatemala	0.32	3.5	0.01	0.1	49.3	46.1	0
BB	Indonesia	0.18	25.1	-0.21	-10.1	76.4	89.1	1	BB	Latvia	0.14	12.2	-0.01	-0.3	73.5	73.1	3
BB	Philippines	0.18	21.2	-0.21	-8.6	72.4	84.2	0	BB	Vietnam	0.17	16.3	-0.15	-5.1	70.3	77.2	0
BB	Portugal	0.05	2.5	0.14	2.5	4.9	9.7	3	B	Argentina	0.14	9.8	-0.18	-4.4	48.0	57.7	1
BB	Romania	0.19	23.3	0.08	3.4	84.2	85.8	2	B	Dominican	0.54	4.5	-0.80	-4.2	0.1	70.9	1
BB	Turkey	0.18	17.4	-0.17	-5.8	70.2	77.9	1	B	Ecuador	0.14	4.0	0.57	4.1	0.0	57.7	5
B	Ukraine	0.18	15.3	-0.07	-2.0	71.2	72.1	4	B	Egypt	0.12	9.8	-0.10	-2.8	64.7	69.6	1
B	Venezuela	0.14	8.5	-0.13	-2.8	42.0	46.0	4	B	Lebanon	0.11	7.6	-0.19	-4.4	44.0	60.3	2
CCC	Greece	0.06	3.2	0.30	5.6	6.1	29.2	4	B	Pakistan	0.17	13.8	-0.18	-5.2	68.2	76.6	2
Average	AAA	0.15	17.4	0.34	13.6	52.0	83.6	0.0	Average	AAA	0.13	10.2	0.13	3.9	60.2	71.5	0.3
Average	AA	0.17	17.3	0.14	4.6	65.2	76.0	0.8	Average	AA	0.13	9.9	0.07	2.0	62.7	70.6	0.7
Average	A	0.19	24.4	0.00	0.1	80.5	85.6	0.3	Average	A	0.08	5.5	0.21	4.6	31.0	50.1	2.5
Average	BBB	0.17	19.4	-0.05	-1.9	69.0	75.5	1.0	Average	BBB	0.12	9.4	0.06	1.3	55.0	57.3	1.6
Average	BB	0.16	18.3	-0.03	-2.0	63.8	71.6	1.5	Average	BB	0.39	6.7	-0.53	-1.2	48.3	45.0	0.8
Average	B	0.16	11.9	-0.10	-2.4	56.6	59.1	4.0	Average	B	0.20	8.3	-0.15	-2.8	37.5	65.5	2.0
Overall	Mean	0.17	18.7	0.01	0.2	66.4	74.6	1.2	Overall	Mean	0.18	8.8	-0.05	1.1	52.1	62.3	1.1
Overall	SD	0.04	8.0	0.18	6.4	22.1	18.4	1.2	Overall	SD	0.21	4.2	0.55	3.8	22.8	18.9	1.2
Overall	Min	0.05	2.5	-0.21	-10.1	4.9	9.7	0.0	Overall	Min	0.05	0.3	-2.91	-5.2	0.0	0.0	0.0
Overall	Med	0.18	18.3	-0.04	-1.2	74.5	81.7	1.0	Overall	Med	0.12	8.5	0.02	0.5	55.0	67.1	1.0
Overall	Max	0.20	34.4	0.36	13.6	90.0	92.7	4.0	Overall	Max	1.26	17.1	0.57	9.9	85.6	85.7	5.0

Table OA.11: Regression Results for the Common Factor z and Credit Risk Premium. The table reports the regressions of changes in the estimated common factor z (in percent) and the 5-year credit risk premium (in percent, computed by (9), averaged over all 7 ratings) on changes in the CBOE VIX index, the CDX NA IG index, the 5-Year US Treasury rate, as well as the returns in the MSCI World stock market index, the S&P 500 Index, and the DAX index. t-statistics are reported in square brackets. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Common Factor z								5-y Risk Premium							
Intercept	VIX	MSCI	DAX	S&P 500	CDX	Treasury	R^2(%)	Intercept	VIX	MSCI	DAX	S&P 500	CDX	Treasury	R^2(%)
0.00	1.83***						40.58	0.01	1.95***						45.61
[0.31]	[8.10]							[0.53]	[8.97]						
0.01		-2.27***					45.63	0.01		-2.41***					51.08
[0.71]		[-8.98]						[0.98]		[-10.01]					
0.01			-1.57***				28.38	0.02			-1.67***				31.76
[0.86]			[-6.17]					[1.09]			[-6.68]				
0.01				-2.34***			40.60	0.01				-2.45***			44.18
[0.69]				[-8.10]				[0.92]				[-8.72]			
0.00					0.73***		32.85	0.00					0.80***		39.67
[0.10]					[6.85]			[0.27]					[7.95]		
0.00						-0.08	1.61	0.00						-0.12*	3.64
[0.13]						[-1.25]		[0.23]						[-1.91]	
0.01	0.93***	-1.51***					51.00	0.01	0.99***	-1.60***					57.18
[0.62]	[3.23]	[-4.49]						[0.90]	[3.68]	[-5.07]					
0.01	0.91***	-1.91***	0.40				51.49	0.01	0.98***	-2.03***	0.42				57.73
[0.51]	[3.17]	[-3.62]	[0.98]					[0.77]	[3.62]	[-4.09]	[1.11]				
0.01	0.89***	-2.57**	0.37	0.76			51.73	0.01	0.94***	-3.26***	0.36	1.43			58.57
[0.50]	[3.09]	[-2.33]	[0.89]	[0.68]				[0.77]	[3.50]	[-3.17]	[0.96]	[1.37]			
0.01	0.85***	-2.46**	0.40	0.83	0.12		52.05	0.01	0.87***	-3.07***	0.42	1.55	0.21		59.58
[0.42]	[2.89]	[-2.21]	[0.96]	[0.74]	[0.79]			[0.62]	[3.19]	[-2.98]	[1.10]	[1.49]	[1.51]		
0.01	0.84***	-2.46**	0.34	0.86	0.13	0.02	52.16	0.01	0.88***	-3.07***	0.44	1.53	0.20	-0.01	59.61
[0.46]	[2.82]	[-2.19]	[0.80]	[0.76]	[0.86]	[0.46]		[0.58]	[3.18]	[-2.97]	[1.12]	[1.47]	[1.42]	[-0.26]	

Table OA.12: Credit Risk Premium. This table reports the time-series averages for the difference (in basis point) $CDS(M) - CDS^P(M)$ and the credit risk premium (in percent) $[CDS(M) - CDS^P(M)]/CDS(M)$. The first column reports the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted. The sample consists of monthly observations between January 2004 and March 2012.

		$CDS(M) - CDS^P(M)$						$[CDS(M) - CDS^P(M)]/CDS(M)$					
Rating	Country	1y	2y	3y	5y	7y	10y	1y	2y	3y	5y	7y	10y
AAA	Germany	3.1	5.7	7.9	9.4	15.9	23.4	22.5	36.5	48.5	73.0	71.4	77.5
AA	Austria	3.1	6.1	8.4	10.5	15.8	23.4	13.9	21.7	34.5	62.1	64.6	69.4
AA	Belgium	3.9	8.9	14.5	15.7	28.7	39.3	9.3	18.7	26.9	65.6	59.7	64.6
AA	China	4.0	8.8	14.6	26.6	37.9	51.6	21.4	35.2	38.8	47.7	55.7	64.6
AA	Czech	5.8	12.4	14.5	24.9	35.5	48.3	15.1	30.2	56.9	66.4	69.1	74.2
AA	Japan	3.4	6.6	8.5	15.0	22.1	31.3	17.7	36.7	55.5	63.7	67.8	73.9
AA	Qatar	2.5	5.9	9.9	18.7	27.4	38.8	6.8	11.8	17.6	28.4	37.5	47.6
A	Chile	4.1	9.6	15.7	28.1	39.0	52.0	11.6	20.7	28.8	42.0	51.7	61.7
A	Israel	4.2	9.9	16.3	29.0	40.5	53.5	6.9	13.9	20.5	32.1	41.3	51.0
A	Korea	4.2	9.8	16.2	28.7	39.5	52.1	7.2	14.2	20.8	32.4	41.5	51.0
A	Malaysia	4.1	9.6	15.9	27.8	39.4	52.4	8.7	16.7	24.1	36.4	46.1	56.0
A	Poland	6.6	13.9	17.1	32.6	46.0	61.0	12.7	29.5	53.1	57.4	60.5	65.5
A	Slovakia	6.6	14.5	16.7	27.4	39.0	52.3	16.4	29.6	56.8	68.2	71.3	76.3
BBB	Brazil	12.7	27.8	43.6	75.1	93.1	113.0	12.8	23.2	31.7	43.1	50.8	57.9
BBB	Bulgaria	11.8	24.1	34.6	56.1	72.0	88.2	19.9	28.5	37.6	43.5	49.5	56.4
BBB	Colombia	17.2	38.9	59.9	93.3	115.7	134.2	20.8	32.8	41.5	51.1	59.4	65.7
BBB	Croatia	11.5	23.3	33.8	54.4	69.9	85.7	16.4	27.5	35.8	42.5	49.0	56.0
BBB	Iceland	14.1	29.9	43.6	45.4	74.0	84.2	7.4	14.5	21.7	48.1	36.4	41.6
BBB	Italy	5.5	11.0	16.5	29.0	38.9	49.7	15.9	35.1	44.7	49.5	55.7	63.2
BBB	Mexico	10.0	21.3	32.8	53.5	69.6	86.4	12.8	22.7	30.9	43.4	52.2	61.1
BBB	Panama	15.5	34.6	53.4	85.3	107.6	127.6	18.3	30.8	40.0	52.2	59.7	67.0
BBB	Peru	11.1	25.1	40.5	68.8	89.9	110.1	13.5	23.6	31.9	43.7	50.9	58.1
BBB	Russia	10.6	23.2	35.8	57.3	73.5	90.0	8.8	16.7	23.8	34.9	42.9	51.2
BBB	South Africa	10.1	21.3	32.8	53.5	69.8	86.9	13.6	22.2	29.9	42.2	51.0	59.9
BBB	Thailand	9.9	21.0	32.4	53.2	69.6	86.9	32.0	39.1	45.5	56.6	64.8	73.4
BB	Hungary	11.8	24.1	35.2	54.1	68.2	82.0	21.8	29.8	34.8	41.4	48.1	55.4
BB	Indonesia	25.0	55.2	81.8	120.4	142.8	160.6	29.0	38.1	45.4	54.4	61.0	66.5
BB	Philippines	19.9	45.2	67.9	102.7	123.9	140.4	20.7	31.7	38.9	48.4	53.8	58.7
BB	Portugal	9.4	18.6	27.5	34.6	50.3	57.8	15.1	31.0	33.7	49.9	46.1	53.5
BB	Romania	24.7	45.7	62.1	89.6	109.5	127.7	20.7	39.0	45.1	49.6	56.5	64.2
BB	Turkey	20.9	47.0	70.9	109.5	130.6	149.4	16.7	27.8	35.9	46.3	53.9	60.5
B	Ukraine	86.2	137.1	170.3	208.5	235.0	255.5	13.6	21.2	27.4	37.2	43.2	50.0
B	Venezuela	42.3	79.2	105.6	136.4	149.6	159.2	8.3	13.9	17.7	23.4	26.9	30.6
CCC	Greece	44.9	58.9	58.5	71.8	84.5	97.1	16.3	29.9	45.6	50.5	53.3	58.4
—	AAA	3.1	5.8	7.9	9.6	15.3	22.8	18.5	29.7	42.2	68.3	68.4	73.7
—	AA	3.2	6.5	10.0	15.3	25.0	34.8	13.6	28.6	37.7	55.7	55.9	63.3
—	A	4.6	10.5	15.8	27.4	38.7	51.4	12.0	22.2	34.7	46.3	52.7	60.9
—	BBB	12.3	25.6	37.1	59.0	75.2	91.1	17.9	28.5	38.5	47.8	54.6	61.8
—	BB	19.3	42.6	63.9	95.7	116.5	133.8	15.3	25.7	32.4	41.5	47.6	53.3
—	B	84.8	139.9	178.9	216.8	253.6	275.4	26.7	32.7	38.3	45.4	53.0	60.4
—	CCC	225.4	312.5	359.5	410.5	440.2	470.7	8.2	13.0	16.4	21.2	24.6	28.4
—	Overall	14.6	28.3	39.3	56.7	72.2	86.6	15.4	26.1	35.9	47.9	53.1	60.2

Table OA.13: OLS regression of Country-Specific Factors on Macro Variables. This table reports the OLS regression of monthly variations of the estimated country-specific factor y on macro variables (GDP growth rate, GDP per capita, Government effectiveness, Stock market return, and Total reserve) for each country. Reported are the regression betas together with there respective statistical significance when all variables are included in the regression. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively. All data are obtained from the World Bank Open Data service. We include an independent variable only if it has at least 9 observations, otherwise we input the mark "NA" indicating not available. In each month, we use the most recent observation if there is no data for that month. In the first column, we report the last-month rating for each country. The last row reports the averaged adjusted-R^2, where the 3rd to 7th column report the results of bivariate regressions.

Rating	Country	GDPgr	GDPpc	GovEff	MarRet	Reserve	Adj-R^2
AAA	Germany	0.12***	-0.31***	0.26	0.16	0.79	53.07
AA	Austria	-0.24	0.66**	0.01**	-0.04	0.02***	56.47
AA	Belgium	-0.03***	0.40	0.41	-0.07	0.80***	72.47
AA	China	0.46	1.15***	-0.52**	-0.12	-0.23***	57.90
AA	Czech Republic	-0.24	-0.50***	0.11**	0.00	1.00***	34.52
AA	Japan	-0.20***	0.71***	0.14***	0.10*	-0.11	45.05
AA	Qatar	-0.32***	0.49	-0.27	-0.03**	0.46***	57.75
A	Chile	-0.12	0.69	0.26***	0.02	-1.28	42.68
A	Israel	0.19**	0.12*	-0.09	0.32	0.43***	28.31
A	Korea	-0.29	0.34***	0.33***	-0.17**	-0.67***	38.71
A	Malaysia	0.05	-0.14*	0.42**	-0.19	0.13***	24.54
A	Poland	-0.08*	0.81	0.35	-0.02	-0.03***	85.73
A	Slovakia	-0.35***	0.15***	-0.08***	NA	NA	15.37
BBB	Brazil	0.34***	0.10	0.05	0.04	-0.84***	74.87
BBB	Bulgaria	-0.09**	1.05	-0.16	-0.07***	-0.49**	58.82
BBB	Colombia	0.35	-0.10*	0.05	0.08**	-0.71***	84.78
BBB	Croatia	-0.11**	0.04***	0.47	0.03	0.13	38.39
BBB	Iceland	-0.34***	0.38*	-0.70	-0.19*	-0.51***	60.59
BBB	Italy	0.08	-0.40	-0.03***	-0.17**	0.91	56.87
BBB	Mexico	0.35***	-0.01	0.00	0.08	-0.76***	66.50
BBB	Panama	-0.16**	-0.53***	-0.11	NA	-0.11	63.80
BBB	Peru	0.16***	-0.22	0.13	0.00	-0.70***	70.43
BBB	Russia	-0.37***	-0.06***	0.37	-0.46	-0.14	50.16
BBB	South Africa	0.17*	-0.11***	0.02***	-0.01	-0.52	40.78
BBB	Thailand	0.32	-0.02***	0.67	0.07*	0.08***	59.43
BB	Hungary	-0.13***	-0.06***	-0.11*	-0.04	0.60***	45.99
BB	Indonesia	0.24***	-0.20***	-0.02***	-0.03***	-0.59*	67.13
BB	Philippines	0.17***	-0.82	0.00***	0.02***	-0.06	85.81
BB	Portugal	0.02***	0.75	-0.09	-0.15	0.63	31.99
BB	Romania	0.41*	-0.61	-0.59	0.28	0.35**	33.25
BB	Turkey	0.31***	-0.51	-0.60***	0.07	0.48	64.48
B	Ukraine	-0.25***	0.21**	0.86***	-0.15	-0.07**	55.77
B	Venezuela	0.05***	0.50	0.08***	-0.17**	0.30	38.91
CCC	Greece	-0.14	0.31***	-0.30	-0.02**	0.28***	32.46
Average	Adj-R^2	9.87	32.38	18.42	1.99	33.04	52.76

Table OA.14: Mean Absolute Pricing Error Relative to Bid-Ask Spread (Full Sample). The pricing errors are based on the estimated model with both observed and derived data of all 68 countries. We also report the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	3.6	2.6	1.4	1.2	2.2	3.2	AAA	Australia	1.3	0.6	0.2	1.3	1.1	0.5
AA	Austria	2.0	1.4	0.9	1.2	1.5	2.4	AAA	Denmark	2.1	1.0	0.6	1.0	1.2	1.7
AA	Belgium	1.6	1.0	1.2	0.7	1.3	3.1	AAA	Finland	3.0	1.2	0.5	1.1	1.1	1.5
AA	China	1.9	1.5	0.9	1.2	1.4	2.5	AAA	Hong Kong	0.8	0.7	0.5	0.3	0.9	1.6
AA	Czech	0.9	0.8	0.8	0.4	1.1	2.9	AAA	Netherlands	1.9	1.2	0.6	1.0	1.3	1.8
AA	Japan	4.7	2.3	1.1	1.4	2.1	2.9	AAA	Norway	1.3	1.1	0.7	0.8	0.9	1.4
AA	Qatar	1.0	0.5	0.3	0.7	0.7	1.1	AAA	Sweden	2.3	1.4	0.6	1.2	1.2	1.6
A	Chile	0.7	0.5	0.3	0.6	0.5	0.9	AAA	Switzerland	1.2	1.0	0.5	0.9	1.1	0.8
A	Israel	1.1	0.4	0.3	0.8	0.6	0.7	AAA	UK	5.1	3.2	1.4	2.2	2.2	2.2
A	Korea	1.2	0.9	0.6	1.2	1.2	2.0	AA	Abu Dhabi	1.8	1.3	0.7	0.9	1.1	2.2
A	Malaysia	1.7	1.1	0.5	1.1	1.0	1.5	AA	Estonia	1.5	0.7	0.6	0.9	1.1	1.7
A	Poland	2.0	1.1	0.9	1.1	1.8	3.3	AA	France	3.1	2.2	1.0	1.7	2.0	2.6
A	Slovakia	0.8	0.8	0.8	0.5	1.2	2.9	AA	New Zealand	0.4	0.8	1.1	0.6	1.0	2.8
BBB	Brazil	4.9	2.9	1.3	3.4	3.1	4.7	AA	Saudi Arabia	0.4	0.5	0.2	0.4	0.5	1.3
BBB	Bulgaria	1.7	0.8	0.5	0.9	1.2	2.2	AA	USA	0.8	0.7	0.7	0.6	1.1	1.9
BBB	Colombia	3.7	2.1	1.0	1.7	2.3	3.2	A	Slovenia	1.6	0.8	0.6	1.0	1.1	1.5
BBB	Croatia	1.1	0.7	0.6	0.7	1.0	1.8	A	Spain	2.0	1.5	1.5	1.7	2.0	3.1
BBB	Iceland	0.8	0.8	0.4	0.4	1.3	2.4	BBB	Bahrain	0.6	0.4	0.4	0.6	0.7	1.6
BBB	Italy	1.5	1.2	1.1	1.2	1.6	3.0	BBB	Ireland	1.2	1.5	1.3	1.4	2.6	3.9
BBB	Mexico	3.2	1.5	0.8	2.0	1.9	2.8	BBB	Kazakhstan	2.4	0.8	0.4	1.6	1.3	1.6
BBB	Panama	1.9	1.0	0.6	0.8	1.3	2.0	BBB	Lithuania	1.3	0.9	0.6	0.6	1.5	2.5
BBB	Peru	2.5	1.2	0.6	1.3	1.5	2.2	BBB	Morocco	0.5	0.4	0.3	0.2	0.6	1.1
BBB	Russia	3.9	1.3	0.8	2.8	2.3	2.7	BB	Costa Rica	1.1	1.1	0.7	0.3	1.1	1.7
BBB	South Africa	2.9	1.4	0.6	1.8	1.6	2.0	BB	Cyprus	0.9	1.1	0.9	0.5	1.7	3.1
BBB	Thailand	1.3	0.9	0.6	0.9	1.0	1.8	BB	El Salvador	0.9	0.5	0.4	0.4	0.6	1.1
BB	Hungary	2.2	1.1	0.7	1.7	1.7	2.7	BB	Guatemala	0.5	0.5	0.3	0.2	0.5	0.7
BB	Indonesia	1.9	1.9	1.5	1.2	1.8	3.3	BB	Latvia	1.5	1.1	0.6	1.1	1.8	2.5
BB	Philippines	3.0	2.5	1.6	2.3	2.3	3.6	BB	Vietnam	0.7	0.6	0.5	0.6	0.9	1.4
BB	Portugal	1.3	1.3	1.1	1.0	2.4	3.7	B	Argentina	6.6	3.8	1.7	3.2	4.8	8.1
BB	Romania	1.6	1.0	0.6	0.8	1.7	2.8	B	Dominican	1.1	0.4	0.1	0.5	0.6	0.9
BB	Turkey	5.2	3.5	1.7	3.2	3.7	6.3	B	Ecuador	1.5	0.7	0.8	1.1	1.8	2.2
B	Ukraine	3.2	2.1	1.0	2.0	2.8	4.4	B	Egypt	1.0	0.7	0.5	0.6	1.1	1.8
B	Venezuela	3.6	2.4	1.1	2.5	3.7	5.2	B	Lebanon	1.4	1.3	1.0	0.5	1.5	2.8
CCC	Greece	1.5	1.3	0.8	1.5	2.8	4.4	B	Pakistan	1.1	0.9	0.8	0.4	1.1	1.8
—	AAA	2.7	2.0	1.1	1.2	1.9	2.8	—	AAA	2.2	1.4	0.7	1.2	1.4	1.7
—	AA	2.5	1.4	0.9	0.9	1.4	2.4	—	AA	1.2	1.0	0.9	0.9	1.2	2.2
—	A	1.2	0.8	0.7	0.8	1.1	2.2	—	A	1.3	1.0	0.7	0.8	1.4	2.5
—	BBB	2.3	1.1	0.7	1.5	1.7	2.5	—	BBB	1.7	0.8	0.5	1.2	1.5	2.0
—	BB	3.1	2.3	1.2	2.1	2.5	3.9	—	BB	0.9	0.7	0.5	0.5	1.0	1.5
—	B	4.6	2.6	1.0	2.1	3.7	5.6	—	B	3.2	2.1	1.1	1.5	2.6	4.4
—	CCC	1.1	0.5	0.4	1.1	1.5	1.7	—	CCC	1.3	0.6	0.6	1.1	1.5	1.8
—	Overall	2.2	1.4	0.8	1.4	1.7	2.8	—	Overall	1.8	1.2	0.7	1.0	1.4	2.2

Table OA.15: Mean Absolute Pricing Error Relative to Bid-Ask Spread (Even Sample). We also report the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

In-Sample Countries								Out-of-Sample Countries							
Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Denmark	1.9	0.9	0.6	0.9	1.1	1.6	AAA	Australia	0.8	0.4	0.4	1.2	0.7	1.0
AAA	Germany	3.2	2.3	1.3	1.2	1.9	2.6	AAA	Finland	2.8	1.0	0.5	1.0	1.0	1.4
AAA	Hong Kong	0.8	0.6	0.4	0.3	0.8	1.5	AAA	Norway	1.3	1.1	0.6	0.8	0.9	1.3
AAA	Netherlands	1.7	1.0	0.6	1.0	1.1	1.6	AAA	Sweden	2.1	1.3	0.6	1.2	1.1	1.5
AAA	UK	4.4	2.9	1.2	2.1	2.0	1.8	AAA	Switzerland	1.0	0.9	0.4	0.8	1.0	0.8
AA	Austria	1.7	1.3	0.8	1.1	1.3	2.1	AA	Abu Dhabi	2.4	1.4	0.6	1.2	1.3	2.1
AA	Belgium	1.7	0.9	1.1	0.9	1.4	2.7	AA	Estonia	1.8	0.8	0.6	1.0	1.3	1.6
AA	China	2.3	1.7	0.9	1.3	1.6	2.4	AA	France	2.7	1.8	0.9	1.6	1.6	2.1
AA	Czech	1.0	0.7	0.7	0.6	1.1	2.6	AA	New Zealand	0.3	0.6	1.0	0.7	0.6	2.3
AA	Japan	5.1	2.5	1.2	1.5	2.3	2.9	AA	Saudi Arabia	0.4	0.3	0.2	0.5	0.4	0.9
AA	Qatar	1.3	0.7	0.3	0.8	0.9	1.0	AA	USA	0.7	0.7	0.7	0.5	0.9	1.7
A	Israel	1.4	0.6	0.3	0.8	0.8	0.7	A	Chile	1.0	0.5	0.3	0.6	0.6	0.8
A	Korea	1.5	1.0	0.6	1.2	1.4	1.9	A	Slovakia	0.8	0.7	0.7	0.6	1.2	2.6
A	Malaysia	2.2	1.4	0.5	1.2	1.2	1.6	A	Slovenia	1.6	0.9	0.5	1.0	1.1	1.4
A	Poland	2.5	1.1	0.8	1.4	2.0	3.1	A	Spain	2.0	1.4	1.4	1.8	1.7	2.6
BBB	Bulgaria	1.7	0.8	0.5	0.9	1.2	2.2	BBB	Bahrain	0.6	0.3	0.4	0.8	0.5	1.3
BBB	Colombia	3.8	2.0	0.9	1.9	2.3	2.9	BBB	Brazil	4.9	2.8	1.1	3.8	3.0	4.3
BBB	Croatia	1.1	0.7	0.6	0.7	0.9	1.8	BBB	Iceland	0.8	0.8	0.4	0.4	1.4	2.5
BBB	Italy	1.6	1.1	1.0	1.4	1.4	2.4	BBB	Ireland	1.1	1.4	1.4	1.4	2.4	3.9
BBB	Mexico	3.4	1.6	0.8	2.1	1.9	2.8	BBB	Kazakhstan	2.3	0.7	0.5	1.6	1.3	1.6
BBB	Panama	2.0	1.0	0.5	1.0	1.2	1.8	BBB	Lithuania	1.4	1.0	0.6	0.7	1.6	2.8
BBB	South Africa	3.0	1.4	0.6	1.9	1.7	2.0	BBB	Morocco	0.5	0.4	0.4	0.3	0.7	1.2
BBB	Thailand	1.4	0.9	0.5	0.9	1.0	1.7	BBB	Peru	2.6	1.2	0.5	1.5	1.5	2.0
BB	Hungary	2.2	1.1	0.7	1.8	1.8	2.8	BBB	Russia	4.0	1.3	0.8	3.0	2.4	2.7
BB	Indonesia	1.8	1.6	1.2	1.2	1.6	2.8	BB	Costa Rica	1.1	1.0	0.7	0.3	1.0	1.7
BB	Philippines	3.0	2.3	1.3	2.6	2.2	3.2	BB	Cyprus	0.9	1.1	0.8	0.8	2.1	3.4
BB	Portugal	1.3	1.3	1.1	1.1	2.3	3.5	BB	El Salvador	0.8	0.4	0.3	0.5	0.5	0.7
BB	Romania	1.7	1.1	0.6	1.0	1.8	2.9	BB	Guatemala	0.5	0.5	0.2	0.2	0.6	0.8
BB	Turkey	5.0	3.2	1.4	3.5	3.6	5.3	BB	Latvia	1.6	1.3	0.7	1.2	2.1	3.0
B	Argentina	4.9	2.8	1.2	2.4	3.3	5.7	BB	Vietnam	0.8	0.6	0.5	0.7	1.1	1.5
B	Pakistan	0.8	0.6	0.5	0.4	0.8	1.2	B	Dominican	0.9	0.4	0.1	0.4	0.5	0.8
B	Ukraine	2.6	1.7	0.7	2.0	2.2	3.2	B	Ecuador	2.0	1.0	0.6	1.5	2.4	2.4
B	Venezuela	3.4	2.3	1.1	2.6	4.0	5.3	B	Egypt	1.0	0.7	0.5	0.6	1.2	1.9
CCC	Greece	1.7	1.4	0.8	1.8	3.1	4.5	B	Lebanon	1.2	1.0	0.9	0.5	1.2	2.2
—	AAA	2.4	1.6	0.9	1.2	1.5	2.0	—	AAA	1.6	1.1	0.6	1.0	1.1	1.5
—	AA	2.5	1.4	0.8	1.0	1.5	2.2	—	AA	1.4	1.0	0.9	1.1	1.1	2.0
—	A	1.6	0.9	0.6	1.0	1.2	2.0	—	A	1.1	0.8	0.6	0.7	1.1	1.9
—	BBB	2.2	1.2	0.7	1.4	1.6	2.5	—	BBB	2.5	1.0	0.6	1.7	1.8	2.5
—	BB	2.9	2.1	1.1	2.2	2.6	3.7	—	BB	1.7	1.2	0.6	1.3	1.5	2.1
—	B	3.0	1.7	0.9	1.5	2.3	3.8	—	B	1.6	1.1	0.7	0.6	1.3	2.3
—	CCC	1.0	0.5	0.3	0.9	1.4	1.6	—	CCC	2.4	1.2	0.6	2.0	3.0	3.3
—	Overall	2.3	1.4	0.8	1.4	1.7	2.6	—	Overall	1.7	1.0	0.6	1.2	1.3	2.0

Table OA.16: Mean Absolute Pricing Error Relative to Bid-Ask Spread (Observed Sample). The pricing errors are based on the estimated model with the observed data of all 68 countries. We also report the last-month rating for each country. The average for each rating is computed according to the actual rating when the price is quoted rather than the last-month rating for each country. The sample consists of monthly observations between January 2004 and March 2012.

Rating	Country	1y	2y	3y	5y	7y	10y	Rating	Country	1y	2y	3y	5y	7y	10y
AAA	Germany	—	—	16.9	0.4	0.8	0.9	AAA	Australia	—	—	—	0.0	—	—
AA	Austria	—	—	0.8	0.7	—	0.9	AAA	Denmark	—	—	2.3	0.3	—	2.0
AA	Belgium	—	—	2.8	1.4	—	2.6	AAA	Finland	—	—	4.5	0.3	—	1.6
AA	China	0.3	0.7	0.2	0.2	0.3	0.4	AAA	Hong Kong	—	—	0.3	0.0	0.3	0.2
AA	Czech	—	—	—	0.2	0.1	0.6	AAA	Netherlands	—	—	2.3	0.4	—	1.6
AA	Japan	—	—	1.4	0.1	0.5	0.3	AAA	Norway	—	—	4.9	0.2	—	0.5
AA	Qatar	0.7	0.3	0.5	0.0	0.3	1.2	AAA	Sweden	—	—	—	0.4	—	1.7
A	Chile	0.5	0.3	0.1	0.1	0.3	0.6	AAA	Switzerland	—	—	—	0.5	—	0.5
A	Israel	1.2	0.7	0.5	0.2	0.7	1.6	AAA	UK	—	—	15.9	0.7	—	1.5
A	Korea	0.8	0.4	0.2	0.3	0.4	0.4	AA	Abu Dhabi	—	—	—	0.0	—	—
A	Malaysia	0.8	1.2	0.5	0.3	0.7	0.6	AA	Estonia	—	0.2	—	0.1	—	0.8
A	Poland	0.8	0.4	0.6	0.3	0.7	0.9	AA	France	—	—	0.8	0.8	0.1	1.0
A	Slovakia	1.0	0.4	0.3	0.2	0.3	0.9	AA	New Zealand	—	—	—	0.0	—	—
BBB	Brazil	5.6	4.4	1.7	2.6	3.7	6.2	AA	Saudi Arabia	—	—	—	0.0	—	—
BBB	Bulgaria	0.9	0.5	0.3	0.2	0.3	1.1	AA	USA	0.5	—	3.5	0.2	—	0.4
BBB	Colombia	5.1	2.9	1.7	1.3	3.2	4.4	A	Slovenia	—	—	—	0.0	—	1.7
BBB	Croatia	0.8	0.5	0.5	0.2	0.4	0.6	A	Spain	0.4	2.2	5.1	4.1	—	3.8
BBB	Iceland	0.9	—	—	0.7	—	2.9	BBB	Bahrain	—	—	—	0.0	—	—
BBB	Italy	3.8	1.2	1.9	2.3	1.4	3.1	BBB	Ireland	4.4	5.2	—	3.4	2.3	3.9
BBB	Mexico	3.2	2.8	1.4	1.4	3.1	3.4	BBB	Kazakhstan	1.1	2.0	0.6	0.2	0.3	0.5
BBB	Panama	1.9	1.5	0.8	0.4	1.4	2.5	BBB	Lithuania	—	—	0.8	0.1	—	1.4
BBB	Peru	2.5	2.1	1.7	0.9	2.1	2.7	BBB	Morocco	—	—	—	0.0	—	—
BBB	Russia	2.4	1.1	1.1	1.5	0.5	1.6	BB	Costa Rica	—	—	—	0.0	—	—
BBB	South Africa	1.8	1.1	1.0	0.8	1.0	1.2	BB	Cyprus	—	—	1.5	1.2	—	1.2
BBB	Thailand	0.6	0.8	0.2	0.2	0.3	0.5	BB	El Salvador	—	—	—	0.0	—	—
BB	Hungary	0.9	1.1	1.0	0.8	1.1	1.6	BB	Guatemala	—	—	—	—	—	—
BB	Indonesia	2.6	2.7	1.8	0.8	1.6	3.4	BB	Latvia	5.4	—	0.3	0.4	—	2.1
BB	Philippines	3.8	2.8	1.4	1.7	2.4	4.1	BB	Vietnam	0.8	—	0.9	0.0	0.3	1.1
BB	Portugal	2.1	3.6	0.6	2.4	0.8	3.0	B	Argentina	8.2	5.1	3.0	2.8	6.3	12.1
BB	Romania	0.6	0.5	0.4	0.2	0.5	0.9	B	Dominican	—	—	—	—	—	—
BB	Turkey	5.7	3.8	1.6	3.3	3.7	7.5	B	Ecuador	—	0.3	0.6	0.5	—	1.5
B	Ukraine	3.5	2.9	1.3	1.8	3.0	6.0	B	Egypt	—	—	—	0.0	—	—
B	Venezuela	4.3	3.0	1.5	2.9	3.7	6.3	B	Lebanon	—	—	—	0.0	—	—
CCC	Greece	2.4	3.3	0.7	2.1	2.8	4.1	B	Pakistan	—	—	1.4	0.2	—	0.8
—	AAA	—	—	16.9	0.5	0.8	0.9	—	AAA	0.5	—	6.9	0.5	0.1	1.6
—	AA	2.2	1.2	1.3	0.5	0.7	2.2	—	AA	0.4	2.2	1.7	1.2	0.3	3.3
—	A	0.7	0.6	0.4	0.6	0.4	1.5	—	A	—	0.2	7.4	0.4	—	3.4
—	BBB	1.6	1.2	1.0	0.7	1.1	1.7	—	BBB	1.5	2.7	0.7	0.4	0.5	1.5
—	BB	4.2	3.1	1.5	1.9	2.8	5.0	—	BB	2.0	—	0.9	0.1	0.3	1.6
—	B	4.9	3.4	1.8	1.4	3.2	6.8	—	B	8.2	5.1	3.0	1.5	6.3	10.9
—	CCC	1.2	0.6	0.3	0.8	3.5	3.2	—	CCC	—	0.3	0.6	0.5	—	1.5
—	Overall	2.7	2.2	1.3	1.0	1.8	2.7	—	Overall	6.3	4.5	3.1	0.7	3.4	2.7