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Systemic sovereign credit risk: Lessons from the U.S. and Europe

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ABSTRACT

We study the nature of systemic sovereign credit risk using CDS spreads for the U.S. Treasury, individual U.S. states, and major Eurozone countries. Using a multifactor affine framework that allows for both systemic and sovereign-specific credit shocks, we find that there is much less systemic risk among U.S. sovereigns than among Eurozone sovereigns. We find that both U.S. and Eurozone systemic sovereign risk are strongly related to financial market variables. These results provide strong support for the view that systemic sovereign risk has its roots in financial markets rather than in macroeconomic fundamentals.

1. Introduction

We provide a new perspective on systemic sovereign credit risk by contrasting the systemic credit risk of sovereigns within the U.S. with that of sovereign issuers within Europe. Comparing the U.S. and Europe helps resolve the long-standing debate about the source of systemic risk. In particular, one strand of the literature views systemic risk as arising from the effects of common macroeconomic shocks on economic fundamentals.[1] The other strand focuses on the role that financial markets play in creating systemic risk through capital flows, funding availability, risk premia, and liquidity shocks.[2]

The relation between U.S. states closely parallels that of the sovereigns in the Eurozone. First, under the U.S. Constitution, states are sovereign entities and can repudiate their debts without bondholders being able to claim assets in a bankruptcy process. Thus, states within the U.S. have sovereign immunity just as countries within the Eurozone. While the recent debt crisis in Europe makes clear that sovereign credit risk is present in the Eurozone, the default risk of states is also non-negligible; several states have defaulted and repudiated debt in the past.

Second, each set of sovereigns is in a currency union; U.S. states share the dollar as a common currency, while Eurozone members have the euro as their common currency. For these reasons, we simply refer to both states and Eurozone countries as sovereigns throughout this paper.

In addition, there are many economic, legal, and political linkages between states, just as there are similar linkages among European countries. On the other hand, sovereign debtors in the U.S. have much closer fiscal linkages than is the case in the Eurozone. On many dimensions – product markets, economic growth, financial markets, fiscal policy, financial

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[1] Key examples include Gorton (1988), Calomiris and Gorton (1991), Calomiris and Mason (2003), Reinhart and Rogoff (2008, 2009), and others.

[2] Examples include Diamond and Dybvig (1983), Allen and Gale (2000), Kodres and Pritsker (2002), and Brunnermeier and Pedersen (2009), and others.

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regulation and reform, and political and federal ties – U.S. states are more integrated than Eurozone countries.[3] If systemic risk is driven by common shocks to macroeconomic fundamentals, one would expect a higher level of systemic risk among U.S. states than would be the case among European sovereigns.

We use a novel dataset of state and sovereign credit default swap (CDS) spreads. A key advantage of using CDS data is that it provides a much more direct measure of the credit risk of a sovereign than do sovereign debt spreads. This is because sovereign debt spreads are driven not only by sovereign credit risk, but also by interest rate movements, changes in the supply of the underlying bond, illiquidity effects in sovereign debt prices, and other factors. The disadvantage, however, of using CDS spreads is that the relations we uncover between systemic and sovereign-specific credit risk is limited by the use of data post-2008, which is colored by the financial crisis.

We interpret systemic risk in the context of the multivariate credit framework of Duffie and Singleton (2003), which models both the systemic and sovereign-specific components of sovereign credit risk. In this framework, nonsystemic shocks lead to individual sovereign defaults while the realization of a systemic shock may trigger a cascade of defaults. Thus, systemic credit risk arises because of the shared vulnerability of sovereigns in the U.S. or Europe to a major adverse event. This definition of systemic credit risk closely parallels the current situation in Europe where widespread losses in the banking sector have weakened sovereign finances, and in the U.S. where large declines in the housing markets have played a similar role.[4]

A number of important empirical results emerge. First, we find that there is dramatic variation across sovereigns in terms of their exposure to systemic or common shocks. For example, California has more than five times as much systemic risk as the average for the other states in the sample, and nearly three times as much as the U.S. Treasury. In stark contrast, New York has virtually no systemic risk; New York's credit risk appears to be almost entirely idiosyncratic in nature. In Europe, Greece has about three times the systemic risk of other vulnerable sovereigns such as Portugal, Ireland, Italy, Spain, and Belgium, which, in turn, have roughly twice as much systemic risk as the remaining sovereigns in the Eurozone.

Second, we show that there is much less systemic sovereign risk in the U.S. than in the Eurozone. In particular, systemic credit risk represents only about 12% of the total credit risk of U.S. states. In contrast, systemic credit risk constitutes about 31% of the total credit risk of the Eurozone sovereigns. These results provide direct evidence against the hypothesis that the tighter macroeconomic linkages should lead to higher levels of systemic risk in the U.S. than in Europe.

Third, we find that systemic sovereign credit risk in both the U.S. and the Eurozone is strongly related to financial market variables. Specifically, systemic sovereign credit risk in the U.S. declines significantly when the S&P 500 increases, and similarly for the Eurozone when the DAX increases. Systemic sovereign risk in the U.S. is also significantly related to changes in interest rates and corporate credit. Curiously, U.S. systemic risk is strongly negatively related to changes in the VIX volatility index. This is consistent with the view that when global financial markets experience turbulence, the U.S. may benefit from flight-to-quality-related capital flows. These results provide new evidence that systemic risk has deep roots in the flows and liquidity of financial markets.

There is an extensive literature on sovereign credit risk. Previous theoretical work focuses on the incentives faced by sovereign debtors to repay their debt building on Eaton and Gersovitz (1981). A number of empirical studies including Edwards (1984, 2002), Boehmer and Megginson (1990), and Duffie et al. (2003) focus on the factors that determine individual sovereign credit spreads. Another strand of research, like Mauro et al. (2002), Geyer et al. (2004), Pan and Singleton (2008), and Longstaff et al. (2011), provides evidence that sovereign credit spreads are related to common global and financial market factors. In contrast to these papers, we focus on U.S. sovereign credit risk and contrast it with sovereign credit risk within the Eurozone. The paper also is the first to estimate the systemic component of sovereign credit spreads from the cross section of CDS term structures.

2. U.S. federal, state, and Eurozone sovereigns

U.S. states are comparable to Eurozone member countries in many ways. First, the GDP of states is roughly similar to the GDP of European countries. Second, and probably less familiar, is that U.S. states have the same sovereign immunity as countries: states can repudiate debt, creditors have few, if any, rights to claim assets, and there is no bankruptcy mechanism. Third, both U.S. states and European nations have long histories of default.

2.1. U.S. states and Eurozone sovereigns are economically similar

The GDP of U.S. states is roughly comparable to the GDP of Eurozone countries both in terms of levels and dispersion. Table 1 reports the 2009 nominal GDP of the U.S. states and Eurozone countries used in our study. California's economy is larger than Spain and approximately 90% the size of Italy and 70% the size of France. The dispersion of GDP across the largest states is also roughly similar to the dispersion of GDP across Eurozone countries. Florida is roughly equivalent to the

[3] We thank our discussant Hui Chen for demonstrating the larger economic linkages of U.S. states compared to Eurozone countries. States are not completely integrated even though they are certainly more integrated than countries in the Eurozone; Pirinsky and Wang (2011) and Schultz (2012) both document that there is segmentation across states in municipal bond markets.

[4] The term systemic risk is often loosely defined, and is often similar to the notion of systematic risk. The two are difficult to distinguish empirically, but it is difficult to deny the systemic nature of a U.S. default or a German default—as we define systemic exposure below. Some alternative definitions of systemic risk that are based on credit spread contagion across sovereigns use pure empirical models, rather than pricing models as we do, incorporating lead–lag behavior of CDS spreads or co-movements of higher moments (see, for example, Zhang et al., 2011; Caporin et al., 2012).

Table 1
GDP and debt statistics. This table reports the 2009 nominal GDP for the indicated states and countries, where GDP is measured in millions of U.S. dollars. The table also reports the percentage ratios of total debt to GDP and total debt to revenue for the indicated states and countries. Data are from the IMF, World Bank, Bureau of Economic Analysis, and Moody's Investor Service.

Sovereign	GDP	Debt-to-GDP (%)	Debt-to-revenue (%)
California	1,884,452	7.4	163
Florida	729,485	5.2	123
Illinois	621,101	13.6	297
Massachusetts	362,413	14.2	272
Michigan	361,126	5.0	78
Nevada	125,115	3.1	119
New Jersey	478,391	13.2	223
New York	1,085,131	4.4	102
Ohio	466,021	2.9	72
Texas	1,141,287	2.3	65
USA	14,119,000	94.4	305
Austria	384,908	72.2	149
Belgium	468,522	96.7	198
Finland	237,512	48.4	92
France	2,649,390	82.3	166
Germany	3,330,032	84.0	192
Greece	329,924	142.8	365
Ireland	227,193	94.9	279
Italy	2,112,780	119.0	258
Netherlands	792,128	63.7	142
Portugal	227,676	92.9	224
Spain	1,460,250	60.1	168

Netherlands and Ohio has approximately the same GDP as Belgium. Michigan, despite its recent industrial decline, still has an economy greater than Greece, Portugal, or Ireland taken separately.

Table 1 also reports debt-to-GDP ratios and debt-to-revenue ratios in 2010. Although the debt-to-GDP ratio for the U.S. is 94.4%, and is similar to the 84.0% figure for Germany, the average state debt-to-GDP ratios are much lower than Eurozone countries: the average debt-to-GDP ratio for U.S. states is 7.1% versus 87.0% for Eurozone countries. The debt-to-GDP ratio, however, is misleading as an indicator of credit risk because the size of state governments is much smaller than Eurozone countries. The last column of Table 1 reports debt-to-revenue ratios. These ratios are similar across states and Eurozone sovereigns. Average debt-to-revenue ratios are 151% for U.S. states, excluding the U.S. itself which has a debt-to-revenue ratio of over 300%. The average debt-to-revenue ratio for Eurozone countries is just above 200%. Thus, based on debt-to-revenue measures, U.S. states have similar indebtedness problems to their Eurozone country counterparts.

2.2. *States are sovereigns*

State debt is sovereign debt. The 11th Amendment to the U.S. Constitution guarantees that states are treated as sovereigns, no individual, domestic or foreign, can bring suit against a state, with one exception. Suits can be brought against states only with the consent of a state.[5] Thus, just as individual investors cannot claim the assets of the federal government, investors cannot seize state property. Furthermore, in one case where another sovereign sued a state (*Principality of Monaco v. Mississippi*), the Supreme Court ruled in 1934 that foreign countries cannot sue U.S. states without their consent. Thus, states have sovereign status and there is also no bankruptcy mechanism for handling state default in the U.S., just as there is no international sovereign bankruptcy court.[6] Thus, state and federal debt have economically equivalent status.

2.3. *U.S. federal and state default*

Although the U.S. has legally never defaulted on its debt, it has unilaterally changed the terms of its debt. The 1934 Gold Reserve Act changed the value of a U.S. dollar from $20.67 per troy ounce to $35. Economically this is a default; the U.S. reduced the value of its debt payments relative to an external measure of value and at that time all major currencies were backed by gold. Reinhart and Rogoff (2008) classify the U.S. abrogation of the gold clause in 1934 as a default.

In contrast to the implicit default on federal obligations during the Great Depression, the history of state debt in the U.S. is littered with episodes of explicit defaults. Many states have defaulted. In the 1830s and 1840s, several states issued debt to finance canals and railroads. McGrane (1935) discusses these events in detail and lists eight defaulting states and one territory: Arkansas,

[5] It is notable that despite the many attempts to collect money through the courts from defaulted states, not one defaulting state has ever given consent (see McGrane, 1935 for a detailed account).

[6] Local municipalities in certain states can enter Chapter 9 of the Bankruptcy Code similar to Chapter 11 for corporations. However, this does not apply to states.

Florida Territory, Illinois, Indiana, Louisiana, Maryland, Michigan, Mississippi, and Pennsylvania. McGrane notes that most states resumed payment, but Florida Territory and Mississippi repudiated their debt completely (also see English, 1996).

These bonds were widely held in Europe, particularly in the United Kingdom. Markham (2002) notes that the drop in value of these bonds and their credit risk was the subject of a nightmare of Ebenezer Scrooge in Charles Dickens' 1843 novel, *A Christmas Carol*, in which Scrooge's investments withered into a "mere United States security."

The partial or complete repudiation of these states' debts was even placed in states' constitutions, or legislation was passed prohibiting payment. McGrane (1935) recounts that when Florida achieved statehood, it wiped out its debt by legislative fiat and its legislature voted that it did not bear liability for debts incurred while Florida was still a territory. Similarly, in 1875, Mississippi's state constitution was amended forbidding any payment on bonds issued on behalf of its two chartered banks, Planters' and the Union. Arkansas defaulted in 1841 and the first amendment to the Arkansas constitution in 1875, which was adopted by an overwhelming popular vote of eight to one, made it illegal to ever pay the interest or principal on the defaulted state railroad and levee bonds (see Bayliss, 1964).

Ten states also defaulted after the Civil War during the 1870s and 1880s: Alabama, Arkansas, Florida, Georgia, Louisiana, Minnesota, North Carolina, South Carolina, Tennessee, and Virginia. All of these states with one exception, Minnesota, took on large debts during the period of Reconstruction and were unable to service them. As McGrane (1935) describes, Minnesota's case is particularly interesting because it was a state untouched by the Civil War. Minnesota defaulted on railroad bonds and although the Governor and other state officials were willing to make investors whole, they were stymied for over 20 years by constitutional amendments passed by Minnesota repudiating the "swindling bonds."

Arkansas has the dubious distinction of the only state to default three times. Its last default, which was also the last default of any state, was in 1933 during the Great Depression. Arkansas defaulted on highway bonds. Reaves (1943) describes that the defaulting bonds were partially refunded in 1934, but it was only in 1943 that the majority of the defaulting issues were refinanced and the state returned to good standing in debt markets.

Clearly, states have defaulted in the past. Investors in defaulted federal or state debt have little redress to settle their claims. Furthermore, in all defaulting state cases so far, the federal government did not step in to make investors whole.[7]

2.4. Eurozone country default

There have also been defaults among countries which are currently members of the Eurozone.[8] Reinhart and Rogoff (2008) describe several of these episodes. During the Great Depression, Greece went off the gold standard in 1932 and declared a moratorium on all debt payments. Spain suspended interest payments on external debt from 1936 to 1939 during the Spanish Civil War. Several nations defaulted on debt raised to fight World War II, including Austria, which rendered many previous bond issues worthless in 1945, and Germany, which instituted a brutal currency reform in 1948 by introducing the Deutschmark and rendering most balances in the previous currency, the Reichmark, close to worthless. However, an important difference between these defaults and the situation of Eurozone member countries today is that these defaults were done when each country had a separate currency. In contrast, the previous defaults of the U.S. states happened under a currency union. Future possible defaults of Eurozone sovereigns would occur with this feature.

3. Data

The data for the study include weekly midmarket CDS spreads for the term structure of one-year, two-year, three-year, four-year, and five-year CDS contracts on the U.S. Treasury and ten states.[9] These states are California, Florida, Illinois, Massachusetts, Michigan, Nevada, New Jersey, New York, Ohio, and Texas. The data are obtained from the Bloomberg system which collects CDS market quotation data from industry sources. The notional for the U.S. Treasury CDS contract is specified in Euros. The notional for the state CDS contracts is specified in dollars. The data for the study cover the 139-week period from May 14, 2008 to January 5, 2011. The beginning of this sample period is dictated by the availability of liquid CDS data for all of the states in the study.

In addition to the U.S. data, we also collect the corresponding CDS term structure data for 11 of the largest sovereign borrowers within the Eurozone: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain. The data for the Eurozone sovereigns also cover the period from May 14, 2008 to January 5, 2011. The notional amounts for the Eurozone data are all specified in dollars.[10]

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[7] In 1975, New York City came perilously close to bankruptcy. New York City is notable because the New York Metropolitan area, which includes Northern New Jersey, has a slightly larger GDP than New York State itself. New York City's Mayor Abraham Beame appealed to the federal government for assistance which was denied. This prompted the famous, succinct headline from the Daily News, "FORD TO CITY: DROP DEAD." Thus, implicit or explicit bailouts from the U.S. to the states are certainly not guaranteed. Explicit federal guarantees would have the effect of increasing the common components of systemic risk in the U.S., while we find the opposite result.

[8] Other non-Eurozone countries within the European Union have also defaulted. For example, the United Kingdom last defaulted in 1932 when most of its outstanding debt incurred during World War I was consolidated into a 3.5% consol bond.

[9] See Duffie (1999), Longstaff et al. (2005), and Pan and Singleton (2008) for descriptions on how CDS contracts work.

[10] For several of the Eurozone sovereigns, five-year CDS data is missing for a few weeks. For these weeks, we use four-year CDS data to report summary statistics and use the one-year to four-year term structure data to conduct the empirical analysis.

Table 2
Summary statistics for U.S. and Eurozone sovereign CDS spreads. This table reports summary statistics for the five-year CDS spreads for the indicated sovereigns. The sample consists of weekly observations for the May 14, 2008 to January 5, 2011 period.

Sovereign	Mean	Std. dev.	Min.	Med.	Max.	Serial corr.	*N*
California	243.57	81.98	63.00	268.00	402.00	0.962	133
Florida	137.10	50.47	39.00	135.00	240.00	0.960	133
Illinois	187.61	87.32	25.00	191.00	369.00	0.982	130
Massachusetts	120.93	54.67	21.00	124.00	243.00	0.978	134
Michigan	207.45	87.76	45.00	218.00	394.00	0.976	131
Nevada	171.76	73.03	42.00	183.00	329.00	0.967	138
New Jersey	179.06	76.31	33.00	196.00	337.00	0.973	135
New York	176.95	77.19	32.00	196.00	318.00	0.976	131
Ohio	122.04	52.04	35.00	125.00	251.00	0.972	134
Texas	86.82	42.01	20.00	79.00	180.00	0.976	134
USA	38.52	18.06	7.10	37.98	99.26	0.964	139
Austria	82.78	47.29	6.80	77.82	260.90	0.952	136
Belgium	75.63	48.76	10.00	62.01	227.68	0.977	139
Finland	31.04	16.59	5.30	28.98	88.33	0.970	139
France	47.49	26.95	6.75	43.78	108.84	0.975	139
Germany	33.56	17.16	4.40	33.75	90.61	0.959	139
Greece	353.34	316.99	32.19	230.25	1055.41	0.986	139
Ireland	205.94	143.40	17.30	162.48	613.43	0.982	139
Italy	121.86	58.34	24.75	113.68	241.03	0.963	139
Netherlands	44.58	26.38	6.30	41.27	123.33	0.970	139
Portugal	155.43	133.54	21.33	93.84	500.02	0.978	139
Spain	126.61	80.54	24.25	98.83	349.90	0.977	139

Table 2 provides summary statistics for the federal and state five-year CDS spreads. All spreads are denominated in basis points.[11] The average values of the spreads range widely across the various sovereigns. The average CDS spread for the U.S. Treasury is 38.52 basis points. The average spreads for the 10 states are all higher than for the U.S. Treasury, and range from a low of 86.82 basis points for Texas to a high of 243.57 basis points for California.[12]

Both the standard deviations and the minimum/maximum values indicate that there is significant time-series variation in the CDS spreads. For example, the five-year CDS spread for the U.S. Treasury reached a maximum of 99.26 basis points in early 2009. Around the same time period, the CDS spreads for California and Michigan reached maximum values of 402 basis points and 394 basis points, respectively. The median values of the CDS spreads are typically fairly close to the average values.

Table 2 also reports summary statistics for the five-year CDS spreads of the Eurozone sovereigns in the sample. As shown, many of the average CDS spreads are smaller than those for the states. On the other hand, many of the maximum values for the Eurozone sovereigns are comparable to those for the states. The reason for this is simply that while both U.S. and Eurozone sovereigns had similar CDS spreads at the beginning of the sample periods, CDS spreads in the U.S. widened more rapidly as the subprime/financial crisis unfolded than did European spreads. After the Greek credit crisis of mid-2010, however, European CDS spreads quickly increased to levels comparable to, or even in excess of, those in the United States.

4. Modeling CDS spreads with systemic risk

We apply a framework proposed by Duffie and Singleton (2003) to the sovereign CDS spreads.[13] A key advantage of this framework is that sovereign defaults may be triggered by the realization of a systemic shock. Specifically, the model allows for two independent types of credit events to trigger sovereign defaults. The first is an idiosyncratic shock that triggers the default of an individual sovereign. This type of credit event is essentially the same as those underlying standard reduced-form credit models such Duffie and Singleton (1997, 1999), Pan and Singleton (2008), and many others. In particular, the model treats idiosyncratic default as being triggered by the first jump of a sovereign-specific Poisson process. Let ξ_{it} denote the intensity of the Poisson process for country *i*. Following Longstaff et al. (2005), we assume that this intensity process follows a standard square-root process

$$d\xi_{it} = (a_i - b_i \xi_{it})\, dt + c_i \sqrt{\xi_{it}}\, dZ_{it}, \tag{1}$$

where a_i, b_i, and c_i are the constants and the Brownian motion Z_{it} are sovereign specific.

[11] Recently, many CDS contracts are executed on the basis of the protection seller paying points up front rather than a running spread. Despite this, however, the market convention is to quote CDS contracts in terms of their equivalent running spread. We adopt this standard market convention in this paper.

[12] Even though the notional for the CDS contract on the Treasury is denominated in Euros, the CDS spread is expressed as a rate and is, therefore, free of units of account. Thus, no currency translation is required for the U.S. Treasury CDS contract.

[13] This model is described in Section 10.7 of Duffie and Singleton, pp. 247–249. Other authors modeling sovereign credit spreads include Duffie et al. (2003), Pan and Singleton (2008), and Longstaff et al. (2011).

These dynamics allow for mean reversion and conditional heteroskedasticity in the intensity process and guarantee that the intensity process is non-negative. We place no restrictions on the correlation structure of the Brownian motions across sovereigns or on the correlation of idiosyncratic defaults across sovereigns.[14]

The second type of credit event can be viewed as a systemic shock. This type of event has potential ramifications for all sovereigns within a common area such as a monetary union. In particular, we assume that when a systemic shock occurs, which is modeled as the arrival of a Poisson jump, each sovereign has some probability of defaulting. The probability of default conditional on the systemic shock, however, is sovereign specific and is denoted γ_i. Thus, some sovereign borrowers may be more fragile or susceptible to systemic shocks than others. Given our relatively short sample period, it is reasonable to assume that γ_i is constant. Let λ_t denote the intensity of the Poisson process triggering a systemic shock. This intensity also follows a standard square-root model

$$d\lambda_t = (\alpha - \beta\lambda_t)\,dt + \sigma\sqrt{\lambda_t}\,dZ_{\lambda t}, \tag{2}$$

where α, β, and σ are the constants, and $Z_{\lambda t}$ is a Brownian motion that is uncorrelated with the Brownian motions driving the idiosyncratic intensity processes.

Let us now consider the ways in which a sovereign default can occur in the Duffie and Singleton framework. First, default occurs the first time that there is an arrival of the sovereign-specific Poisson process. Second, default occurs with probability γ_i the first time that there is an arrival of the systemic Poisson process (provided, of course, that there has not been a previous idiosyncratic default). Third, default occurs with probability $(1-\gamma_i)\gamma_i$ the second time that there is an arrival of the systemic Poisson process. This follows since the sovereign has a $1-\gamma_i$ probability of surviving the first systemic shock, but then faces a γ_i probability of succumbing to the second systemic shock. Fourth, default occurs with probability $(1-\gamma_i)^2\gamma_i$ the third time that there is an arrival of the systemic Poisson process, and so forth. Thus, there is an infinite number of ways in which a sovereign default can occur in this model. This contrasts sharply with the usual univariate modeling framework in which default occurs the first time there is an arrival of the underlying Poisson process.[15]

Given the properties of Poisson processes, and conditional on the realized paths of the intensity processes ξ_{it} and λ_t, the probability that no default occurs by time t equals

$$\begin{aligned}
&= \exp\left(-\int_0^t \xi_{is}\,ds\right)\left[\sum_{j=0}^{\infty}\frac{1}{j!}\exp\left(-\int_0^t \lambda_s\,ds\right)\left((1-\gamma_i)\int_0^t \lambda_s\,ds\right)^j\right],\\
&= \exp\left(-\int_0^t \xi_{is}\,ds\right)\exp\left(-\int_0^t \lambda_s\,ds\right)\exp\left(\int_0^t (1-\gamma_i)\lambda_s\,ds\right),\\
&= \exp\left(-\int_0^t \gamma_i\lambda_s + \xi_{is}\,ds\right).
\end{aligned} \tag{3}$$

Thus, we can now proceed to value credit derivatives using the standard reduced-form framework, but with the twist that the instantaneous probability of a default in this Duffie and Singleton (2003) model is proportional to $\gamma_i\lambda_t + \xi_{it}$. We will designate this value the total intensity. The total intensity can thus be interpreted as a default probability arising from exposure to a systemic source λ_t, with exposure γ_i, and from a sovereign-specific source, ξ_{it}. Perhaps in the more familiar terminology from factor models or APT models, credit risk that is shared across sovereigns, where each sovereign has a different exposure to the common shock, we term systemic risk. Credit risk exposure that is idiosyncratic to an individual sovereign we term sovereign-specific risk. Note that in this model, sovereign-specific shocks can be correlated across countries.

Let r_t denote the riskless rate. Although r_t is stochastic, we assume that it is independent of the intensity processes λ_t and ξ_{it}, and of the realizations of the underlying Poisson processes. This assumption greatly simplifies the model, but has little effect on the empirical results. As in Lando (1998), we make the assumption that a bondholder recovers a fraction $1-w$ of the par value of the bond in the event of default.

Given the independence assumption, we do not need to specify the risk-neutral dynamics of the riskless rate to solve for CDS spreads. We require only that these dynamics be such that the value of a riskless zero-coupon bond $D(T)$ with maturity T be given by the usual expression

$$D(T) = E\left[\exp\left(-\int_0^T r_t\,dt\right)\right]. \tag{4}$$

Following Longstaff et al. (2005), it is now straightforward to represent the values of U.S. Treasury or state CDS spreads in terms of simple expectations under the risk-neutral measure. Let s_i denote the spread paid by the buyer of default protection on sovereign i. Assuming that the premium is paid continuously, the present value of the spread leg of a sovereign CDS

[14] The only exceptions for this are the U.S. and Germany, which we assume have no idiosyncratic risk. Since our framework allows idiosyncratic defaults to have some (although not perfect) correlation across sovereigns, we are using the term idiosyncratic in the broader sense of being nonsystemic.

[15] Because multiple defaults can occur simultaneously, the Duffie and Singleton model differs from the standard doubly stochastic credit framework. Recent evidence by Das et al. (2007) argues against the doubly stochastic model. Furthermore, the events surrounding the Lehman default of 2008 provide support for the clustered default implication of the Duffie and Singleton model we use. In the absence of defaults, however, the two frameworks are observationally equivalent. We thank Ken Singleton for this insight.

contract can be expressed as

$$E\left[s_i \int_0^T D(t) \exp\left(-\int_0^t \gamma_i \lambda_s + \xi_{is}\, ds\right) dt\right]. \tag{5}$$

Similarly, the value of the protection leg of a CDS contract can be expressed as

$$E\left[w \int_0^T D(t)(\gamma_i \lambda_t + \xi_{it}) \exp\left(-\int_0^t \gamma_i \lambda_s + \xi_{is}\, ds\right) dt\right]. \tag{6}$$

Setting the values of the two legs of the CDS contract equal to each other and solving for the spread gives

$$s_i = \frac{wE\left[\int_0^T D(t)(\gamma_i \lambda_t + \xi_{it}) \exp\left(-\int_0^t \gamma_i \lambda_s + \xi_{is}\, ds\right) dt\right]}{E\left[\int_0^T D(t) \exp\left(-\int_0^t \gamma_i \lambda_s + \xi_{is}\, ds\right) dt\right]}. \tag{7}$$

Given the square-root dynamics for the intensity processes, standard results such as those in Duffie et al. (2000) make it straightforward to derive closed-form solutions for the expectations in Eq. (9). The Supplementary Appendix shows that the sovereign CDS spread can be expressed as

$$s_i = \frac{w \int_0^T D(t)(A(\lambda,t)C(\xi_i,t) + \gamma B(\xi_i,t)F(\lambda,t)\, dt}{\int_0^T D(t)A(\lambda,t)B(\xi_i,t)\, dt}, \tag{8}$$

where ξ_i and λ denote the current (or time-zero) values of the respective intensity processes and the expressions for $A(\lambda,t)$, $B(\xi_i,t)$, $C(\xi_i,t)$, and $F(\lambda,t)$ are given in the Supplementary Appendix.

Two caveats of the model should be noted.[16] First, the model treats default as a simple arrival of a Poisson process—either through a process contingent on systemic default, or through a process capturing sovereign-specific default. In reality, default in a CDS contract is triggered by a credit event. The precise legal definition of default, and whether it corresponds to an actual economic default, is not captured in this model.[17]

Second, the inferred default processes and intensities of the model are estimated under the risk-neutral measure. Thus, the default probabilities we study are not the actual or objective probabilities. Rather, they reflect the market cost of buying protection against these defaults. To convey the intuition, imagine that an insurer sells protection against a risk that has a 1% probability. The actuarially fair price for a \$10,000 contract would be \$100. To compensate the insurer for bearing the risk, however, the price of the contract might be \$200. In this situation, the objective probability of a loss would be 1%, but the risk-neutral probability would be 2%. As Berndt et al. (2008) and others have shown, variation in the credit risk premium is an important driver of changes in CDS spreads.

From the perspective of investors and policy makers, the risk-neutral probabilities place greater weights on bad states of the world where agents' marginal utilities are high. On the other hand, we cannot estimate actual default probabilities due to the lack of defaults in the data. Recent research by Giesecke et al. (2011), however, indicates that the long-run average ratio between risk-neutral and objective default probabilities is on the order of two. Thus, we expect that inference on real intensities would be qualitatively similar to those we report, particularly since we focus on changes, not levels.

5. Model estimation

We estimate the model using the term structure of one-, two-, three-, four-, and five-year CDS spreads for each issuer for each date during the sample period. The estimation approaches provide estimates of the time-series of systemic and country-specific risk-neutral default intensities, estimates of the parameters of the intensity processes, as well as the sensitivity coefficient for each sovereign.

The values for the zero-coupon bonds $D(t)$ that appear in the valuation formula are bootstrapped from one-, three-, six-, and twelve-month LIBOR rates and two-, three-, and five-year swap rates using a standard cubic spline interpolation algorithm.[18] The LIBOR and swap data are obtained from the Bloomberg system. We assume that the loss given default is 50% (w=0.5). This is in the middle of the 30–75% range of the estimated recovery values on sovereign debt restructurings estimated by Sturzenegger and Zettelmeyer (2008).[19]

[16] Another concern may be the potential lack of integration across the CDS derivatives market and the underlying physical sovereign bond market. Fleckenstein et al. (in press) document that pricing in the physical market can imply mispricing in a derivative market, or vice versa. We do not examine underlying bond markets.

[17] Prior to the restructuring of Greek debt in 2012, a number of CDS market participants expressed concerns about whether the restructuring would trigger payments to investors who had purchased default protection. These concerns were resolved when the International Swaps and Derivative Association (ISDA) declared the Greek restructuring a credit event in March 2012, thereby triggering protection payments.

[18] For a description of this algorithm, see Longstaff et al. (2005). Bootstrapping zero-coupon bond prices from the Treasury curve rather than the swap curve would have little effect on the fitted value of the CDS spread.

[19] The loss given default assumption has little effect on our estimates of systemic versus idiosyncratic decompositions since it is applied symmetrically to both legs of the CDS contract in the estimation process. We note, however, that the assumption that recovery rates are constant is important in this framework. For example, if recovery rates vary over time, and if the recovery rate for the European sovereigns varies more than U.S. states, then this could lead to stronger co-movement in European sovereign CDS spreads without more systemic default risk. We are grateful to the referee for this observation.

Let s_{ikt} denote the market spread for the i-th issuer for a CDS contract with maturity k years as of date t. Let $\hat{s}_{ikt}$ be the corresponding value implied by substituting in the estimated values of the systemic intensity λ and the sovereign-specific intensity process ξ_i along with the estimated parameters vector θ into the closed-form solution in Eq. (8). The parameter vector and the time series of the systemic intensity and sovereign-specific intensity processes are then estimated by minimizing the objective function

$$\min_{\lambda,\xi_1,\xi_2,\ldots,\xi_N,\theta} \sum_i \sum_j \sum_t [s_{ijt} - \hat{s}_{ijt}]^2. \tag{9}$$

We follow the same procedure in estimating the model for the Eurozone sovereigns, with the exception that the identification conditions apply to Germany rather than the U.S. Treasury.[20]

Observe that by minimizing the sum of squared deviations between the model and market values in Eq. (9), the estimation procedure is simply nonlinear least squares. Intuitively, the algorithm chooses first a trial set of the parameters α, β, σ, a_i, b_i, c_i, and γ_i. Given these parameters, the CDS spread on the U.S. Treasury at time t depends only on the value of λ_t, which we can estimate by a nonlinear least squares fit of the model to the one-year through five-year CDS spreads at time t. Intuitively, the value of λ_t essentially captures the level of the shortest-maturity CDS spread while the parameters α, β, and σ capture the average slope and curvature of the CDS term structure throughout the sample period.

With the estimated value of λ_t at time t, we can similarly estimate ξ_{it} by a nonlinear least squares fit to the one-year through five-year CDS spreads for sovereign i at time t. The estimated value of ξ_{it} reflects the level of the shortest-maturity CDS spread for sovereign i after controlling for the systemic component, and the exposure to the systemic component is captured by the γ_i parameter. The sovereign-specific parameters a_i, b_i, and c_i capture the average shape of the CDS term structure not already explained by the systemic component. A rough approximation of γ_i, that does not take into account the endogenous dynamic structure of intensities and the over-identifying term structure restrictions, can be obtained by regressing changes in sovereign CDS spreads on changes in the CDS spread for the U.S. Treasury or Germany.

5.1. *Identification*

We impose two identifying restrictions. First, we normalize the sensitivity coefficient γ for the U.S. to be one. Thus, the γ_i coefficients for the states have the interpretation as measuring systemic sensitivity relative to that of the U.S. Treasury. This assumption is simply for convenience in scaling the results.

Second, we make the realistic assumption that a Treasury default can only occur in conjunction with a systemic shock. This assumption makes intuitive sense since it is difficult to imagine a scenario in which the U.S. Treasury defaults without sending systemic shock waves throughout the credit markets. An alternative and much more complex econometric procedure would be to treat the systemic intensity as latent. This would produce similar results to assuming the U.S. as the systemic risk because the algorithm would identify the lowest default intensity – which is the U.S. – as being the systematic risk.

5.2. *Parameter estimates*

The upper part of Table 3 reports the estimated parameters a_i, b_i, and c_i for the sovereign-specific processes for the individual states, and the estimated parameters α, β, and σ for the systemic process. The lower part of the table gives the corresponding results for the Eurozone sovereigns. Table 3 also reports the asymptotic standard errors for the parameters and the root mean squared error (RMSE) from fitting the model to the term structure of CDS spreads for each issuer.

Table 3 shows that the speed of mean reversion parameter b_i or β is negative for many of the U.S. and Eurozone sovereigns. This feature is not uncommon in estimating affine models and does not pose a problem since we are estimating the speed of mean reversion under the risk-neutral measure rather than the objective measure, and the speed of mean reversion parameter under the objective measure is presumably positive (see Dai and Singleton, 2002). This implies that there could be a significant risk premium embedded into the pricing of U.S. and Eurozone sovereign CDS contracts.

Table 3 also shows that the model fits the term structure of CDS spreads well. The RMSEs from fitting the model to U.S. sovereign issuers range from a low of about one basis point for the term structure of U.S. Treasury CDS contracts, to a high of roughly 16 basis points for Illinois. Six of the states have RMSEs of less than ten basis points. Comparing these RMSEs to the average five-year CDS values shown in Table 2 indicates that these RMSEs are a relatively small percentage of the absolute level of CDS spreads for these issuers. Similar results hold for the Eurozone sovereign issuers.

Finally, note that the systemic intensity process in the U.S. has parameters that are very similar to those for the systemic intensity process in the Eurozone. Similarly, the model fits both the term structure of U.S. Treasury CDS spreads and the term structure of Germany CDS spreads very closely. The RMSEs from fitting the U.S. Treasury and German CDS term structures are 1.179 and 2.528 basis points, respectively.

[20] Since Germany has the lowest default intensity, identifying the systematic risk in the Eurozone as Germany is innocuous.

Table 3
Estimation results for the CDS valuation model using federal, state, and Eurozone CDS spreads. This table reports the parameter estimates and their standard errors obtained by fitting the CDS valuation model to the term structure of CDS spreads for the indicated federal, state, and Eurozone CDS contracts. For the systemic processes, the parameters reported are α, β, and σ. The RMSEs are measured in basis points. The sample consists of weekly observations for the May 14, 2008 to January 5, 2011 period.

Sovereign	Parameter			Standard error			RMSE
	a	b	c	a	b	c	
California	0.00250	−0.1768	0.1064	0.00013	0.0114	0.0254	11.790
Florida	0.00306	0.1912	0.0268	0.00015	0.0187	0.2914	9.384
Illinois	−0.00010	−0.0566	0.0096	0.00019	0.0094	0.2592	15.758
Massachusetts	0.00140	0.0813	0.0174	0.00005	0.0068	0.1290	4.115
Michigan	0.00214	0.0549	0.0440	0.00018	0.0151	0.1074	13.448
Nevada	0.00171	−0.0508	0.1724	0.00012	0.0153	0.0246	10.218
New Jersey	0.00092	−0.0332	0.0253	0.00011	0.0135	0.1466	9.505
New York	0.00206	−0.1980	0.0607	0.00009	0.0064	0.0252	7.549
Ohio	0.00108	−0.0796	0.2172	0.00004	0.0043	0.0049	3.595
Texas	0.00091	0.0914	0.0389	0.00007	0.0135	0.1213	5.419
U.S. systemic	0.00009	−0.4720	0.2868	0.00001	0.0041	0.0020	1.179
Austria	0.00006	−0.0976	0.0506	0.00005	0.0176	0.0901	5.592
Belgium	−0.00019	−0.4646	0.2319	0.00002	0.0091	0.0070	4.181
Finland	0.00033	−0.1356	0.0228	0.00002	0.0188	0.1950	2.253
France	−0.00026	−0.4346	0.2013	0.00001	0.0065	0.0056	1.632
Greece	0.00081	−0.9786	0.5692	0.00022	0.0194	0.0083	51.694
Ireland	0.00115	−0.2562	0.3291	0.00010	0.0083	0.0076	12.742
Italy	0.00136	−0.1176	0.1623	0.00008	0.0166	0.0288	8.904
Netherlands	0.00041	0.0136	0.0954	0.00002	0.0175	0.0571	2.548
Portugal	0.00063	−0.1926	0.2969	0.00012	0.0115	0.0126	16.556
Spain	0.00129	−0.0792	0.2232	0.00009	0.0118	0.0182	10.153
Eurozone systemic	0.00042	−0.4332	0.2672	0.00002	0.0161	0.0056	2.528

6. Systemic sovereign risk

In Fig. 1, we plot the total risk-neutral intensity $\gamma_i\lambda_t + \xi_{it}$ implied by the model for selected states and Eurozone countries. These intensities are not small and are of roughly the same order of magnitude for these selected sovereigns. At the end of the sample, January 5, 2011, the total intensity for Greece is 0.1201 and the total intensity for California is 0.0530. If λ_t were constant, these total intensities would represent risk neutral default probabilities of $1-\exp(-0.01201) = 0.1132$ and $1-\exp(-0.0530) = 0.0516$ over the next year, respectively. Default probabilities for California, Illinois, Greece, and Ireland all start off in May 2008 below 100 basis points and increase during the financial crisis of 2008. For most of 2009, the total intensities of California and Illinois are higher than Greece and Ireland, with California's intensity being slightly higher than Illinois'. Sovereign credit risk for Greece increases rapidly during early 2010 followed by Ireland in late 2010. Illinois' default intensity also increases, but not to the same extent as Greece and Ireland. The total default intensities shown in Fig. 1 include both exposure to systemic risk (either U.S. or Eurozone) and sovereign-specific default risk. We now separately characterize each of these components of sovereign credit risk.

6.1. Systemic credit risk

Fig. 2 plots the intensity λ_t of the systemic risk for the U.S. and the Eurozone. The U.S. intensity has been, on average, higher than the Eurozone intensity. Thus, the market perceives that a U.S. default is slightly higher than a German default. The systemic default intensities of the U.S. and the Eurozone are highly correlated at 0.9406. This high degree of commonality in systemic risk across the U.S. and euro market areas is consistent with Longstaff et al. (2011), who find that sovereign credit risk is highly correlated across countries. The high correlation between the U.S. and Eurozone systemic intensities is also partly driven by our sample period which covers the financial crisis. As is well known, correlations tend to increase during market downturns and crisis periods, as shown by Ang and Bekaert (2002).

The U.S. and Eurozone systemic intensities increase markedly during the last quarter of 2008 after the default of Lehman Brothers (September 15, 2008). Both systemic intensities reach their peaks of 102 and 90 basis points, respectively, at the end of February 2009. The increases in default intensities during the financial crisis come through two channels. First, there is an explicit increase of sovereign liabilities by bringing onto sovereign balance sheets many of the liabilities of private banks (in the U.S. through the Capital Purchase Program (CPP), the Troubled Asset Relief Program (TARP), and loans and assistance to American International Group (AIG) and auto manufacturers and in Germany the nationalization of Hypo Real Estate and state support of banks through the Financial Market Stabilization Fund). Second, there is an implicit increase in

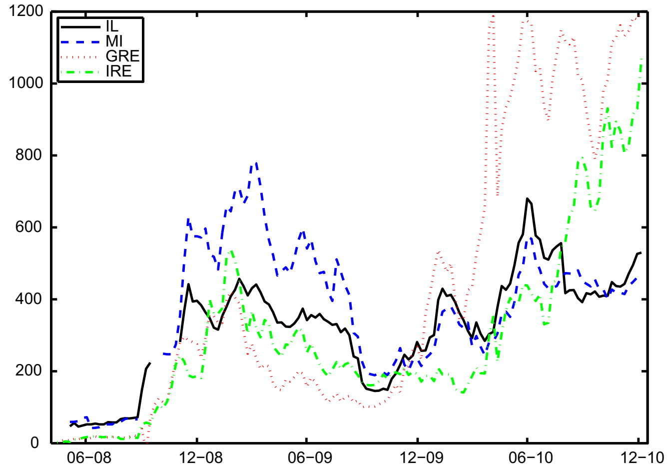

Fig. 1. Selected state and sovereign total risk-neutral default intensities. This figure plots the estimated time series of the total risk-neutral intensity processes for the indicated states and sovereigns. The intensity process is measured in basis points.

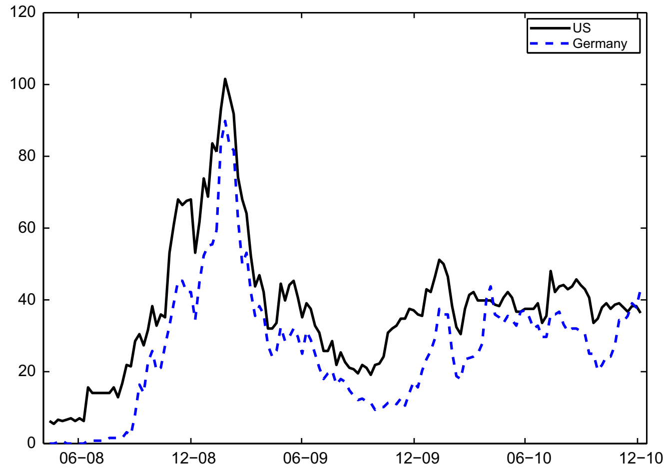

Fig. 2. U.S. and Eurozone systemic sovereign credit risk-neutral intensities. This figure plots the estimated time series of the risk-neutral intensity process for the two systemic sovereign credit risk factors, the U.S. and Germany. The intensity process is measured in basis points.

the riskiness of sovereign finances through the deterioration of economic conditions and the fragility of the banking sectors in each country.

Systemic default intensities for both the U.S. and the Eurozone decrease during the first three quarters of 2009. The U.S. intensity starts to increase in November 2009, while the Eurozone intensity follows later in late December 2009. The U.S. increase may reflect the large losses from Fannie Mae and increasing concerns about large deficits during that quarter. The increase in Eurozone systemic sovereign risk is likely due to the deteriorating finances of Greece and the downgrading of Greek debt in December 2009. Since March 2010, the U.S. credit intensity has averaged 39 basis points, representing a one-year probability of default of 0.0039 and has been fairly stable. Eurozone systemic sovereign risk has been a little more volatile, increasing in April and May 2010 and in December 2010 and January 2011. This volatility reflects the sovereign debt crisis of Ireland, Spain, Portugal, and other Eurozone periphery nations. Note that the Eurozone systemic default intensity is not elevated through this period indicating that systemic Eurozone risk has been relatively subdued even though the yields and default rates of other European nations dramatically increase during this time.

6.2. *Systemic sensitivity*

By normalizing the value of γ to one for the U.S. Treasury, the estimated values of γ_i for the other sovereigns represent the ratio of the conditional probability of default for the sovereign to that of the United States. Similarly, we normalize the Eurozone sovereigns by the conditional default probability for Germany. Thus, the estimated values of γ_i can be viewed as an index of relative systemic default risk.

Table 4 shows the estimated systemic default risk indexes. Surprisingly, nine of the ten states studied actually have an systemic index of less than one. The exception is California which has a systemic index of 2.647. The average value of the systemic index taken over all 10 states is 0.72; the median value of the systemic index is 0.63. It is also interesting to observe that several of the states appear to have little or no systemic default risk. In particular, Illinois, New York, and Ohio have systemic indexes that are less than 0.10. These results have important implications for the nature of state sovereign default risk in the U.S. since they imply that state default risk is largely sovereign specific rather than systemic.

In stark contrast to the results for the states, Table 4 shows that systemic default risk is far more important for the sovereigns in the Eurozone. In particular, seven of the Eurozone sovereigns have systemic indexes in excess of one, implying that their probability of a default given a systemic shock exceeds that of Germany. The highest value of the systemic index is for Greece which has a value of 4.688. The next highest values are for Italy, Portugal, Belgium, and Ireland with indexes of 1.710, 1.674, 1.662, and 1.604, respectively. The smallest value for the index is for Finland with a value of 0.356. The average value of the systemic index taken over all 10 Eurozone sovereigns is 1.597; the median value of the systemic index is 1.555.

6.3. How large is the systemic component?

Since the instantaneous default risk of each sovereign is $\gamma_i \lambda_t + \xi_{it}$, the systemic component is given simply by $\gamma_i \lambda_t$, while the sovereign-specific component is given by ξ_{it}. Table 5 reports summary statistics for the systemic component expressed as a percentage of the total default risk for each sovereign.

The results in Table 5 tell a similar story as the results for the systemic index. In particular, the size of the systemic component for the states is typically very small. The average systemic percentage taken over all 10 states is only 12.2%. Even for California, which has the highest systemic index of $\gamma_i = 2.647$, the average systemic component is only 36.8% of the total credit risk. This reinforces the earlier evidence that state credit risk in the U.S. is largely sovereign-specific in nature rather than systemic.

The results for the Eurozone are again very different from those for the U.S. The systemic component taken over all Eurozone sovereigns is 30.9%; the median is 37.0%. The smallest average among Eurozone sovereigns is 16.8% for Ireland. The highest average among Eurozone sovereigns is 53.1% for France. Thus, the results indicate that systemic default risk tends to be two to three times as large a component of default risk in Europe as it is in the U.S.

6.4. What drives systemic sovereign risk?

We now investigate the extent to which a set of domestic and global variables explain changes in the systemic intensity values. Since there is virtually an unlimited number of variables that could be related to sovereign credit risk, it is important to be selective in the variables considered. In particular, we focus on market-determined variables since we can observe

Table 4
Systemic default indexes. This table reports the estimated value of the systemic default index parameter γ and its standard error for the indicated sovereigns. The value of γ is constrained to be 1.000 for the USA and Germany. The sample consists of weekly observations for the May 14, 2008 to January 5, 2011 period.

Sovereign	Systemic index	Standard error
California	2.647	0.045
Florida	0.909	0.035
Illinois	0.000	0.031
Massachusetts	0.468	0.014
Michigan	0.731	0.054
Nevada	0.854	0.043
New Jersey	0.982	0.041
New York	0.000	0.022
Ohio	0.066	0.011
Texas	0.536	0.018
USA	1.000	–
Austria	1.173	0.028
Belgium	1.662	0.014
Finland	0.356	0.007
France	0.933	0.005
Germany	1.000	–
Greece	4.688	0.238
Ireland	1.604	0.049
Italy	1.710	0.037
Netherlands	0.668	0.011
Portugal	1.674	0.057
Spain	1.506	0.036

Table 5
Summary statistics for the percentage systemic component of U.S. and Eurozone sovereign default risk. This table reports summary statistics for the percentage that the systemic component represents of the total credit risk of the indicated sovereigns. The sample consists of weekly observations for the May 14, 2008 to January 5, 2011 period.

Sovereign	Mean	Std. dev.	Min.	Med.	Max.	*N*
California	36.78	13.62	17.60	32.16	92.81	133
Florida	18.18	12.32	5.80	14.53	73.17	133
Illinois	0.00	0.00	0.00	0.00	0.00	130
Massachusetts	10.59	6.02	3.46	9.49	40.07	134
Michigan	8.83	4.33	3.35	7.71	26.76	131
Nevada	13.63	6.24	6.27	12.11	47.64	138
New Jersey	15.05	5.55	7.15	13.59	36.72	135
New York	0.00	0.00	0.00	0.00	0.00	131
Ohio	1.28	0.38	0.62	1.22	2.50	134
Texas	17.73	9.73	5.58	15.42	60.01	134
USA	100.00	0.00	100.00	100.00	100.00	139
Austria	34.31	16.16	0.00	30.76	100.00	136
Belgium	56.87	25.23	0.00	67.67	89.97	139
Finland	39.75	22.20	0.00	33.49	100.00	138
France	53.15	23.70	0.00	55.99	92.58	139
Germany	100.00	0.00	100.00	100.00	100.00	139
Greece	44.48	30.24	0.00	35.00	100.00	138
Ireland	16.77	9.82	0.00	15.30	45.71	139
Italy	31.84	15.36	0.00	31.32	71.60	139
Netherlands	39.79	21.10	0.00	34.27	100.00	138
Portugal	32.84	26.78	0.00	22.24	96.01	139
Spain	28.24	19.53	0.00	22.32	79.74	139

Table 6
Regression results for systemic risk. This table reports the *t*-statistics and other summary statistics from the regression of weekly changes in the risk-neutral systemic credit process on the indicated variables. Mkt denotes the return on the S&P500 for the U.S., and the return on the DAX for Europe. VIX denotes the weekly change in the VIX volatility index. Corp denotes the weekly change in the CDX IG index for the U.S., and the weekly change in the ITraxx index for Europe. Japan, China, and EM denote the weekly changes in the CDS spreads for the respective sovereigns or sovereign indexes. The sample consists of weekly observations for the May 14, 2008 to January 5, 2011 period. Single and double asterisks indicate significance at the 95% and 99% levels, respectively.

Region	Intercept	Mkt	Swap	VIX	Corp	Japan	China	EM	R2	N
U.S. systemic	0.55	−4.31**	2.60**	−2.83**	1.80*	1.64	1.80*	−0.50	0.352	138
Eurozone systemic	0.56	−1.97**	−0.61	−1.60	1.86*	1.44	2.67**	1.02	0.431	138

these at a higher frequency than other variables such as tax receipts or budget deficits (which are generally only available on an annual or semiannual basis).

The first set of four variables are taken from the domestic financial markets. For the U.S., we use the weekly return on the S&P 500 index (excluding dividends), the weekly change in the five-year constant maturity swap rate, the weekly change in the VIX volatility index, and the weekly change in the CDX North American Investment Grade Index of CDS spreads. For the Eurozone, we use the weekly return on the DAX index, the weekly change in the five-year constant maturity euro swap rate, the weekly change in the VIX volatility index, and the weekly change in the European ITraxx Index of CDS spreads. The data for these variables are all obtained from the Bloomberg system.

The second set of explanatory variables consists of weekly changes in the five-year CDS spreads for three sovereigns or sovereign indexes. In particular, we include the weekly change in the CDS contract for Japan, China, and for the CDX Emerging Market (CDX EM) Index of sovereign CDS spreads. The data for these CDS spreads are also obtained from the Bloomberg system.

Table 6 reports the results from the regressions of weekly changes in the default risk for the issuers on the explanatory variables. Specifically, the table reports the Newey–West *t*-statistics from the regressions along with the R^2s. Table 6 shows that U.S. systemic sovereign risk is strongly related to the financial market variables. The R^2 for the regression is 0.35, indicating that a substantial proportion of U.S. systemic credit risk can be explained in terms of the financial market and global credit variables.

The single most significant variable in the regression is the return on the stock market, which has a *t*-statistic of −4.31. Thus, U.S. systemic credit risk declines significantly as the stock market rallies, and vice versa. U.S. systemic risk is significantly positively related to changes in the swap rate, indicating that the level of interest rates has an important effect on credit risk.

Changes in the VIX index are significantly negatively related to U.S. systemic credit risk. Earlier authors like Pan and Singleton (2008) and Longstaff et al. (2011) have also noted the strong relation between VIX and sovereign risk. The negative VIX coefficient is consistent with the view that Treasury bonds may play the role of a “reserve investment” in the financial markets. Specifically, that when uncertainty in the financial markets increases, the resulting global flight to U.S. Treasury bonds makes it easier for the U.S. to finance its operations with nominal debt.

U.S. systemic credit risk is positively related to changes in investment grade corporate bond spreads (significant at the 10% level) and is also related to the credit spreads of the two largest holders of U.S. Treasury debt. In particular, the *t*-statistic for the CDS spread of Japan is 1.64 (which just misses significance at the 10% level), while the *t*-statistic for China is 1.80 which is significant at the 10% level.

Turning now to the results for Eurozone systemic sovereign risk, we see a very similar pattern. Eurozone systemic risk is again significantly negatively related to stock market returns. As for the U.S., Eurozone systemic risk is significantly positively related to changes in corporate credit spreads. Note that the coefficient for changes in the VIX is not significant, consistent with the intuition of the unique role played by U.S. Treasury debt discussed above. Finally, Eurozone systemic risk is strongly positively related to the CDS spread of China. As before, the R^2 of 0.431 for this regression indicates that much of the variation in Eurozone systemic sovereign risk is captured by these financial market variables.

The finding that systemic risk is strongly related to financial market variables may be partly behind the larger exposures of Eurozone countries to systemic risk than U.S. states. Large banks hold large amounts of Eurozone sovereign debt (see Blundell-Wignall, 2012). State debt, in contrast, is held mostly by individuals (see Ang et al., 2010). Thus, the financial effects from bank interactions affect systemic risk in Europe, whereas state debt plays little role in the underpinnings of the U.S. financial system.

We acknowledge that by identifying systemic default risk with the CDS spreads for the U.S. and Germany, we are focusing on a specific definition of systemic risk. The negative coefficient on VIX may reflect increased demand for U.S. Treasury or German bunds as investors react to an adverse shock in a peripheral sovereign. There is a “flight-to-quality” effect pushing down bond yields and causing CDS spreads to fall, but the overall systemic risk may actually be increasing.[21]

7. Sovereign-specific risk

7.1. Does geography matter?

To provide an alternative perspective on the cross-sectional structure of default risk, we conduct a multivariate cluster analysis of the correlation matrix of weekly changes in the estimated sovereign-specific components. In this cluster analysis, the algorithm attempts to sort the states into groups where the members of each group are as similar as possible. At the same time, the algorithm attempts to form the groups to be as dissimilar from one another as possible.[22] We use a simple rule of thumb that the number of clusters be roughly $N/3$, where N is the number of individual items to be grouped. For the 10 sovereigns in the U.S. and the 10 in the Eurozone, this rule of thumb suggests forming three clusters (we exclude the U.S. Treasury and Germany since, by assumption, their default risk is due entirely to the systemic factor).

Table 7 reports the composition of the clusters. There is no particular significance to the ordering of the sovereigns within each group in cluster analysis. Similarly, the cluster analysis algorithm does not place any restrictions on the number of items that can appear in any cluster (other than the obvious requirement that a cluster has to contain at least one element).

The results illustrate that there is a strong regional flavor to state credit risk. In particular, the first cluster contains five states, four of which are located in Midwest/Central part of the U.S.: Illinois, Michigan, Ohio, and Texas. The second cluster consists primarily of states on the East and West Coasts such as New York, New Jersey, and California. The third cluster consists only of Florida. This suggests that the credit risk of Florida is sufficiently distinct from that of the other states that the algorithm places it in a separate category altogether.

Turning to the results for the Eurozone, a somewhat different pattern emerges. In particular, the largest cluster consists of the Eurozone periphery: Greece, Ireland, Italy, Portugal, and Spain—all countries that have experienced moderate or severe financial distress recently. This pattern is also consistent with the second cluster which consists of Austria, Finland, and the Netherlands, which have all represented strong credits through the global financial crisis. The third cluster shows the most geographical similarity since France and Belgium are neighbors and share many common features such as language. We will next examine in further detail the time series of the state-specific and country-specific intensity processes.

7.2. State-specific sovereign risk

Fig. 3 plots the states-specific intensities of the states in the various clusters shown in Table 7. Panel A plots the state-specific ξ_{it} intensities of the states in the first cluster: Illinois, Massachusetts, Michigan, Ohio, and Texas. The states in this cluster all exhibit two large increases in credit risk, beginning with the start of the financial crisis in 2008 when U.S.

[21] We are grateful to the referee for this insight. One way to measure this type of flight-to-liquidity systemic risk might be to first extract the component of sovereign CDS spreads that is related to U.S. or German CDS spreads, and then to study the principal components or factor structure of the residual spreads. In the NBER version of the paper, we conducted a principal components analysis of CDS spread changes (for the five-year maturity)—we find that all CDS spreads are negatively correlated. This is an interesting area for future research.

[22] The cluster analysis is done using Ward's method, see Anderberg (1973, pp. 142–145).

Table 7
Credit Clusters. This table reports the clusters formed on the basis of the correlation matrix of the weekly changes in the risk-neutral nonsystemic sovereign credit processes. The pairwise correlations in the correlation matrix are computed using all available overlapping observations for each pair.

Region	Cluster 1	Cluster 2	Cluster 3
USA	Illinois	California	Florida
	Massachusetts	Nevada	
	Michigan	New Jersey	
	Ohio	New York	
	Texas		
Eurozone	Greece	Austria	Belgium
	Ireland	Finland	France
	Italy	Netherlands	
	Portugal		
	Spain		

systemic credit risk also increases (see Fig. 2) and again in 2010. These state-specific intensities are large; Michigan's intensity reaches a peak of 740 basis points in April 2009 and Illinois' maximum intensity is 680 basis points in June 2010.

The increase in default intensities during 2010 reflects different circumstances for different states. Using data from the Bureau of Economic Analysis, Illinois has the largest debt to GDP ratio, 20.6%, in 2009 of all the states considered in the sample and financed the largest projected deficit to GDP ratio in 2011, 2.7%, according to the Center on Budget and Policy Priorities. Massachusetts moved from budget surpluses during the late 1990s to budget deficits during our sample period, resulting from a combination of reducing taxes prior to the financial crisis and increased demand for social services during the financial downturn. Similarly, estimates of budget deficits for Texas started increasing dramatically in June 2010 to top $20 billion. In early January 2011, Texas legislators eventually cut spending by more than $30 billion.

Panel B of Fig. 3 graphs the state-specific intensities for the states in the second cluster: California, Nevada, New Jersey, and New York. California's state-specific default risk appears to be similar to these other states, so its overall high default probabilities are due to California's large loading on U.S. systemic risk (see Table 6). The intensities for these four states are highly correlated with an average cross-correlation of 90%. These states share a number of similarities: California and Nevada have the highest state unemployment rates among the states considered over the sample and California and Nevada have been very hard hit by declining property prices. Although much smaller than its neighboring state California, it is not surprising that Nevada is exposed to many of the same economic forces facing California.

New Jersey and New York are adjoining states and there is a high linkage of these economies. It is not surprising that the correlation between the New Jersey and New York specific intensities is 0.98. Note that the systematic index parameter for New York is zero (see Table 6), so the New York specific intensity represents all of New York's credit risk. New Jersey is highly correlated with New York, but New Jersey is also exposed to U.S. systematic risk (with a systematic index of 0.98).

There are other connections between the states in the second group that can explain the common increase in the states' intensities in February 2010 and June 2010. California and New York's fiscal years end in March 2010 and the challenges for both states in meeting budget deficits could have spilled over to shared concerns in the neighboring states. Similarly, the increase in intensities in June 2010 may reflect the difficulties in financing deficits for the budget deadline of July 1 for California and the June 28 deadline for approving New York's budget bill, which if not passed would have led to a New York government shutdown.

Finally, Panel C of Fig. 3 graphs the default intensity of the third cluster, which consists of just Florida. Unlike the first two clusters, Florida saw a very early spike in its state-specific intensity in July 2008. This coincides with the bailouts and credit lines provided to Fannie Mae and Freddie Mac to deal with deteriorating conditions in the mortgage market, to which Florida was highly exposed.

7.3. Euro country-specific sovereign risk

In Fig. 4, we plot country-specific intensities ξ_{it} for the euro members. Panel A graphs the intensities for the countries in the first cluster: Greece, Ireland, Italy, Portugal, and Spain, all of which are euro periphery countries. Policymakers have been preoccupied in managing financing and avoiding default for these countries since the financial crisis. Interestingly, all these countries, with the exception of Greece, saw large increases in their sovereign-specific default risk from late 2008 to 2009. This mirrors the increase in German systemic risk and corporate default rates over this time. It is only in January 2010 that Greek-specific intensities start to rise, even though knowledge of Greece's financing problems were known in 2009. The intensity for Greece rises from 187 basis points at the end of December 2009 to close at 10% at the beginning of May 2010. This is when Ireland's intensity starts to rapidly increase, also reaching nearly 10% at the end of the sample. This is due to market perceptions that Ireland's measures taken in 2008–2009 to fix the problems in its banking sector are insufficient and additional measures, involving co-ordinated euro action, are necessary.

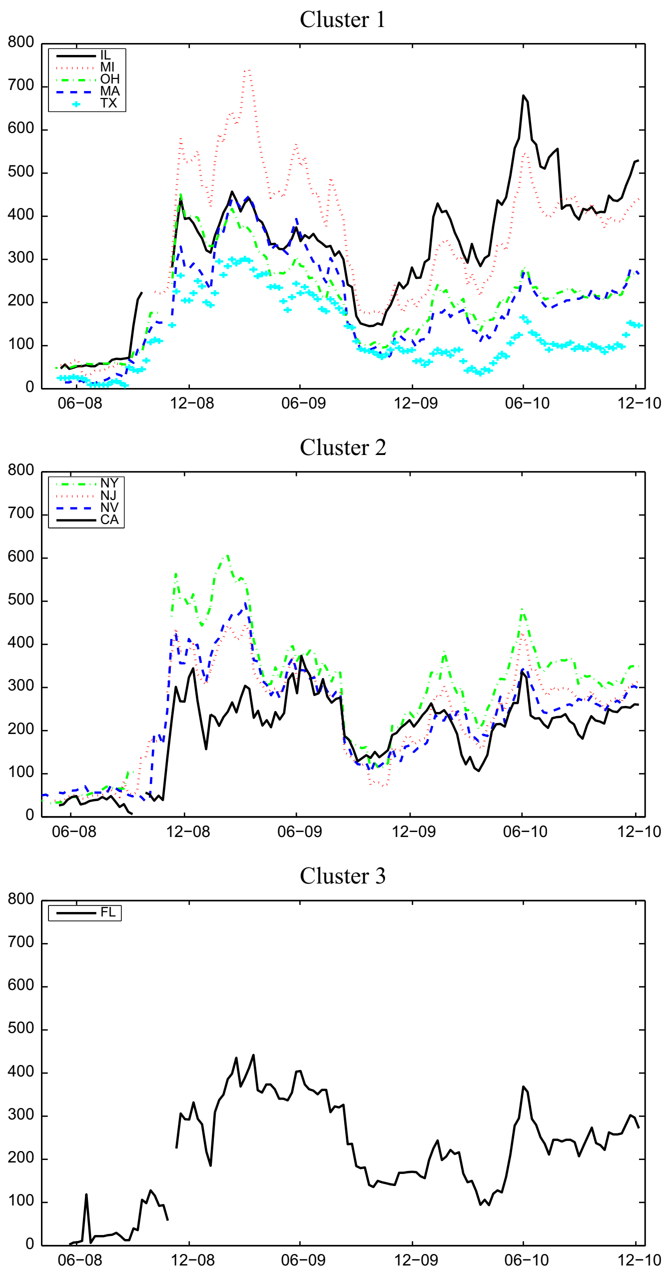

Fig. 3. State-specific risk-neutral intensities for U.S. clusters. The upper, middle, and lower panels plot the state-specific intensity process for the states in the first, second, and third clusters, respectively. The intensities are measured in basis points.

Panel B of Fig. 4 plots the intensities for the countries in the second cluster: Austria, Finland, and the Netherlands. As is the case for the states (see Fig. 3) and the countries in the first cluster, default intensities rise during the financial crisis. They remain elevated, and for the Netherlands also increase, after 2009. In contrast, the Belgian and French country-specific default risk shown in Panel C barely changes during the financial crisis. Only towards the end of the sample do Belgian and French sovereign-specific intensities start to increase.

8. Conclusion

We study the nature of systemic sovereign credit risk by examining the pricing of CDS contracts on the U.S. Treasury, a number of key U.S. states, and major Eurozone countries. The analysis provides new insights into whether systemic sovereign credit risk arises from common macroeconomic fundamentals or from the influence of global financial markets.

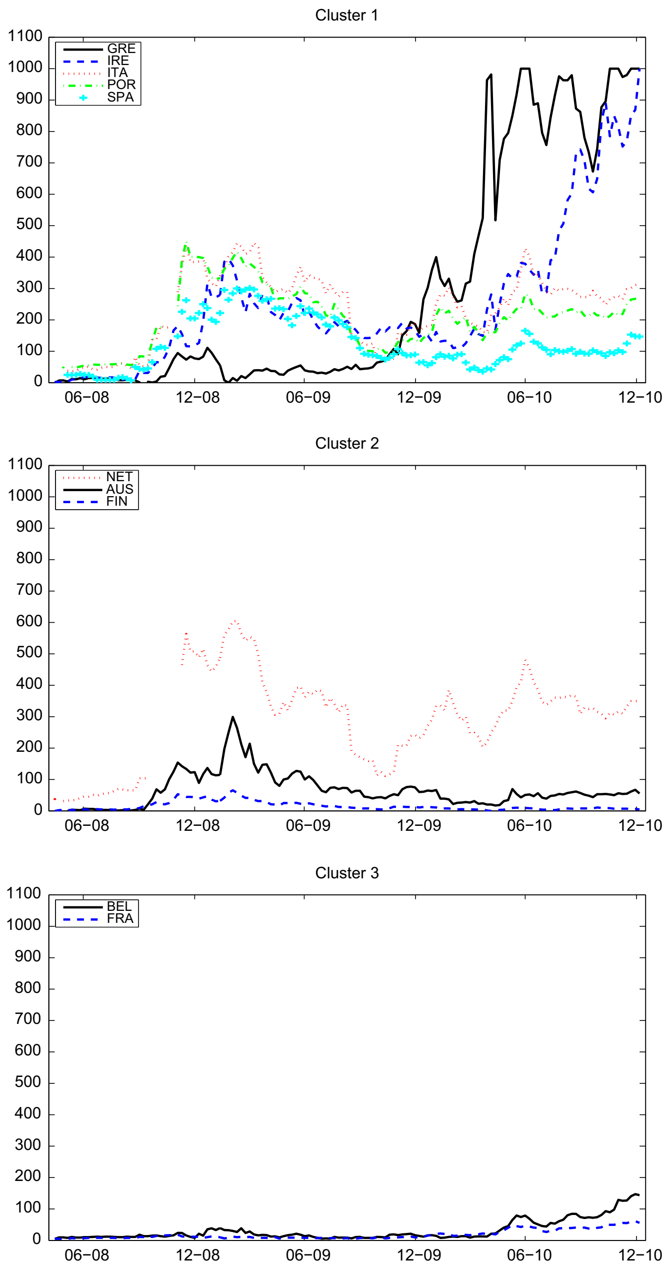

Fig. 4. Country-specific risk-neutral intensities for Eurozone clusters. The upper, middle, and lower panels plots the country-specific intensity processes for the countries in the first, second, and third Eurozone clusters, respectively. The intensities are measured in basis points.

By applying the multifactor credit model of Duffie and Singleton (2003), we are able to decompose sovereign credit risk into a systemic component and a sovereign-specific component. We find that systemic risk represents a much smaller fraction of total credit risk for U.S. states than is the case for members of the Eurozone. This result is surprising since we would expect U.S. states to be more closely linked in terms of their economic fundamentals. This result provides clear evidence against the hypothesis that systemic risk is primarily an artifact of common macroeconomic fundamentals.

We find that U.S. systemic sovereign credit risk is highly correlated with Eurozone systemic credit risk. Furthermore, we show that both are strongly related to financial market variables such as stock returns. This argues that systemic risk may arise largely through the global financial system. We find that U.S. systemic risk decreases as markets become more volatile, as measured by the VIX index, which is consistent with flights to quality to the U.S. in turbulent periods.

The results in this paper have at least two important implications for sovereign credit risk. First, systemic risk is not directly caused by macrointegration. Second, systemic risk is highly correlated with financial market variables. Clearly, future work is needed to understand the deep reasons for the strong relation between systemic sovereign risk and financial markets.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2013.04.009.

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