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Immunity and infection: Emerging and developed market sovereign spreads over the Global Financial Crisis

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ABSTRACT

We compare sovereign bond spreads during the international financial crisis across groups drawn from 43 countries, including 20 emerging economies. We extend traditional factor analyses and utilize propensity score matching to select a non-crisis sample for comparison with the crisis sample that is more robust to exogenous crisis dating. We find minimal changes over the crisis period in the average spreads of local-currency-denominated emerging market bonds. In contrast, the spreads of peripheral Eurozone sovereign bonds increased by large amounts and were subject to sovereign risk contagion.

1. Introduction

Since 2007, international financial markets have experienced a prolonged period of major shocks that have emanated from advanced economies. One phase of the Global Financial Crisis (GFC) has been particularly marked by a significant escalation in sovereign bond yield spreads around the world, associated with troubled European sovereign debt. In this study we re-examine the spread of financial contagion across sovereign debt markets, motivated by these developments. In particular, we aim to understand differences in the way developed and emerging economies experienced the spread of financial turbulence, and the implications of that contagion for sovereign debt yield spreads. The question of whether any markets were entirely immune from the adverse impacts of the recent spate of shocks remains unclear to researchers, regulators and market participants. The scope and duration of the great recession allows us to assess and compare the economic vulnerabilities of various debt-issuing countries. Our results propose effective diversification strategies for sovereign bond holders and show the importance of currency choice for sovereign debt issuers.

Sovereign bond yields are benchmarks from which other debt and capital instruments are priced (Dittmar and Yuan, 2008). To explain the level and changes in sovereign yields is therefore an important task for financial researchers and policymakers. Some commentary has postulated that a deterioration in country-specific fundamentals drove sovereign spreads upwards during the fi-

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nancial crisis although no single factor can explain all sovereign spread movements. Studies concur that prior to and during the first stage of the GFC, changes in global risk aversion were the chief cause of changes in sovereign spreads (Caceres et al., 2010; Sgherri and Zoli, 2009). However from 2009 onwards, country-specific fundamentals became dominant. The perceived fragility of a country's financial sector and consequently its potential to deplete public finances, as well as weaker macroeconomic fundamentals and changes in trade variables, explain differences in sovereign spreads of Eurozone countries since the onset of the European sovereign debt crisis (Arghyrou and Kontonikas, 2012; Chiarella et al., 2015; Dieckmann and Plank, 2012; Mody, 2009; Schuknecht et al., 2010). Country-specific fundamentals, proxies for risk aversion and liquidity have also been documented to be major determinants of credit spread variations in emerging market bonds in recent years (Fender et al., 2012; González-Rozada and Yeyati, 2008; Hilscher and Nosbusch, 2010; Remolona et al., 2008). The importance of country-specific factors during the GFC stands in sharp contrast to previous crises in emerging countries where changes in spreads were driven mainly by global factors (Diaz and Gemmill, 2006; Martinez et al., 2013; Mauro et al., 2002).[1]

There are many possible sources of influence on sovereign spreads and it is important to understand what factors - global, country-specific or latent - are the main drivers behind recent changes in sovereign spreads. The literature on financial contagion offers a taxonomy of transmission channels that can be used to categorize factors that are likely to affect spreads. Dungey and Martin (2007) classify the transmission channels into three categories: 1) Common or market shocks 2) Country-specific shocks and 3) Latent or idiosyncratic shocks. Moreover, Giordano et al. (2013) offers a useful economic interpretation of crisis-related changes in common shocks as “shift contagion”, in country-specific transmissions as “wake-up-call” contagion, and new latent factor transmissions as “pure contagion”.

Our main objective and contribution in this study is to comprehensively assess recent changes in sovereign borrowing costs, as experienced in different bond market segments, in order to better understand the potential costs of financial market interdependence in times of crisis. In doing so, we also contribute to the literature on financial contagion by measuring the true extent of contagion using a novel approach that is more robust to traditional exogenous crisis dating methods. Researchers who want to measure pure contagion effects must, first, choose a robust set of fundamental factors, and second, choose dates for crisis and non-crisis periods. We extend standard factor analyses and apply propensity score matching techniques combined with an Average Treatment Effect on the Treated (ATET) method to correct for potential biases in the selection of a matching “control” non-crisis sample period. We then compare across crisis and matched non-crisis periods to detect material changes in sovereign spreads. Crisis period observations are “treated” units in the ATET setup. We can thus test whether the spreads during crisis periods are statistically different from non-crisis periods, holding all factors that determine spreads constant. It is particularly important to understand the behaviour of emerging market bond spreads because other studies have shown them to be negatively related to emerging countries' economic output, investment and trade balances (Uribe and Yue, 2006).

Our sample includes sovereign bonds of all maturities from 43 countries classified into nine representative test groups based on market type (developed or emerging), geographical location (peripheral Eurozone) and also currency of debt denomination (US dollars, Euros and local currencies). Thus, the nine test groups consist of a composite of all 43 sovereigns, as well as groups of developed markets, emerging markets, Euro-denominated, US dollar-denominated, local currency denominated (for developed and emerging markets, respectively) and the group of troubled peripheral Eurozone countries (PEC) - Portugal, Ireland, Italy, Greece, and Spain.

Our study provides several major new findings. First, we find that the changes in spreads between crisis and non-crisis periods that we estimate with traditional exogenous dating methods are very different from the results from matched estimation. The estimates of average changes in spreads that we made with traditional dating methods are much larger than the estimates we made with propensity score matching. Second, our new empirical test reveals that in addition to the more stable developed markets, local currency denominated sovereign bonds from emerging markets also exhibited very low proportional changes in spreads throughout the crisis. The policy implication of this new finding is that emerging market sovereigns could strengthen their future immunity from external global shocks by raising their capacity to borrow in their own currencies. Third, we find that the funding costs for peripheral Eurozone (PEC) sovereign bonds were significantly affected throughout the prolonged crisis, with economically significant increases in spreads. Fourth, both “shift” and “wake-up-call” contagion affected sovereign bond market segments throughout the crisis, which shows that it is important for governments to remain vigilant over both the financial health of their own economies and over global conditions. Our results corroborate for sovereign bond markets Bekaert et al.'s (2014) finding that wake-up-call contagion played a critical role in the spread of the GFC across international equity markets.

Section 2 sets out the data sources and choice of variables for our base factor regression models; Section 4 describes the propensity matching model, Section 5 contains the summary of contagion tests, and Section 5 concludes.

2. Method

We start by describing the construction of the zero coupon bond yield spread series, then the estimation of panel factor models for all sovereign bond groups.

[1] Other studies attribute the increase in global liquidity to the fall of emerging market spreads and a shift from common factors to country-specific factors during the GFC (Eichengreen et al., 2012; Hartelius et al., 2008). Similarly, unobservable factors and risk aversion have accounted for a large part of the observed variations in emerging market sovereign CDS spreads (Coudert and Gex, 2008; Longstaff et al., 2011).

2.1. Variables and data description

We collect the fair market value zero coupon sovereign bond curves (FMCZCB) available at a daily frequency from Bloomberg from January 3, 2000 to May 31, 2013 for a global sample of 43 countries (of which 23 are developed and 20 are emerging).[2] These sovereign bond curves have the distinctive feature that they are derived from actual bond prices and give a good approximation of the theoretical price for non-traded maturities. Bloomberg calculates the zero coupon curves with the same base model for different maturities and countries so we can aggregate values for groups of countries and also compute spreads relative to the US sovereign bond curves across all maturities traded.

We compute value-weighted group yields to account for differences in the economic importance of individual countries within each maturity segment for each group. First we compute the weights ($w_{i,j}$) of sovereign debt securities at each maturity j for any country i as:

$$w_{j,i} = \frac{v_{j.i}}{\sum_{j=1}^{n} v_{j.i}} \tag{1}$$

where $v_{j,i}$ is the US dollar (USD) denominated value of a sovereign bond outstanding with a maturity $j = 1, 2,\dots n$ in country i and $\sum_{j=1}^{n} v_{j.i}$is the sum of the USD values of all n issues of sovereign bonds in country i. The value-weighted theoretical bond yield for any given country i at time t is:

$$Y_{i,t} = \sum_{j=1}^{n} w_{i,j} y_{i,j,t} \tag{2}$$

where $y_{i,\ j,\ t}$ is the yield at time t for country $i = 1,\dots,43$ for bonds with maturity j . Notice that $w_{i,\ j}$ is kept constant[3] for all t in a given country i's proportion of bonds outstanding for a given maturity segment j. $Y_{i,\ t}$ is the market-weighted theoretical bond yield for country i across all maturity segments. We define the daily spread for country i at time t as:

$$spread_{i,t} = Y_{i,t} - Y_{us,t} \tag{3}$$

where $Y_{i,t}$ is the value-weighted theoretical bond yield of country i and $Y_{us,t}$ is the United States' weighted average sovereign bond yield that results from Eq. (2).

We compute the monthly yields for each country by summing the daily log yields within each month. We combine these with sizes of bond issues and apply Eqs. (1) to (3) to compute the monthly theoretical value-weighted spread for each of the 43 countries.

We arrange these country series into nine groups differentiated by geography, developed or emerging status and issue currency. Table 1 sets out the countries included in each group. The groups are 1) an All Countries Group that includes the 43 countries in the sample; 2) a Developed Market Group; 3) an Emerging Market Group (groups 1 and 2 are divided according to the MSCI classification prior to the European Sovereign Debt (ESD) crisis so that Greece is treated as a developed rather than an emerging market, as it is in the post ESD re-classification); 4) a Euro-denominated Group that includes all countries from the Euro zone that issue their debt in Euros; 5) a USD-denominated Group that includes the countries that issue debt in USD dollars; 6) a Local-currency Group that includes countries who issue debt in their local currency; 7) a Local Developed Group of developed markets that issue debt in their local currency; 8) a Local Emerging market Group of emerging economics that issue debt in their local currency; and 9) the troubled Peripheral Eurozone Countries (Portugal, Ireland, Italy, Greece and Spain (PEC)) Group.[4]

In order to aggregate the spreads of countries in each group we apply Eq. (4):

$$SPREAD_{p,t} = \left(\frac{V_{i,p}}{\sum_{i=1}^{p} V_{i,p}} \right) spread_{i,p,t} \tag{4}$$

where $spread_{i,\ p,t}$ is the spread from Eq. (3) for a country i that is part of group $p = 1,\dots, 9$ at time t, and $V_{i,\ p}$ is the total value of sovereign bonds outstanding of a member country i of group p in US dollars.[5] $\sum_{i=1}^{p} V_{i,p}$ is the sum of the total value of sovereign bonds outstanding for all countries i in each sovereign bond group p, and $SPREAD_{p,\ t}$ is the market value weighted spread of group p at time t. Table 1 reports the descriptive statistics for the group spreads obtained from the sample.

[2] One reason for using actual yield spreads rather than Credit Default Swap (CDS) spreads is that CDS are priced using a risk-neutral framework, therefore default probabilities for CDS tend to be higher than those inferred from historical bond prices (Hull et al., 2012).

[3] In order to compute the weights, we use the last reported total issued amount outstanding as of May 31st, 2013 as there is no longitudinal data source on the amount issued available. This data limitation should not qualitatively affect our results since most countries would typically rollover maturing debts with new issues of similar size. We collect data on the amount of bond issues outstanding and the USD exchange rate for that date from Bloomberg.

[4] Since some countries issue bonds in local currency, USD and/or EUR, we allocated countries to groups based on the currency of the largest amount issued. For example in the case of Colombia and Brazil we had data for local currency and USD bonds but the amount issued in USD was larger, therefore for the study we use USD. In the case of the Eurozone the only country that adopted the Euro after the start date of our dataset was Greece and all bonds for this country are in Euros.

[5] Issues denominated in Euros or local currencies are converted using the exchange rate vis-à-vis the USD as at May 31, 2013 to correspond to the date for which we have the value of sovereign bonds outstanding.

Table 1
Descriptive statistics sovereign spreads (monthly).
This table reports the descriptive statistics of the value-weighted spreads over the US zero coupon yield of the same maturity (Eq. (4)) sourced from Bloomberg (FMCZCB) from January 1, 2000 to May 31, 2013 for nine groups from 43 countries in our sample. The results are reported in basis points. A negative sign implies that the value-weighted theoretical yield in that group was lower on average than the equivalent US sovereign bond yield during the period of observation. The spreads are aggregated into nine (9) individual value-weighted sovereign bond groups. The countries included in each test group are shown below in each column. The panel is unbalanced. The following countries have different starting points: Chile, October 2015; Peru, April 2006; Venezuela, January 2002; Bulgaria, June 2005; Greece, January 2001; Indonesia, February 2003; Philippines, August 2001; Romania December 2009; Slovakia, April 2003; Turkey, July 2000; and Russia, April 2006. Since some countries issue bonds in local currency, USD or EUR, we allocate countries to Groups by the currency of the largest amount issued. In the case of the Eurozone the only country that adopted the Euro after the start date of our dataset was Greece and all bonds for this country are in Euros.

All countries		Developed	Emerging	EUR	USD	Local	Local developed	Local emerging	PEC
Mean	148.31	22.50	320.81	71.67	419.43	100.49	−7.69	263.72	151.27
Median	76.61	9.97	273.23	29.28	313.26	61.12	−13.86	254.78	45.29
Maximum	4276.79	4276.79	2219.71	4276.79	2219.71	969.81	1538.50	969.81	4276.79
Minimum	−547.31	−547.31	−348.31	−186.86	−348.31	−547.31	−547.31	−339.52	−149.42
Std. Dev.	302.70	242.96	291.33	292.57	329.32	243.53	192.75	239.30	427.12
Skewness	2.85	6.70	1.48	7.26	1.78	0.53	1.79	0.26	4.96
Kurtosis	25.41	91.26	7.74	80.82	7.58	3.32	14.75	2.39	37.89
Observations	6383	3691	2692	1881	1127	3375	2093	1443	793
Colombia	Japan	Austria	Colombia	Austria	Colombia	Chile	Australia	Chile	Portugal
Brazil	Malaysia	Australia	Brazil	Belgium	Brazil	Peru	Canada	Peru	Italy
Mexico	Netherlands	Belgium	Mexico	Finland	Mexico	Australia	Denmark	Bulgaria	Ireland
Venezuela	New Zealand	Canada	Venezuela	France	Venezuela	Bulgaria	Hong Kong	Czech Republic	Greece
Chile	Norway	Denmark	Chile	Germany	Indonesia	Canada	Japan	Hungary	Spain
Peru	Philippines	Finland	Peru	Greece	Philippines	Czech Republic	New Zealand	India	
Austria	Poland	France	Bulgaria	Ireland	Russia	Denmark	Norway	Malaysia	
Australia	Portugal	Germany	Czech Republic	Italy	Slovakia	Hong Kong	Singapore	Poland	
Belgium	Romania	Greece	Hungary	Netherlands	Turkey	Hungary	Korea	Romania	
Bulgaria	Russia	Hong Kong	India	Portugal		India	Sweden	South Africa	
Canada	Singapore	Ireland	Indonesia	Slovakia		Japan	Switzerland	Thailand	
Czech Republic	Slovakia	Italy	Malaysia	Spain		Malaysia	United Kingdom		
Denmark	South Africa	Japan	Philippines			New Zealand			
Finland	Korea	Netherlands	Poland			Norway			
France	Spain	New Zealand	Romania			Poland			
Germany	Sweden	Norway	Russia			Romania			
Greece	Switzerland	Portugal	Slovakia			Singapore			
Hong Kong	Thailand	Singapore	South Africa			South Africa			
Hungary	Turkey	Korea	Thailand			Korea			
India	United Kingdom	Spain	Turkey			Sweden			
Indonesia		Sweden				Switzerland			
Ireland		Switzerland				Thailand			
Italy		United Kingdom				United Kingdom			

The descriptive statistics show the heterogeneity in the global sample. As expected, the yield of the PEC Group exhibits the highest volatility, and the yield of the Developed markets' Local Currency Group exhibits the lowest volatility.

To model these spreads, we collect an array of explanatory variables that are known to be determinants of country spreads.[6] We capture common factor or "shift contagion" with global equity premia, regional bond yield spreads, global risk aversion and a measure of bond market activity based on group bond prices. We use returns to the S&P Global 1200 index less $Y_{us,\ t}$ as a proxy for the risk-free rate to measure the global equity premia. For the U.S. equity premium, we use returns to the S&P500 less $Y_{us,\ t}$. For regional bond yields, we use the approach employed by Longstaff et al. (2011): we compute the value-weighted yield to bonds from the group[7] excluding the country under observation, less $Y_{us,\ t}$. We measure global risk aversion with the implied volatility index (VIX) on the S&P 500 index (from Bloomberg).

For country-specific determinants of spreads and "wake-up-call" contagion, we represent the local equity premium by the changes in the local stock market index of each country, adjusted by the domestic currency/USD exchange rate, less $Y_{us,\ t}$. Also, we measure bond market conditions for each country by computing a value-weighted average of bond price returns in each country less the same measure for the U.S. We also include a set of macroeconomic variables, explained in detail below. We extracted most of the data for the country-specific factors from the IMF statistics module in Bloomberg in order to

6 There is a vast literature on the determinants of country spreads (see inter alia, Mauro et al., 2002, Eichengreen and Mody, 1998, Remolona et al., 2008 and Martinez et al., 2013).

7 The Groups are constructed as aggregate value-weighted returns using the same procedure through which we aggregated the spreads using Eq. (4). All data are extracted from Bloomberg.

ensure consistency among the variables used. However, we collected the growth rate of GDP per capita for each country from the World Bank.[8]

2.2. Factor models

To account for the influence of common and local factors on spreads, we estimate separate panel regressions for each of the nine groups. Martinez et al. (2013) argue that panel data models can deal with the cross sectional heterogeneity and time effects that are present in macroeconomic data, whilst Baur and Fry (2009) argue that in a panel data model with common factors, significant time fixed effects can capture the latent or pure contagion factor.[9] We follow the specification proposed by Giordano et al. (2013) to model sovereign yield spreads:

$$spread_{i,t} = \alpha_i + \beta_s{}' spread_{i,t-j} + \beta_l{}' Z_{i,t} + \beta_c{}' F_t + \gamma_0 D_{c,t} + \gamma_1' \left(Z_{i,t}{}' D_{c,t} \right) + \gamma_2{}' \left(F_t{}' D_{c,t} \right) + \varepsilon_{i,t} \tag{5}$$

where α_i is the country-specific intercept, $Z_{i,t}$ is a vector of country-specific local factors which in our model includes the exchange rate (of the local currency against the USD), total debt to GDP ratio, investment to GDP ratio, external debt to exports ratio, GDP per capita growth, reserves, the local equity premium and country-specific bond price returns.[10] F_t is a vector of common factors described above,[11] β_s is a vector of coefficients on lagged values of the spread, β_l is a vector of coefficients on local factors, and β_c is a vector of coefficients on common factors. The expected sign of the coefficients on both country-specific ($Z_{i,\ t}$) and common (F_t) factors are summarized in Table 2. Where macroeconomic data are available only quarterly, the same value is used for all 3 months in each quarter.

We test for changes in transmission channels during the crisis period with the γ coefficients on the crisis indicator (D_C) and the interactions with the country-specific and common factors. We date the crisis from October 2008, coinciding with the collapse of global markets associated with the failure of Lehman Brothers. We allow the crisis indicator to continue to the end of our sample in March 2013 because of the persistent weakness in the global economy over that period. A significant coefficient on γ_o can be interpreted as “pure contagion”. In other words, this coefficient measures an unobservable latent factor that is neither related to changes in country-specific fundamentals or common factors, but possibly affects all sovereign bond markets simultaneously (Calvo, 1988; Calvo and Mendoza, 2000). The vector of coefficients γ_1 relate to “wake-up-call contagion”. Specifically, an element of this vector is significant when there is a change in the effect of a country-specific factor during a period of turbulence. For example, the crisis may act as a “wake-up-call” to investors, causing them to reassess their investment position in one country based on perceived similarities with macro-economic or financial fundamentals in crisis-affected countries (Giordano et al., 2013; Goldstein, 1998). A significant element in the vector of coefficients γ_2 indicates the presence of “shift contagion”. These parameters measure changes in the intensity of transmissions from a common factor during a crisis period (Bekaert et al., 2014; Forbes and Rigobon, 2002).

We estimate panel OLS regressions with country fixed effects and robust standard errors. The robust error specification has been used by Longstaff et al. (2011) for analysing sovereign CDS spreads. Table 3 reports results of these estimations for each of the nine (9) groups.

Among the set of common factors, results show coefficients on the returns on the regional bond groups have a consistently significant positive effect on spreads. Coefficients on the global equity premia are significant for the All Countries, Emerging, USD, and Local-currency Emerging groups, and have the expected negative sign. For many groups, country-specific factors also help explain yield spreads, including (variously) the exchange rate, debt/GDP, current account/GDP and the local equity premium.

We find evidence of pure contagion during the crisis period in the form of significant coefficients on the crisis indicator (D_C) in the cases of the EUR, Local Developed and PEC groups. We also find some evidence that, in several groups, associations between macroeconomic indicators and spreads (wake-up-call contagion), and common factors and spreads (shift contagion) changed during the GFC. For example, Giordano et al. (2013) and Beetsma et al. (2013) found evidence to support an increased focus by investors on fundamentals in *developed* countries during the GFC due to the stream of bad news originating from the PEC economies that served to alarm investors and caused them to monitor other countries' fundamentals more closely. Results here show that, for the *Emerging* market group, the usual negative relation between the yield spreads and such macro factors as the exchange rate, investment/GDP, current account/GDP and the local equity premium, was weakened during the crisis period. However spreads for the Local-currency Emerging Market portfolio are not significantly affected by any kind of contagion during the crisis.

Overall, the results of the factor models show a variety of reactions to the crisis; the spread of contagion was not the same across international sovereign debt markets. However, as noted above, measures of contagion can be greatly affected by the choice of exogenously determined crisis and non-crisis periods. In the next section we address this concern; we extend our factor

[8] Where data are available only on a quarterly basis, the same value is used for all 3 months in each quarter.

[9] Recent examples of studies that apply panel techniques for explaining sovereign spreads using country-specific determinants can be found in Csonto and Ivaschenko (2013), Beirne and Fratzscher (2013), Aizenman et al. (2012), and Hilscher and Nosbusch (2010).

[10] The literature supporting the selection of country-specific proxies is extensive but some classic examples are Eichengreen and Mody (1998), Boehmer and Megginson (1990), Edwards (1984), Edwards and Levy Yeyati (2005), Dittmar and Yuan (2008), and Berg et al. (2005).

[11] The literature has typically used the common factors and proxies of global risk aversion from equity markets. See for example, Coudert and Gex (2008), Dahiya (1997), Diaz and Gemmill (2006), Fender et al. (2012), Longstaff et al. (2011), Chiarella et al. (2015) and Wu et al. (2016).

Table 2
Sovereign spread factors.

Country specific factors	Common factors
1) The exchange rate is expected to have a positive (+) coefficient since depreciations are associated with weaker economic conditions and higher spreads.	1) The global market equity premium acts as a transmission mechanism of global conditions and is expected to have a negative (−) coefficient if there is a strong global outlook, and under weak global prospects we expect to have a (+) sign.
2) The ratio of debt to GDP (Debt/GDP) is expected to have a positive (+) coefficient. An increase in this ratio implies an increase in the probability of default. Consequently, the creditors would require a higher spread in order to be compensated for this additional risk.	2) The Regional bond yield spread acts as a plausible transmission mechanism of regional conditions and can either have a negative (−) or positive (+) coefficient depending on the region of analysis.
3) The ratio of investment to GDP (Investment/GDP) could have positive (+) or negative (−) effects. A higher investment ratio can be tied with future GDP growth and better economic prospects, so if this is the case the sign of the coefficient is expected to be negative. However, a higher investment ratio can also be financed by increasing public debt and if this is the case, the coefficient is expected to have a positive sign.	3) The US equity premium acts as a plausible transmission mechanism of global conditions during the crisis and can either have a negative (−) or positive (+) coefficient depending on the region of analysis.
4) The ratio of debt to exports (Debt/Exports) acts as a proxy for debt service and liquidity. A higher ratio is related to lower liquidity and a greater strain on available resources to meet future debt servicing obligations, so for this variable we expect a positive (+) sign.	4) The global risk aversion index acts as the proxy for aggregate risk aversion during all crisis episodes and is expected to have a (+) sign during crisis periods as more risk averse investors demand a higher spread.
5) GDP per capita is expected to be negatively (−) correlated with spreads. A positive increase in GDP per capita can be interpreted as a proxy for economic development and enhanced terms of credit due to future expectations of GDP growth.	
5) The ratio of current account balance to GDP (Current Account/GDP) acts as a proxy for aggregate funding liquidity. A negative ratio represents a deficit and less liquidity to meet future obligations, so in this case we expect a negative (−) sign. A positive ratio represents a surplus and more funds available to meet future obligations, so in this case we expect a positive (+) sign.	
7) Reserves to GDP ratio (Reserves) is expected to have a negative (−) sign. A country with higher foreign currency reserves is more likely to meets its debt obligations. Imports (Imports/GDP) behave in the opposite way.	
8) The local equity premium is expected to have a negative (−) coefficient. An increase in the local stock market performance is related to the perception of strong economic growth.	
9) The country bond return acts as a measure of bond market conditions where higher returns should reduce spreads.	

analyses and outline a novel propensity score matching method to select a comparable non-crisis sample that provides a more robust check of the changes in spreads for different sovereign bonds during the crisis.

3. Proposed empirical method for testing differences in spreads during the crisis

Here we use factors from the panel models as explanatory variables in logit models of the crisis period, which generate the propensity scores matched to a non-crisis sample. Our aim is to assess whether the sovereign bond spreads of each of the nine groups systematically changed during the crisis. To do so, we use the explanatory variables identified from the estimation of Eq. (5) for each of the nine groups to obtain the implied probability that a crisis occurred at time *t*, by estimating the following panel logit model:

$$\Pr\left(D_{C,t}=1\middle|X_{p,i,t}\right)=\left(1+\exp\left(-\alpha_o-\beta_{p,i,t}X_{p,i,t}\right)\right)^{-1} \tag{6}$$

where $D_{C,\ t}$ is an indicator function denoting the timing of the crisis; $X_{p,i,t}$ is a matrix that contains all the significant country-specific factors ($Z_{p,i,t}$) as well as common factors ($F_{p,\ t}$) for each group $p = 1,\ldots, 9$, previously identified in the procedure detailed above. Once we obtained the coefficients of interest and the predicted cumulative probabilities of being in the crisis phase conditional on the set of crisis determinants, $\Pr(D_{C,\ t} = 1)$, from Eq. (6), we then computed the fitted cumulative probability that the observation is *not* in the crisis 'treatment' period ($pr_{p,\ i,\ t}$).

$$pr_{p,i,t}=1-\Pr\left(D_{C,t}=1\middle|X_{p,i,t}\right) \tag{7}$$

Once we estimated the probability values for all groups over time (t), we subsequently implemented a matching procedure described below. Table 4 summarises the results of the panel logit regression estimated for the crisis period:

Table 3
Panel regression estimates.
This table reports the results of the panel regression: $spread_{i,t} = \alpha_i + \beta_s{}' spread_{i,t-j} + \beta_l{}' Z_{i,t} + \beta_c{}' F_t + \gamma_0 D_{c,t} + \gamma_1'(Z_{i,t}{}' D_{c,t}) + \gamma_2{}'(F_t{}' D_{c,t}) + \varepsilon_{i,t}$ where $spread_{i,\ t}$ is the yield spread of any country i at time t from January 2000 to May 2013, α_i is the country-specific intercept, $Z_{i,\ t}$ is a set of country-specific factors consisting of the USD exchange rate, total debt to GDP ratio, investment to GDP ratio, external debt to exports ratio, GDP per capita growth, current account to GDP, imports, reserves, and local equity premium.F_t is a set of common factors consisting of the global equity premium, US equity premium, the value-weighted regional bond yield spread, the bond price return premium and global risk aversion, and the subscripts i and t stand for country and month respectively. The crisis dummy, $D_{c,\ t}$ is an indicator taking the value of one for September 2008–May 2013 and zero otherwise. Coefficients on the crisis indicator and interactions show types of contagious transmissions: γ_0 represents "pure" contagion, γ_1 represents "wake-up-call" "contagion" and γ_2 represents "shift" contagion. ***p < 0.01; **p < 0.05; and *p < 0.1.

	All countries	Developed	Emerging	EUR	USD	Local	local developed	Local emerging	PEC
Spread (t-1)	1.4114***	1.5248***	1.2824***	1.5025***	1.2469***	1.2794***	1.1855***	1.2732***	1.4553***
	(0.1121)	(0.2009)	(0.0417)	(0.2138)	(0.0553)	(0.0317)	(0.1201)	(0.0400)	(0.2281)
Spread (t-2)	−0.5279***	−0.6848**	−0.3698***	−0.6801**	−0.3338***	−0.3989***	−0.0401	−0.4092***	−0.6474**
	(0.1466)	(0.2741)	(0.0585)	(0.2963)	(0.0725)	(0.0539)	(0.1909)	(0.0681)	(0.3177)
Spread (t-3)	0.0687	0.1075	0.0379	0.1001	0.0157	0.0859***	−0.1737*	0.0934**	0.0874
	(0.0596)	(0.1226)	(0.0344)	(0.1376)	(0.0417)	(0.0332)	(0.1033)	(0.0427)	(0.1502)
Country specific factors									
Exchange rate	−0.0114***	0.0013	−0.0230***	0.0070*	−0.0227***	−0.0091***	−0.0005	−0.0197***	0.0057
	(0.0026)	(0.0015)	(0.0046)	(0.0036)	(0.0068)	(0.0023)	(0.0017)	(0.0048)	(0.0057)
Debt/GDP	0.0032***	0.0027***	0.0025	0.0130***	0.0022	0.0005	0.0008	0.0015	0.0329***
	(0.0009)	(0.0010)	(0.0018)	(0.0042)	(0.0035)	(0.0005)	(0.0005)	(0.0021)	(0.0105)
Investment/GDP	−0.0079	−0.0082	−0.0092	0.0003	−0.0250	−0.0056**	−0.0061**	0.0000	0.0800***
	(0.0060)	(0.0069)	(0.0062)	(0.0091)	(0.0164)	(0.0026)	(0.0030)	(0.0061)	(0.0299)
Debt/exports	0.0012	0.0016	0.0007	0.0032	0.0008	0.0004	0.0012*	0.0002	0.0077*
	(0.0010)	(0.0014)	(0.0019)	(0.0034)	(0.0025)	(0.0006)	(0.0007)	(0.0019)	(0.0045)
GDP per capita growth	−0.0002	−0.0068**	0.0022	−0.0132**	0.0078	−0.0017	−0.0036*	0.0010	−0.0673***
	(0.0030)	(0.0028)	(0.0038)	(0.0054)	(0.0052)	(0.0018)	(0.0020)	(0.0034)	(0.0229)
Current account/GDP	−0.0052	−0.0006	−0.0120**	−0.0109*	−0.0477**	−0.0017	0.0020	0.0004	0.0152
	(0.0043)	(0.0024)	(0.0058)	(0.0062)	(0.0191)	(0.0021)	(0.0024)	(0.0046)	(0.0165)
Reserves	−0.0002	0.0001	−0.0001	−0.0010	−0.0056	0.0003	0.0014	0.0014	0.0108
	(0.0009)	(0.0011)	(0.0017)	(0.0022)	(0.0085)	(0.0008)	(0.0009)	(0.0016)	(0.0125)
Imports	−0.0040	−0.0026	−0.0396***	0.0196	−0.1248**	−0.0030	−0.0047*	−0.0329***	0.1702**
	(0.0026)	(0.0027)	(0.0125)	(0.0217)	(0.0557)	(0.0025)	(0.0027)	(0.0122)	(0.0706)
Local equity premium	−0.0062	−0.0023	−0.0208***	−0.0071	−0.0260*	−0.0041	−0.0018	−0.0149*	−0.0042
	(0.0040)	(0.0043)	(0.0074)	(0.0071)	(0.0136)	(0.0034)	(0.0031)	(0.0077)	(0.0105)
Bond returns	0.0010	−0.0084**	−0.0016	0.0002	0.0190	−0.0099*	−0.0148***	−0.0093	0.0066
	(0.0054)	(0.0042)	(0.0127)	(0.0069)	(0.0246)	(0.0060)	(0.0046)	(0.0141)	(0.0131)
Common factors									
Global equity premium	−0.0067*	−0.0019	−0.0225***	−0.0060	−0.0288**	−0.0042	−0.0018	−0.0146*	−0.0033
	(0.0040)	(0.0042)	(0.0080)	(0.0072)	(0.0147)	(0.0036)	(0.0032)	(0.0082)	(0.0111)
US equity premium	0.0122***	0.0016	0.0374***	0.0034	0.0732***	0.0049	0.0036	0.0124	0.0010
	(0.0041)	(0.0031)	(0.0093)	(0.0047)	(0.0196)	(0.0037)	(0.0030)	(0.0081)	(0.0093)
Regional bond index	0.0520***	0.0619***	0.0335***	0.0801***	0.0732***	0.0452***	0.0500***	0.0429***	0.0851***
	(0.0077)	(0.0054)	(0.0106)	(0.0089)	(0.0196)	(0.0064)	(0.0062)	(0.0095)	(0.0158)
Global risk aversion	−0.0004	0.0002	−0.0016	−0.0003	−0.0019	−0.0002	0.0004	−0.0014	−0.0005
	(0.0006)	(0.0005)	(0.0011)	(0.0008)	(0.0023)	(0.0004)	(0.0004)	(0.0009)	(0.0010)
Pure contagion									
Crisis indicator (D_C)	−0.1645	0.0299	−0.1796	−1.7201**	0.5139	−0.0835	−0.1205*	−0.0502	−2.5145*
	(0.1007)	(0.0820)	(0.1310)	(0.7486)	(0.6124)	(0.0529)	(0.0638)	(0.1180)	(1.5072)
Wake-up-call contagion									
Exchange rate × D_C	0.0041	−0.0030	0.0204***	−0.0113	0.0289***	0.0015	−0.0015	0.0072	−0.0128
	(0.0043)	(0.0029)	(0.0075)	(0.0085)	(0.0101)	(0.0033)	(0.0031)	(0.0072)	(0.0234)
Debt/GDP × D_C	0.0003	0.0001	−0.0013	0.0051***	−0.0042	−0.0006	0.0008	−0.0001	0.0097*
	(0.0008)	(0.0009)	(0.0017)	(0.0019)	(0.0052)	(0.0007)	(0.0008)	(0.0021)	(0.0055)
Investment/GDP × D_C	0.0080*	0.0005	0.0111**	0.0597**	0.0045	0.0056**	0.0056*	0.0075	0.0953*
	(0.0048)	(0.0036)	(0.0056)	(0.0267)	(0.0174)	(0.0023)	(0.0029)	(0.0055)	(0.0495)
Debt/exports × D_C	0.0000	0.0007	−0.0005	0.0016	−0.0030	0.0007	−0.0009	−0.0001	−0.0033
	(0.0010)	(0.0010)	(0.0019)	(0.0018)	(0.0028)	(0.0007)	(0.0009)	(0.0027)	(0.0037)
GDP per capita Growth × D_C	0.0000	0.0062	0.0042	−0.0075	−0.0001	0.0047**	0.0029	0.0007	0.0124
	(0.0010)	(0.0044)	(0.0045)	(0.0110)	(0.0067)	(0.0022)	(0.0026)	(0.0041)	(0.0187)
Current account/GDP × D_C	0.0029	0.0001	0.0083*	0.0290	0.0425**	0.0009	0.0026	0.0034	0.0058
	(0.0032)	(0.0047)	(0.0043)	(0.0187)	(0.0178)	(0.0017)	(0.0019)	(0.0038)	(0.0371)
Reserves × D_C	0.0019	0.0002	−0.0009	−0.0216	−0.0175*	0.0005	−0.0015	−0.0018	−0.0604
	(0.0030)	(0.0011)	(0.0020)	(0.0293)	(0.0093)	(0.0008)	(0.0010)	(0.0030)	(0.0941)
Imports/GDP × D_C	−0.0001	0.0002	0.0137	0.0121	−0.0188	−0.0014	0.0021	0.0015	−0.1952
	(0.0008)	(0.0027)	(0.0148)	(0.0152)	(0.0548)	(0.0023)	(0.0026)	(0.0183)	(0.3126)

Table 3 *(continued)*

	All countries	Developed	Emerging	EUR	USD	Local	local developed	Local emerging	PEC
Local equity premium × D_C	0.0137**	0.0073	0.0355***	0.0182	0.0520**	0.0028	0.0042	0.0118	0.0203
	(0.0058)	(0.0081)	(0.0111)	(0.0124)	(0.0207)	(0.0049)	(0.0060)	(0.0106)	(0.0308)
Bond returns × D_C	0.0020	0.0097	0.0048	0.0318	−0.0146	−0.0048	−0.0094	0.0058	0.0748
	(0.0088)	(0.0130)	(0.0147)	(0.0217)	(0.0279)	(0.0074)	(0.0077)	(0.0164)	(0.0499)
Shift contagion									
Global equity premium × D_C	0.0111*	0.0127*	0.0280**	0.0270**	0.0446**	0.0004	0.0042	0.0062	0.0407
	(0.0062)	(0.0077)	(0.0117)	(0.0122)	(0.0222)	(0.0056)	(0.0060)	(0.0114)	(0.0306)
US Equity premium × D_C	−0.0161**	−0.0021	−0.0513***	−0.0039	−0.0979***	−0.0071	0.0013	−0.0174	0.0126
	(0.0063)	(0.0074)	(0.0125)	(0.0122)	(0.0256)	(0.0057)	(0.0063)	(0.0116)	(0.0285)
Regional bond index × D_C	−0.0156	−0.0188	−0.0308	−0.0349	−0.0415	−0.0153*	−0.0199*	−0.0058	−0.0387
	(0.0115)	(0.0130)	(0.0194)	(0.0214)	(0.0367)	(0.0093)	(0.0114)	(0.0169)	(0.0610)
Global risk aversion × D_C	0.0000	0.0028*	−0.0042**	0.0054**	−0.0111***	−0.0005	0.0002	0.0002	0.0091
	(0.0013)	(0.0015)	(0.0020)	(0.0027)	(0.0040)	(0.0008)	(0.0010)	(0.0016)	(0.0065)
Adjusted R2	0.9807	0.9759	0.9758	0.9714	0.9676	0.9919	0.9888	0.0000	0.9715
Number of observations	6195	3598	2597	1833	1070	3284	2042	1432	778

Our novel procedure for testing the differences in spreads during crisis periods and non-crisis periods is based on the Average Treatment Effect on the Treated (ATET) framework. This procedure uses the probabilities obtained in Eq. (7) to select a sample of counterfactual (non-crisis period) values based on the propensity score matching technique. This procedure has certain advantages over traditional sampling or testing differences in predicted values since it effectively addresses selection bias by choosing the most comparable observations during crisis and non-crisis periods. One key advantage of this method is that we can compare the actual values of the spreads in both settings without foregoing the theoretical richness contained in the observable characteristics of a factor model. In addition, with the ATET approach it is possible to determine exactly which observations in the non-crisis periods are more closely related in terms of the common factor exposures to those experienced in the crisis periods.

In this paper, we modify the framework proposed by Nssah (2006) that applied the ATET approach to economic policy programs, and we reframe it for contagion testing. In the context of corporate bond markets, this framework has been previously used by Almeida et al. (2012) to test the impact of credit supply shocks on firms' capital structure.

In our application, the “treated” sample is characterized by a dummy that represents the crisis dates (D = 1) and the matched “non-treated” sample is represented by the non-crisis dates (D = 0). (We describe the matching procedure below.) Therefore, by dividing the spreads ($spreads_{p,\ t}$) from Eq. (4) into two vectors that represent the crisis period ($\{spread_{crisis,\ p}\}$) and matched non-crisis period ($\{spread_{noncrisis,\ p}\}$) we have:

$$\left\{g_p\right\} = \left(\left\{spread_{crisis,p}\right\} - \left\{spread_{noncrisis,p}\right\}\right) \tag{8}$$

where the average value of the vector $\{g_p\}$ is equal to the ATET. Additionally, if we assume that there is unit homogeneity,[12] since in a Global Financial Crisis countries do not have the freedom to “choose” whether to participate or not in it, we can rewrite $\{g_p\}$ in conditional probability form where:

$$ATET = E\left(\left\{g_p\right\}\middle|X_{p,i,t}, D = 1\right) = E\left(\left\{spread_{crisis,p}\right\}\middle|X_{p,i,t}, D = 1\right) - E\left(\left\{spread_{noncrisis,p}\right\}\middle|X_{p,i,t}, D = 0\right) \tag{9}$$

where $X_{p,i,t}$ is the matrix of common observable characteristics represented by the explanatory variables from Eq. (6) and the averages $E(\{spread_{crisis,\ p}\}|X_{p,\ i,\ t}, D_t = 1)$ and $E(\{spread_{noncrisis,\ p}\}|X_{p,\ i,\ t}, D_t = 0)$ represent the mean of the “treated” and the counterfactual mean of the “non-treated” or, in our setup, the crisis and non-crisis periods respectively.

ATET using propensity matching estimators represents a unique framework for testing contagion because the method yields strong estimates under the assumption of conditional independence (Abadie et al., 2004). The assumption can be formally defined as:

$$\left(spread_{crisis,p}, spread_{noncrisis,p}\right) \perp D_t | X_{p,i} \tag{10}$$

In other words, conditional on observable characteristics, whether countries are in a crisis period or not is independent of the identified outcomes of the sovereign bond spreads. In order to be consistent with the principle of conditional independence, the basic idea behind propensity matching is to select a sample from the non-crisis (non-treated) period that most closely resembles the characteristics of our sample in the crisis (treated) period. Since the counterfactual sample is selected randomly to closely match the characteristics of a treated observation, potential endogeneity due to selection bias is not an issue.

[12] Unit homogeneity in our case refers to the fact that individual countries cannot choose whether they become embroiled in a financial crisis or not, so our observations must comprise a mix of both crisis and non-crisis periods so that there is no bias based on selectivity of crisis periods alone.

Table 4
Logistic regression estimates for calculating propensity scores.
This table reports the results from panel logit regressions of the Global Financial Crisis indicator variable (D_C) on a set of the explanatory variables in Table 3 and Section 2.2. The regression equation is $\Pr(D_C = 1|X_{p,\,i,\,t}) = (1 + \exp(-\alpha_o - \beta_{p,\,i,\,t}X_{p,\,i,\,t}))^{-1}$ where $D_{C,\,t}$ takes the value of 1 for the period between September 2008 and May 2013 and 0 otherwise. ***p < 0.01; **p < 0.05; and *p < 0.1

Dependent variable D_C	All countries	Developed	Emerging	EUR	USD	LOCAL	Local developed	Local emerging	PEC
Spread (t-1)	0.6303***	1.4424***	0.5117***	2.9264***	0.4492***	0.7065***	0.6367***	0.6662***	1.6817
	(0.0975)	(0.2991)	(0.1091)	(0.5652)	(0.1508)	(0.1915)	(0.2153)	(0.1480)	(2.6331)
Spread (t-2)	0.0178	0.1893	−0.0081	0.0703	0.1634	0.0768	0.0892	−0.1808	−0.8620
	(0.1578)	(0.4539)	(0.1761)	(0.7936)	(0.2530)	(0.3018)	(0.3273)	(0.2320)	(3.3086)
Spread (t-3)	−0.2135**	−0.3357	−0.2508**	−0.7777	−0.6852***	−0.2519	−0.0813	−0.0003	4.7539
	(0.0971)	(0.2882)	(0.1078)	(0.4992)	(0.1743)	(0.1865)	(0.2047)	(0.1430)	(3.2531)
Country specific factors									
Exchange rate	−0.0059	−0.0196	0.0201	−0.0827**	0.0366	0.0201	−0.0050	0.0456***	−0.2579
	(0.0091)	(0.0148)	(0.0142)	(0.0342)	(0.0257)	(0.0136)	(0.0104)	(0.0141)	(0.2733)
Debt/GDP	−0.0083***	0.0023	−0.0475***	−0.0079	−0.0919***	−0.0094***	−0.0015	−0.0136***	−0.0341
	(0.0015)	(0.0022)	(0.0032)	(0.0059)	(0.0097)	(0.0028)	(0.0021)	(0.0038)	(0.0515)
Investment/GDP	0.0299***	−0.0236	0.0715***	0.0882*	0.3007***	0.0396***	−0.0208**	0.1248***	0.0713
	(0.0085)	(0.0160)	(0.0112)	(0.0470)	(0.0352)	(0.0115)	(0.0101)	(0.0142)	(0.3084)
Debt/Exports	0.0095***	0.0151***	0.0155***	0.0051	0.0569***	0.0111***	0.0125***	−0.0281***	0.0578
	(0.0012)	(0.0023)	(0.0019)	(0.0064)	(0.0049)	(0.0027)	(0.0021)	(0.0057)	(0.0402)
GDP per capita growth	−0.2202***	−0.3332***	−0.1888***	−0.5839***	−0.2183***	−0.2633***	−0.1369***	−0.1951***	−4.0716***
	(0.0085)	(0.0174)	(0.0118)	(0.0489)	(0.0240)	(0.0136)	(0.0106)	(0.0138)	(0.9633)
Current Account/GDP	0.0059	0.0716***	−0.0448***	0.1300***	−0.3839***	−0.0009	0.0262***	−0.0048	−1.8574***
	(0.0062)	(0.0113)	(0.0107)	(0.0301)	(0.0386)	(0.0086)	(0.0065)	(0.0102)	(0.2983)
Reserves	0.0324***	0.0269***	0.0836***	−0.5072***	0.2805***	0.0451***	0.0195***	0.0736***	−3.5299*
	(0.0025)	(0.0034)	(0.0065)	(0.0785)	(0.0255)	(0.0037)	(0.0025)	(0.0068)	(1.9925)
Imports	−0.0250***	0.0259***	−0.3620***	0.0033	−0.4340***	−0.0371***	0.0071	−0.3266***	−3.3469
	(0.0069)	(0.0084)	(0.0369)	(0.0649)	(0.1306)	(0.0084)	(0.0057)	(0.0408)	(2.1160)
Local Equity premium	−0.1509***	−0.1759***	−0.1217***	−0.0352	−0.1376***	−0.1579***	−0.1155***	−0.0191	−0.0042
	(0.0174)	(0.0268)	(0.0278)	(0.0516)	(0.0514)	(0.0248)	(0.0190)	(0.0250)	(0.2975)
Bond return premium	0.0042	−0.0125	0.0335	0.1376*	0.0531	0.0001	−0.0279	0.0666*	0.6852*
	(0.0237)	(0.0366)	(0.0363)	(0.0707)	(0.0669)	(0.0339)	(0.0265)	(0.0344)	(0.4113)
Common factors									
Global equity premium	−0.1382***	−0.1743***	−0.0955***	−0.0463	−0.1202**	−0.1582***	−0.1129***	−0.0167	−0.2258
	(0.0186)	(0.0284)	(0.0298)	(0.0557)	(0.0540)	(0.0264)	(0.0201)	(0.0270)	(0.2964)
US equity premium	0.2114***	0.2350***	0.2030***	0.1521***	0.2135***	0.2170***	0.1436***	0.0761***	−0.3263
	(0.0203)	(0.0309)	(0.0316)	(0.0549)	(0.0580)	(0.0286)	(0.0219)	(0.0276)	(0.3068)
Regional bond index	0.1018***	0.2583***	0.0228	0.1247	0.2135***	0.1176***	0.1508***	0.0410	−0.8910
	(0.0277)	(0.0515)	(0.0382)	(0.1024)	(0.0580)	(0.0380)	(0.0367)	(0.0345)	(1.0377)
Global risk aversion	0.0069***	0.0083**	0.0069*	0.0236***	0.0070	0.0065*	0.0022	0.0067*	−0.0110
	(0.0024)	(0.0038)	(0.0038)	(0.0068)	(0.0070)	(0.0035)	(0.0027)	(0.0036)	(0.0422)
Pseudo R2	0.2177	0.3738	0.2498	0.5831	0.4553	0.2536	0.3123	0.4518	0.9540
Number of observations	6.196	3.598	2.598	1.833	1.079	3.284	2.042	3.284	778
Obs with dependant = 0	3.889	2.356	1.533	1.185	647	2.057	1.340	2.057	508
Obs with dependant = 1	2.307	1.242	1.065	648	432	1.227	702	1.227	270

Using the probability values from Eq. (7) we can implement the algorithm in the following equation for finding the vector with the nearest neighbour matching estimators (NNB):

$$c(pr_{matched}) = \{j|\ \min\|pr_{crisis} - pr_{noncrisis}\|\}, \tag{11}$$

where $c(pr_{matched})$ represents the vector of matched crisis and non-crisis spreads based on the smallest difference in propensity scores. Therefore, we can formally test for systematic changes in sovereign bond spreads by testing if the average of the matched vector $\{g_p\}$ is statistically significant via a simple ANOVA test for the null of no differences in spreads versus the alternative, formally defined as:

$$\begin{aligned} H_0 &: \overline{spread}_{crisis,p} = \overline{spread}_{noncrisis,p} \\ H_1 &: \overline{spread}_{crisis,p} \neq \overline{spread}_{noncrisis,p} \end{aligned} \tag{12}$$

In this hypothesis, $\overline{spread}_{crisis,p}$ and $\overline{spread}_{noncrisis,p}$ are the mean values of the observations in the related vector. In this way, we can quantify the impact of crisis periods on sovereign bond spreads relative to the observations that had similar exposures to crisis determinants in non-crisis periods. We observe the effect of average spread changes between October 2008 and the end of our sample in March 2013. We compare these results with average spreads calculated using other criteria, such as non-matched equal and unequal samples of the crisis and non-crisis periods as is often the case for other contagion testing methods that use correlations or tests for increases in factor loadings (Dungey et al., 2005).

4. Results

Panel A of Table 5 reports the results from the ATET procedure using the nearest neighbour matching algorithm (NNB). Our results show that for all sovereign bond test groups there was a significant positive difference in sovereign spreads averaged over the crisis relative to the counterfactual non-crisis period. The significant changes in spreads for all groups (sovereign bond groups) can be explained by heightened cross market linkages and weakening fundamentals consistent with the wake-up contagion mechanism that has been documented during the crisis (Beirne and Fratzscher, 2013; Bekaert et al., 2014).

We uncover that the Local-currency denominated Emerging market group reported the smallest proportional change in spreads (24.42 bps) between the crisis and non-crisis periods, behind the two developed market groups (13.39 bps for local currency denominated and 17.22 bps for all developed countries). This indicates that the usually more volatile emerging markets were in fact one of the most immune groups throughout the prolonged GFC and were weakly affected by the financial turmoil originating from developed markets. Interestingly, the change in spreads was much higher in the emerging market group that includes both local and foreign currency denominated sovereign bond issues perhaps, due to liquidity shortages in the USD denominated market segment after the collapse of Lehman Brothers.

Table 5

Average effect on sovereign spreads on groups.

Panel A reports the results from matching the inverse cumulative probabilities (propensity scores) which are obtained by applying Eq. (7) to the predicted probabilities obtained from the logit regressions for each of the nine test groups during the whole GFC period. For the matching procedure between crisis and non-crisis periods we use the algorithm for the nearest neighbour matching estimator (NNB) in Eq. (11). The results reported in the NNB column correspond to the average monthly spread of the counterfactual vector obtained using Eq. (12). The GFC column correspond to the average monthly spread for each group during the crisis date outlined in Section 2. The Average Treatment Effect on the Treated (ATET) is the arithmetic difference between a crisis period average and their corresponding NNB average. The statistical significance of the ATET is tested using an ANOVA test for equality in the means of the vector containing the observations of a crisis periods and their respective vector of NNB counterfactuals. Panel B reports the results for the statistical difference in the average spreads using an unequal sample for the non-crisis period, which is dated from January 2000 to June 2007, versus the average spread for each Group in the respective crisis period. Panel C reports the results for the statistical difference in the average spreads using an equal sample for the non-crisis period versus the average spread for each Group in the respective crisis period, so in the case of the whole GFC the crisis and non-crisis periods are both over 54 months from April 2004 to September 2008. ***p < 0.01; **p < 0.05; and *p < 0.1.

Panel A-NNB matching non-crisis period

Country	GFC	NNB	Difference
All	123.12	74.92	48.20***
Developed	79.23	62.00	17.22**
Emerging	438.21	282.67	155.54***
Euro	139.01	108.45	30.56***
Local	90.85	58.15	32.70***
USD	448.91	393.20	55.72***
Local developed	14.67	1.27	13.39***
Local emerging	447.72	423.30	24.42***
PEC	278.51	54.88	223.63***

Panel B-Unequal sample non-crisis period

Country	GFC	Unequal	Difference
All	123.12	−3.33	126.45***
Developed	79.23	−41.75	120.98***
Emerging	438.21	272.48	165.74***
Euro	139.01	−13.42	152.43***
Local	90.85	−11.57	102.42***
USD	448.91	310.02	138.89***
Local developed	14.67	−72.04	86.71***
Local emerging	447.72	271.67	176.05***
PEC	278.51	−12.06	290.57***

Panel C-Equal sample non-crisis period

Country	GFC	Equal	Difference
All	123.12	−19.29	142.41***
Developed	79.23	−54.15	133.37***
Emerging	438.21	230.91	207.31***
Euro	139.01	−40.17	179.18***
Local	90.85	−16.40	107.25***
USD	448.91	268.08	180.83***
Local developed	14.67	−68.80	83.47***
Local emerging	447.72	229.08	218.64***
PEC	278.51	−36.67	315.18***

Our results shed new light on the impact of the GFC on emerging markets. Local currency denominated emerging market sovereign bonds have traditionally been perceived as a risky asset class but during the GFC it was actually relatively safe from global shocks. However, it should be noted that our approach compares the *characteristics* of a certain crisis period with the *characteristics* of a different time period that *most closely* resembles those of a given historical crisis period. Hence, our results indicate that in the non-crisis sample there were instances with *similar spread volatility* to the crisis period, and that the crisis did not create abnormally *lower* or *higher* spreads for emerging markets. The average spread during the GFC for local currency denominated emerging market debt issuers was 447.72 basis points and those selected in the non-crisis period using neighbour matching estimators (NNB) was only marginally lower at 423.30 basis points. In contrast, Aizenman et al. (2016), using a standard event study based on exogenously determined crisis dates, found that the GFC had large adverse effects on emerging bond market spreads. Our results highlight that the use of a matched sample for benchmarking is crucial for analysing the effects of the GFC on particularly emerging market bonds.

Over the whole global crisis period (see Panel A of Table 5) the largest absolute difference in spreads at 223.63 bps is observed for the troubled countries in the peripheral Eurozone (PEC). In the case of the PEC group, the channel of contagion was related mainly to leading macroeconomic indicators on indebtedness and economic activity (Debt/GDP and the Investment/GDP ratio) as is consistent with the wake-up contagion identified at the beginning of the European sovereign debt crisis (Arghyrou and Kontonikas, 2012; Beirne and Fratzscher, 2013). The smallest absolute difference in spreads between crisis and non-crisis periods is observed for developed market bond spreads, irrespective of the currency of denomination. This is not surprising as this group includes the most stable and highest AAA rated countries like the Scandinavian countries, Canada, Singapore and Australia.

Taking together the evidence in Table 3 and the observed differences in spreads, our results show that local risks continue to be priced in relatively segmented local currency denominated sovereign bond markets, in Europe the bond markets are much more regionally integrated with a single monetary policy, whilst the most liquid USD denominated sovereign bond issues are the most globally integrated. These variations in the degree of sovereign bond market integration are consistent with expectations. Moreover, consistent with Bekaert and Harvey's (2014) recent assessment, our evidence also supports the view that the incomplete integration of emerging markets justifies their place in investors' global bond portfolios.

The results reported in Panel A of Table 5 using the ATET framework are strikingly different from those reported in Panels B and C in which we allow for unequal non-crisis samples and we limit the matching non-crisis sample period to the nearest non-crisis period of equal length to the relevant crisis phase using standard exogenous dating methods.[13] A comparison with Panel A shows that these results are mis-estimated when compared with results obtained with propensity score matching.

The most compelling argument for the use of matched samples is that we can have a reliable measure of the true economic impact on the sovereign borrowing costs on different types of debt issues after controlling for differences in the underlying risk profile of countries in tranquil and crisis periods. Therefore, in Table 6 we report the results for a battery of robustness checks using alternative matching algorithms that impose a region of common support which means that we further limit our random selection of counterfactuals to those observations that are between the minimum and maximum probabilities of being in a crisis period, as outlined in Appendix A.

Comparing these methods with the nearest neighbour matching approach, we can observe that in the case of local currency denominated emerging market sovereign bond issues the difference of 10.81 basis points in spreads during the GFC is even smaller (than the 24.42 basis points from using our initial assumptions). Our empirical results on the behaviour of local currency denominated emerging market government bonds are in line with other recent studies that suggested the possible decoupling of emerging markets from developed markets during the GFC (Dooley and Hutchison, 2009) and corroborates with a more recent study by Dungey et al. (2010) which found that certain phases of the GFC had only a small impact on the volatility of emerging sovereign bond markets.

5. Conclusions

In this study, we extend the standard factor analyses based on country-specific and common market determinants of sovereign bond yield spreads to compute propensity matching estimators for formal tests to detect which types of sovereign bonds have been more vulnerable to the prolonged Global Financial Crisis originating in advanced economies.

During the Global Financial Crisis there were different channels for the transmission of contagion. A common channel of contagion transmission among most groups were macroeconomic fundamentals related to “wake up contagion” where investors pay close attention to the country's ability to meet their financial obligations. There is also some evidence of the existence of a latent factor or “pure contagion” for the Eurozone and PEC bond groups analysed suggesting that self-fulfilling expectations and investor panic also played a role in spreading the sovereign debt crisis internationally.

Our novel approach to contagion testing affirms that the sovereign obligors that were the most affected in terms of absolute rises in spreads throughout the crisis were the troubled Eurozone countries. For the global market-weighted group of the 43 countries in our sample, the average spread rose by an economically significant 48.20 basis points during the crisis, holding all else constant. We also reveal that the groups of local currency denominated emerging and developed market sovereign bonds exhibited the smallest proportional increase in spreads in the crisis period. This evidence suggests that the emerging markets that

[13] In Table 5, Panel B: the unequal sample non-crisis period runs from January 2000–September 2008 and in Panel C: the dates for the equal non-crisis periods are April 2004–September 2008, respectively.

Table 6
Robustness checks for ATET.
This table reports the results from matching the inverse cumulative probabilities (propensity scores) which are obtained by applying Eq. (7) to the predicted probabilities obtained from the logit regressions for each of the (9) Groups during the crisis period. The results reported in the NNB, Gauss and EPNK columns correspond to the Average Treatment Effect on the Treated (ATET) which is the difference between the crisis period average monthly spread vectors and the counterfactual vectors for each country. These results are obtained using Eq. (12) in the case of the NNB and Eqs. (14) and (15) in Appendix A when using Gaussian (GAUSS) and Epanechnikov kernels as outlined in Section 5. The statistical significance of the ATET is tested using an ANOVA test for equality in the means of the vector containing the observations of crisis periods and their respective vector of counterfactuals using three matching methods (NNB, GAUSS and EPNK). For brevity we do not report the average of each counterfactual vector as shown in Table 5, just the final ATET result for each method. ***p < 0.01; **p < 0.05; and *p < 0.1.

Country	GFC		
	NNB	GAUSS	EPNK
All	48.20***	57.60***	69.64***
Developed	17.22**	25.92***	34.24***
Emerging	155.54***	94.51***	120.97***
Euro	30.56***	32.56***	50.11*
Local	32.70***	32.11***	34.02***
USD	55.72***	84.11***	79.05
Local developed	13.39***	14.81***	18.01***
Local emerging	24.42***	23.80***	10.81***
PEC	223.63***	229.91***	204.41***

issued debt denominated in their local currencies continued to experience similar borrowing conditions to those prior to the crisis and thus, faced much smaller material changes in borrowing costs.

Our research contributes new evidence on the impact of the crisis on emerging market sovereigns' funding costs and the importance of emerging markets' ability to issue debt in their local currencies in weathering financial turbulence. New research on sovereign debt markets should focus on assessing other economic benefits that local currency debt issuance may bring for aggregate investments and economic activity. We leave this for future research.

Appendix A. Robustness checks

In order to check the robustness of our results, we use two other algorithms based on kernel matching. The difference between neighbour matching and kernel algorithms is that the first assigns equal weights to all matched observations drawn from the non-crisis period and the latter gives more weight to the observations that are more closely matched. Following the implementation procedure used by Nssah (2006), the proportional weight assigned to the observations in the non-crisis period (p_j) as a function of how close they are to the crisis period (p_i) is:

$$w_{ij} = \frac{K\left(\frac{p_i - p_j}{h}\right)}{\sum_{j\in\{d=0\}} K\left(\frac{p_i - p_j}{h}\right)} \tag{14}$$

where w_{ij} is the assigned weight, and h is the bandwidth which is set at a fixed value of 0.06 (Becker and Ichino, 2002). We define K as the Gaussian (GAUSS) and Epanechnikov kernel (EPNK):

$$\begin{aligned} K(u) &= \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-u^2}{2}\right) \\ K(u) &= \frac{3}{4}\left(1-u^2\right) \mathrm{xI}(|u| \leq 1) \end{aligned} \tag{15}$$

where $u = (p_i - p_j)/\mathrm{h}$ and I is an indicator variable that takes the value of 1 (true) and 0 (false) when the condition $\|p_i - p_j\| < 0.06$ is met. For these two kernels, we also establish an area of common support based on the minimum and maximum propensity scores in the crisis period obtained from Eq. (6). This limits the sample observations drawn from the non-crisis period to those values within the range of those in the crisis period, further reducing the possibility of biases due to outliers that may be present.

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