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Sovereign Default Analysis through Extreme Events Identification

Vasile George MARICA
International Economic Relations
Bucharest University of Economic Studies
6 Piața Romană, Sector 1, Bucharest, 010374, Romania
marica.vasile.george@gmail.com

Lucian Claudiu ANGHEL
Faculty of Management
National University of Political Studies and Public Administration
30a Expoziției Blvd., Sector 1, Bucharest, 012104, Romania
lucian.anghel@facultateademanagement.ro

Abstract. *This paper investigates contagion in international credit markets through the use of a novel jump detection technique proposed by Chan and Maheuin (2002). This econometrical methodology is preferred because it is non-linear by definition and not a subject to volatility bias. Also, the identified jumps in CDS premiums are considered as outliers positioned beyond any stochastic movement that can and is already modelled through well-known linear analysis. Though contagion is hard to define, we show that extreme discrete movements in default probabilities inferred from CDS premiums can lead to sound economic conclusions about the risk profile of sovereign nations in international bond markets. We find evidence of investor sentiment clustering for countries with unstable political regimes or that are engaged in armed conflict. Countries that have in their recent history faced currency or financial crises are less vulnerable to external unexpected shocks. First we present a brief history of sovereign defaults with an emphasis on their increased frequency and geographical reach, as financial markets become more and more integrated. We then pass to a literature review of the most important definitions for contagion, and discuss what quantitative methods are available to detect the presence of contagion. The paper continues with the details for the methodology of jump detection through non-linear modelling and its use in the field of contagion identification. In the last sections we present the estimation results for simultaneous jumps between emerging markets CDS and draw conclusions on the difference of behavior in times of extreme movement versus tranquil periods.*

Keywords*: sovereign default, credit default swaps, jump detection*

A brief history of sovereign defaults

Sovereign debt crises and the default of city states, governments and empires are usual events, even with the onset of sovereign lending. The first historically documented default was that of the Greek temple of Delos (Winkler, 1933).

Most crises in antiquity have ended with a currency “downgrade”, both through inflation or devaluation and rarely through debt restructuring. This last type of default outcome emerged in the 16th century. In a historical analysis published in 2003, Reinhart, Rogoff and Savastano conclude that the states that don’t manage to pay their debts on time are plagued by a high degree of intolerance to external borrowing for decades and that their comeback is painful and slow, without the help of supranational lenders like the IMF or the EU.

It is at the beginning of the 19th century that credit events (defined as the failure of a debtor to honor its contractual obligations) have become more frequent. This was the effect of capital transfers between financially independent governments, through regulated financial markets (Reinhart & Rogoff, 2009).

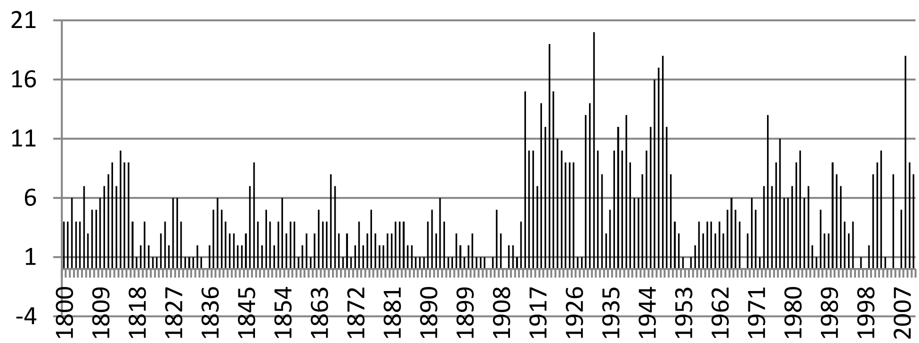

Figure 1. Number of credit events from the beginning of the 19’Th century to the present day
Source: Carmen Reinhart and Keneth Rogoff database

During the past two centuries there have been hundreds of credit events and debt restructuring. The reasons for this have been wars, revolutions, civil wars, all of these eroding the government’s capacity to repay. The suspension ofdebt payments to enemy countries during wars was common practice, like Turkey, Bulgaria and Austro-Hungary during the first world war, or Japan during the second world war (Sturzenegger & Zettelmeyer, 2006). Mexico (1914), Russia (1917), China (1949), Czechoslovakia (1952), and Cuba (1960) refused to pay their debts after the communist revolutions, decisions that triggered civil wars and economic collapses.

The dynamics of national economic tactics and shocks to the real sector have become more subtle since the 19th century with the advent of new phenomena like regional clustering, political instability and over expansion in consumption followed by collapse. Lindert and Morton (1989) identify behavior patterns in the lending business of exuberance followed by default and subsequently reduction in credit availability, a pattern that repeats itself during the 18th century.

The impossibility of exercising coercion on debtors leads to fears and drying of credit to countries that have sound finances. The authors suggest that even if lending might be profitable in the long term, there are similar crises like patterns ignored by investors, despite historical documentation on them. Also, creditors tend to forget the payment history of governments and don't penalize those that have defaulted in the past. According to economical historians Suter and Stamm (1992), eight boom-bust lending cycles can be identified starting with the 19th century, presented in the chart below.

Table 1. Boom-bust lending cycles in the 19th century

Year	**Countries in default**								
1820's	Latin America	Europe							
1830's	USA	Spain	Portugal						
1860-1875	Latin America	USA	Europe	Ottoman Empire	Egypt				
1880's	USA	Australia	Latin America						
1910's	Canada	Australia	South Africa	Russia	Ottoman Empire	Balkan States	Latin America		
1920's	Germany	Australia	Japan	Canada	Argentina	Brazil	Cuba		
1970's	Latin America	Spain	Yugoslavia	Romania	Poland	Turkey	Egypt	Indonesia	Africa
1990's	Latin America	Emerging Asia	Ex-communist countries						

The determinants of sovereign debt

The world is continuously modeled by the accession of new political powers. The fall of centralized blocks like the USSR and the victory of the market economy made people believe that some countries will be able to impose their financial hegemony upon the rest of the world. If it's China, the country with the biggest future GDP, or the western world, with an older population and a continuously rising debt, which will dominate the debt markets, remains to be seen (Fogel, 2010). In the United States, the collapse of the real estate market, coupled with a huge debt service, sustainable only through external borrowing, all these factors only add to the global level of systemic risk.

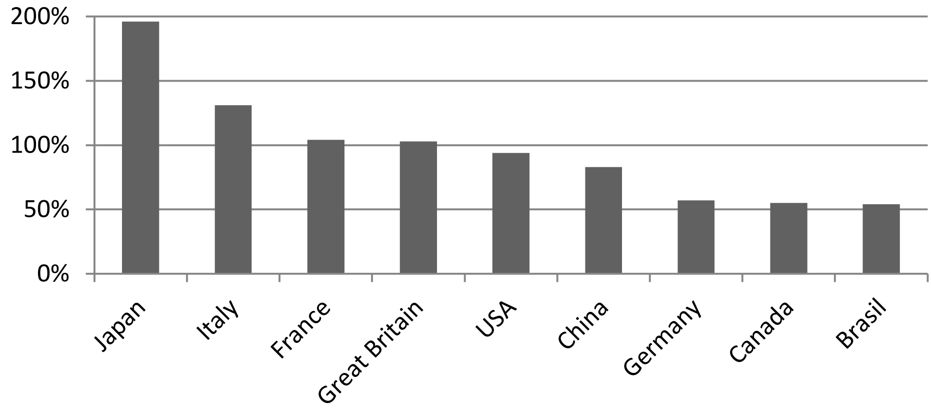

Figure 2. Gross debt as a percentage of gross annual GDP
Source: The World Bank

The above chart presents the level of sovereign gross debt as a percentage of gross annual GDP. From this point of view, Japan and Italy are the most indebted countries. If one would add the private debt to the sovereign one, then the most indebted countries would be Japan and Great Britain, at a level, four times higher than their annual GDP.

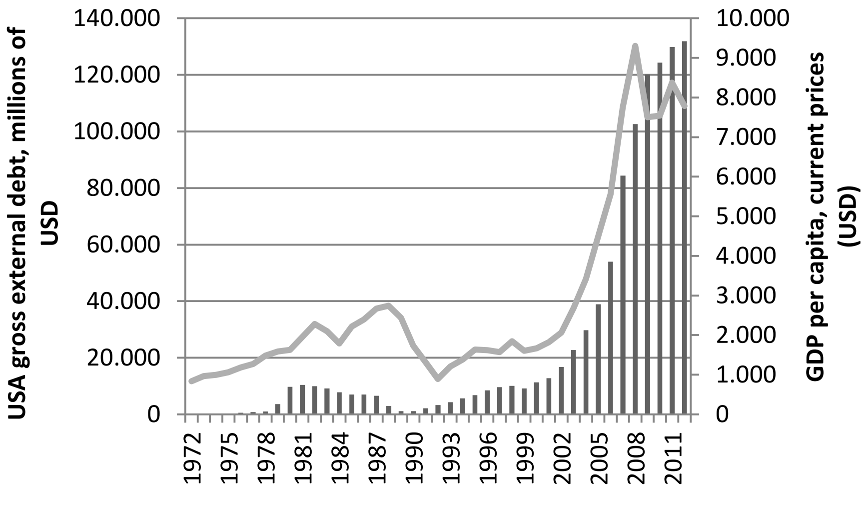

Figure 3. Bar chart: Gross External Debt; Line chart: GDP per capita
Source: IMF world outlook database

Adam and Bevan (2005) studied the link between the fiscal deficit and GDP growth on 45 emerging economies between 1970 and 1999, using an agent model with overlapping generations. The authors found that the government deficit can generate growth if it is financed by moderate monetary mass creation, or it can inhibit it if internal borrowing finances it. Their research also demonstrates that any increase of public spending financed by a tax increase can have a good effect, only if the public debt is at a low level. Saint-Paul (1992) shows by using a neo-classical model of endogenous growth that an increase of the government's public debt reduces future output for generations to come. Saint-Paul (1992) extends the model of Blanchard (1984) - economic agents with a finite time horizon, no endogenous growth -, assuming that there are externalities from endogenous growth, implying a constant rate of return on capital, at an aggregated level.

In classical models, debt growth increases the welfare of the households and brings the economy closer to «the golden rule», that is, the level of savings that maximizes growth. In the model of Saint Paul (1992), it is proven that public debt is not the adequate instrument for welfare maximization, but investment subsidies.

Aizenman et al. (2007) study the optimal public policy for optimal public investment and spending for emerging economies where the tax level can inhibit growth, once a certain level is reached. The authors discover that countries cannot endure a higher tax level because it lowers the growth rate. Also, the reduction in total debt will accelerate GDP growth. The authors discover through their model that persistent differences in output might be the result of the way in which tax money flows to public spending or investment. Having a debt ceiling the government should maintain the GDP to debt ratio constant and public spending should be financed only through tax increases.

Krugman (1988) has made some theoretical contributions, he defined the term "debt overhang", a context in which a country's reserve is smaller than its debt service. In this situation, the creditors have two possibilities: either to continue in supplying credit with a higher expected loss in the hope that fundamentals will improve, or accept a lower payment. Krugman (1988) shows that this choice can be improved through the addition of a dynamical condition, like adjusting the reimbursement condition to the price of a market commodity or to international lending rates.

Contagion

Contagion is a relatively new concept in the academic literature. The first understandings addressed the problematic of emerging economies, more specifically, about the Asian financial crisis in 1997-1998. Bisignano et al. (2000) have published a series of speeches and articles presented at a conference sponsored by the World Bank, that were intended to find answers and solutions to the Asian crisis. These definitions were the result of worries about transnational propagation of financial distress, but the global financial crisis of 2007-2009 showed that contagion is not limited to emerging economies, but it first appears inside national borders.

The paper "A Primer on Financial Contagion" by Pericoli and Sbracia (2003) considers five possible definitions for contagion:

1) Contagion is a significant increase in the probability of a crisis in one country, conditioned by a crisis in another country.
2) Contagion is present when market volatility heightens from one country to another.
3) Synchronous asset returns from different countries cannot be explained by fundamental economic factors.
4) Contagion is the simultaneous high price movements and high volumes of trading in financial markets, given a crisis in one market.
5) Contagion appears when the transmission channel widens, after a shock in one market.

The speed with which contagion propagates is a critical element for Kaminsky et al. (2003) who find that a financial distress can spread in multiple countries in an interval of days or hours. Studying a large database of capital market crises, speculative foreign exchange attacks or sovereign state defaults between 1980 and 2000, the authors define the term of "unholy trinity", a set of essential conditions for contagion to appear: an abrupt change in capital flows direction, surprise news and a common over indebted creditor.

As a first prerequisite contagion builds on accelerate capital inflow and the initial shock bursts this temporary bubble. During the second phase, the announcement that triggered the chain reaction has to come as a surprise for investors. The difference between anticipated and unanticipated ones is critical, because rational investors adjust their decisions and portfolios in anticipation (Didier, Mauro, & Schmukler, 2008). As a last phase, the over indebted creditor (commercial banks, speculative funds, mutual funds, etc.) retires from the market under the pressure of its own clients, unable to correct the disequilibria created.

For other economists, a change in the correlation between economic variables is the key to understanding contagion. Forbes & Rigobon (2002) consider that price volatility biases correlation indices if one believes that there is a common factor influencing those variables. For example, a shock to a market increases volatility, and subsequently the volatility increases the

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correlation. This is not to be confounded with contagion. The authors suggest filtering the volatility and deciding afterwards if the correlation indicates contagion or interdependence. Based on this definition, Forbes and Rigobon (2002) conclude that the devaluation of the Mexican peso in 1994 and the crash of the US capital market in 1987 were not contagious events, even though most researchers consider them so.

Other researchers followed this intuition too: Bekaert and Harvey (2003) define contagion as an excess of correlation, beyond economic fundamentals. Choosing the fundamental factors is up to the analyst along with the model calibration that can deterministically explain asset returns. By studying the residuals, contagion appears when the correlations expected by the model are surpassed. The authors choose as factors the aggregated return of the US capital market and a regional aggregated market return. If two different markets are integrated for most of the observation period, but the correlation index is subject to short jumps during a crisis, then the null hypothesis of lack of contagion is rejected. On the other side, if these two markets have as a common determinant a regional market index, then the increased correlation can be explained by excess volatility.

The data

We used data on the probability of default derived from credit default swaps, provided by Deutsche Bank Research department. The probabilities were derived assuming a recovery rate of 40%. The data represent daily observations spanning from the 1st of July 2014 to the 1st of January 2015. Bloomberg provided the CDS premiums from which the probabilities are derived. For the scope of this paper, we used a dataset on fourteen emerging economies that have liberalized financial markets and are present on international bond markets. Because the path of the implied probabilities of default was not stationary, we continued this study on the first difference of each time series.

Table 2. Descriptive statistics of the data

Country	Probability variation mean	Probability variation mean	Probability variation kurtosis	Augmented dickey-fuller test
Argentina	0.16%	4.25%	22.751	stationary
Brazil	0.06%	3.08%	6.331	stationary
Croatia	-0.06%	1.68%	23.226	stationary
Hungary	-0.07%	2.30%	6.382	stationary
Indonesia	-0.08%	3.08%	3.696	stationary

Italy	0.04%	4.29%	5.374	stationary
Portugal	-0.05%	4.64%	7.926	stationary
Russia	0.43%	3.67%	4.932	stationary
Slovenia	-0.13%	3.35%	7.452	stationary
Spain	-0.02%	4.86%	4.727	stationary
Thailand	-0.09%	2.66%	8.757	stationary
Turkey	-0.06%	2.89%	4.956	stationary
Ukraine	0.28%	2.64%	6.016	stationary
Venezuela	0.18%	1.56%	3.672	stationary

Jump identification methodology

Identifying jumps in a time series can be done parametrically or non-parametrically. Non parametrical methods have the advantage of low computation time and are less restricted by underlying assumptions: Lee and Mykland (2008) use intraday returns as proxies for volatility; Barndorff-Nielsen et al. (2006) define bi-power variation extendable to a multipower level; Andersen et al. (2012) define the concept of realized volatility.

In the parametric field of jump identification one of the first models for asset returns was that of Press (1967) in which he proposes a Poisson process with constant intensity (jump frequency) and fixed jump size. In Merton (1976) a mixing of pure jumps with a diffusion process was considered an answer to capturing the continuous and the discrete nature of returns, an intuition that was subsequently used by Jorion (1988) to identify jumps in the foreign exchange market. Latter on, Chan and Maheu (2002) proposed a model that would account for ARCH (autoregressive conditional heteroskedasticity) effects in the return path and would also explain the residuals, which were assumed to be jumps, by an ARMA (auto regressive moving average) process. In this paper we will only highlight the equations concerning the jump component:

$$P(n_t = j) = \frac{exp(-\lambda_t)\lambda_t^j}{j!}$$

The probability of observing a jump between periods t-1 and t follows a Poisson distribution. The intensity of the process is time varying and has to be estimated each period.

$$\lambda_t = \lambda_0 + \sum_{i=1}^{r} \rho_{i\lambda_{t-i}} + \sum_{i=1}^{s} \gamma_i \xi_{t-i}$$

The intensity itself is modeled by an autoregressive moving average. This characteristic allows for mean reversion in the case of irrational or unexpected events in the market, or for momentum when traders reach consensus and exhibit herding behavior.

$$\theta_t = \eta_0 + \eta_1 R_{t-1} D(R_{t-1}) + \eta_2 R_{t-1}(1 - D(R_{t-1}))$$

Theta is the jump size which is made to depend asymmetrically on previous returns through the function D(Rt-1) which takes the values of zero or one for positive or negative past returns respectively.

This paper replaces the returns used in the initial methodology of Chan and Maheu (2002) with the first difference of probabilities of default. A visual inspection of the series shows that there are no ARCH effects, and statistical testing using the Engle test for residual heteroscedasticity confirms this with a lack of ARCH effects for 10 of the 14 series, but after filtering the jumps, only one series is left with ARCH effects, which motivated me to suppress the continuous component of the model, in favor of a pure jump process.

Results

Table 3. Total number of co-jumps between countries

	Argentina	**Brazil**	**Croatia**	**Hungary**	**Indonesia**	**Italy**	**Portugal**	**Russia**	**Slovenia**	**Spain**	**Thailand**	**Turkey**	**Ukraine**	**Venezuela**
Brazil	**0**	**39**	**21**	**38**	**62**	**43**	**67**	**71**	**48**	**39**	**24**	**54**	**92**	**96**
Croatia	**0**	**0**	**28**	**37**	**36**	**33**	**58**	**67**	**25**	**31**	**18**	**45**	**78**	**76**
Hungary	**0**	**0**	**0**	**28**	**28**	**29**	**36**	**40**	**19**	**23**	**12**	**36**	**48**	**47**
Indonesia	**0**	**0**	**0**	**0**	**32**	**40**	**51**	**55**	**28**	**35**	**12**	**46**	**68**	**63**
Italy	**0**	**0**	**0**	**0**	**0**	**48**	**68**	**74**	**39**	**40**	**21**	**58**	**86**	**88**
Portugal	**0**	**0**	**0**	**0**	**0**	**0**	**66**	**65**	**31**	**45**	**17**	**47**	**78**	**76**
Russia	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**92**	**40**	**65**	**21**	**66**	**107**	**114**
Slovenia	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**45**	**62**	**22**	**90**	**130**	**128**
Spain	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**21**	**17**	**39**	**55**	**61**

Thailand	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**44**	**67**	**68**
Turkey	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**17**	**31**	**33**
Ukraine	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**100**	**97**
Venezuela	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**147**

The countries that have the most variable default probabilities are in descending order, Venezuela, Ukraine and Russia. It seems that countries that are at war or have autocratic regimes are the most feared by international investors and therefore, most at risk of default. Countries inside the EURO present higher stability. Even if Indonesia is not part of the EURO area, its experience of the Asian crisis and the measures it took, makes it a much more stable country. Portugal and Italy are the most exposed countries to CDS variation, and both react to each other's financial distress. One explanation could be the concentration of the economic activity in specific overdeveloped areas, like the banking sector, as studied by Treapăt (2011) and Mihalcea and Vițelar (2014). From the matrix above, we can see that international creditors cluster their beliefs into groups of countries with different risk profiles: high risk (Russia, Venezuela) or low risk (Thailand, Hungary, Indonesia).

Table 4. Number of positive co-jumps between countries

	Brazil	**Croatia**	**Hungary**	**Indonesia**	**Italy**	**Portugal**	**Russia**	**Slovenia**	**Spain**	**Thailand**	**Turkey**	**Ukraine**	**Venezuela**
Brazil	**12**	**3**	**13**	**14**	**12**	**18**	**24**	**12**	**11**	**5**	**19**	**25**	**31**
Croatia	**0**	**9**	**19**	**8**	**8**	**19**	**30**	**4**	**14**	**7**	**17**	**29**	**31**
Hungary	**0**	**0**	**9**	**11**	**11**	**14**	**16**	**4**	**11**	**3**	**14**	**18**	**15**
Indonesia	**0**	**0**	**0**	**15**	**14**	**16**	**25**	**7**	**14**	**4**	**20**	**22**	**20**
Italy	**0**	**0**	**0**	**0**	**18**	**21**	**28**	**11**	**15**	**7**	**23**	**31**	**22**
Portugal	**0**	**0**	**0**	**0**	**0**	**25**	**25**	**10**	**17**	**5**	**18**	**26**	**25**
Russia	**0**	**0**	**0**	**0**	**0**	**0**	**36**	**11**	**29**	**5**	**22**	**33**	**37**
Slovenia	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**14**	**26**	**8**	**42**	**61**	**49**
Spain	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**4**	**9**	**16**	**17**
Thailand	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**17**	**23**	**23**
Turkey	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**10**	**9**
Ukraine	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**36**	**32**
Venezuela	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**55**

Table 5. Number of negative co-jumps between countries

	Brazil	Croatia	Hungary	Indonesia	Italy	Portugal	Russia	Slovenia	Spain	Thailand	Turkey	Ukraine	Venezuela
Brazil	12	6	15	26	17	27	19	16	12	12	19	21	31
Croatia	0	13	13	15	11	20	28	9	6	5	22	25	23
Hungary	0	0	13	13	10	17	18	9	7	2	15	19	17
Indonesia	0	0	0	12	15	20	21	14	10	5	18	23	17
Italy	0	0	0	0	16	31	26	19	14	8	26	24	28
Portugal	0	0	0	0	0	34	19	13	23	10	20	24	19
Russia	0	0	0	0	0	0	28	23	28	11	28	37	36
Slovenia	0	0	0	0	0	0	0	18	14	3	34	42	31
Spain	0	0	0	0	0	0	0	0	10	5	19	16	24
Thailand	0	0	0	0	0	0	0	0	0	5	14	18	19
Turkey	0	0	0	0	0	0	0	0	0	0	7	10	8
Ukraine	0	0	0	0	0	0	0	0	0	0	0	33	25
Venezuela	0	0	0	0	0	0	0	0	0	0	0	0	32

Table 6. Number of different sign co-jumps between countries

	Brazil	Croatia	Hungary	Indonesia	Italy	Portugal	Russia	Slovenia	Spain	Thailand	Turkey	Ukraine	Venezuela
Brazil	15	12	10	22	14	22	28	20	16	7	16	46	34
Croatia	0	6	5	13	14	19	9	12	11	6	6	24	22
Hungary	0	0	6	4	8	5	6	6	5	7	7	11	15
Indonesia	0	0	0	5	11	15	9	7	11	3	8	23	26
Italy	0	0	0	0	14	16	20	9	11	6	9	31	38
Portugal	0	0	0	0	0	7	21	8	5	2	9	28	32
Russia	0	0	0	0	0	0	28	6	8	5	16	37	41
Slovenia	0	0	0	0	0	0	0	13	22	11	14	27	48
Spain	0	0	0	0	0	0	0	0	5	8	11	23	20
Thailand	0	0	0	0	0	0	0	0	0	4	13	26	26
Turkey	0	0	0	0	0	0	0	0	0	0	6	11	16
Ukraine	0	0	0	0	0	0	0	0	0	0	0	31	40
Venezuela	0	0	0	0	0	0	0	0	0	0	0	0	60

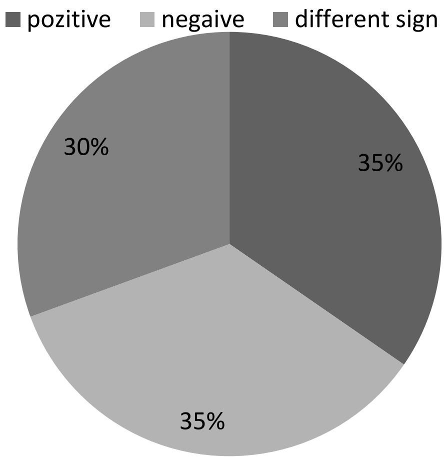

Figure 4. Distribution of co-jumps by direction

When simultaneous extreme events appear in the sovereign bond market, they tend to have the same direction in 65% of cases. This shows that contagion can be inferred in the extreme movement specter.

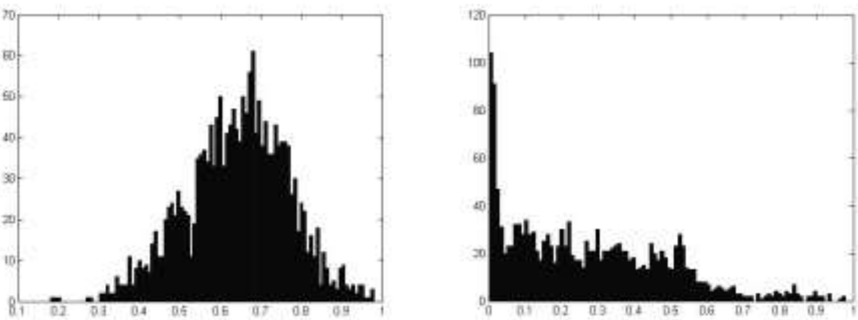

Figure 5. Correlation index between jumps (left) and between normal probability variations

Are extreme movements more correlated than normal ones? The two charts above show the histogram of correlations between all the combinations of two-pair time series in the dataset. The chart on the left clearly indicates that most of the correlation coefficients for extreme movements only have values around 0.65 and that the correlation coefficients for normal movements are uniformly distributed with a tendency to cluster around the value of zero. This means that jumps in CDS or in default probabilities have a different behavior than normal movements and indicate the existence of abnormal correlation.

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Conclusions

The constant integration of international financial markets has made credit more available to sovereign states. Simultaneously, the consolidation of sovereignty renders most republics immune to outside coercion in the business of honoring their debt payments. These two factors have contributed to the multiplication of defaults for governmental debt in the past century as investors panic and credit dries up. In the absence of a supranational lender of last resort, new models for risk assessment must be devised that take into account not only the current capacity of a nation to reimburse its debt, but also the impact of investor sentiment regarding its credit worthiness and credit availability once panic or exuberance overcomes fundamental economics. Contagion needs to be accounted for in any macroeconomic forecast because econometric models that are based on annual or quarterly data cannot cope with the almost instantaneous developments in credit markets and possible multiple equilibrium outcomes, once a crisis unfolds.

Investor behavior in international credit markets can be split into two different spectrums, business as usual and herding behavior. Whether the herding behavior is triggered by consensus, panic or unexpected news, it determines the clustering of opinions about certain sovereign state debtors. Consequently, the CDS premiums suffer violent corrections of nonlinear nature (discontinuous jumps) that are similar in change direction and rarely offset each other. Emerging markets with poorly liberalized economies or which indicate high political instability are having the most volatile probabilities of default. Countries that benefit from the protection of a supranational entity like the EU or IMF, or those that have in place prudential financial policies, remain unaffected by international turmoil. Given the coincidence between the high degree of jump correlation between Russia, Ukraine, Venezuela and Turkey and the international setting in the analyzed period, we conclude that those countries that are perceived as politically unstable or that are subject to international sanctions face not only high volatility but also extreme changes in their CDS premiums. This behavior could be explained by the effort of markets to reach equilibrium or consensus when robust financial analysis based on macroeconomic factors is constantly perturbed by news about political unrest. These observations could be used by investors to make a profit in the CDS markets because in the case of large economies with sound financial indicators, a jump beyond explained volatility should be followed by a return to a fundamental equilibrium level or by a more extreme movement in the opposite direction.

Jumps in asset returns, foreign exchange rates or CDS spreads can serve as an indicator of contagion because by definition, a jump is an unexpected and extreme movement. The econometrical framework proposed by Chan and Maheu (2002) distinguishes the jump component from the linear movements in the time series and from volatility clustering effects therefore isolating that movement which cannot be statistically explained. One possible way of testing if jump identification can serve as a mean for contagion testing is to compare the results of parametrical and non-parametrical jump models against the methodology of Forbes and Rigobon (2002) which eliminates the volatility bias and has already proved that previous episodes of contagion were actually manifestations of interdependence. Because contagion between financial markets becomes more rapid as electronic trading and news availability increase, jumps might serve as an efficient tool for contagion identification because classical correlation analysis loses meaning for high frequency time series.

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