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Systemic Sovereign Risk and Asset Prices: Evidence from the CDS Market, Stressed European Economies and Nonlinear Causality Tests*

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Abstract

This empirical study attempts to measure the direction of effects related to systemic sovereign risk (i.e. proxied by CDS prices) on a number of asset prices in four heavily stressed European economies: Greece, Ireland, Italy and Spain. The paper is innovative in terms of addressing the drawbacks of linear causality by making use of both the Sato et al. (2007) methodological approach, which introduces time-varying vector autoregressive modeling, as well as the Hatemi-J (2012) asymmetric causality test that explicitly introduces asymmetries in causality. The empirical findings suggest that the presence of CDS derivatives aggravated the prices in a number of assets. These results are associated with the overall negative environment in economies that experienced the sovereign debt crisis and had to go through a dramatic reduction in market liquidity as well as strict consolidation programs that led these markets to crash. The findings have important implications for the ongoing debate about how to reform the financial system so as to mitigate systemic risk in the future.

1. Introduction

The rapid development of derivative markets within the last ten years has led to the possibility of trading various types of risks, such as credit and interest rate risk, separately from each other. In addition, the fact that derivative markets react faster to news than cash markets is advantageous to building an asset pricing model based on financial derivatives instead of cash market products. Within some market segments, the notional value of outstanding derivatives is almost as large as or sometimes even larger than the face value of the underlying cash securities. Especially the credit default swap (CDS) market has grown tremendously and is now one of the biggest and most liquid derivative markets. At the same time, the recent sovereign debt crisis that emanated from Europe has exerted its adverse impacts globally, highlighting the speed and force with which financial contagion can occur across national borders in the international financial system.

Motivated by these recent developments, this study seeks to examine whether these types of developments work to affect asset prices within economies suffering from dramatic deteriorations in their sovereign credit risk levels, which enhances

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their sensitivity to changes in those sovereign risk factors that rapidly spread risks across their asset markets. The rapid widening of sovereign credit spreads not only within Europe, but also in other parts of the world, highlights the importance of reaching a better understanding of the driving forces underlying systemic sovereign credit risk.

A CDS is a kind of insurance on an asset. It is the promise to take back the underlying asset at par once there is a default, i.e. to make up the losses of the underlying asset. Many observers have pointed to the creation of CDS as the source of many problems. To mention a few: i) important financial institutions wrote trillions of dollars of CDS insurance; the economy could not run smoothly after they lost so much money on their bad bets, ii) writers of CDS insurance did not even post enough collateral to cover their bets, forcing the government to bail out the beneficiaries, iii) CDS were traded on OTC markets, with a lack of transparency that enabled price gouging, and iv) CDS give investors (at least those who wrote much more insurance than the underlying assets were worth) the incentive to manipulate markets.

Moreover, the presence of CDS markets causes a fall in asset prices. This is due to the fact that when agents sell CDS and put up cash as collateral, they are effectively ranching cash. That raises the value of cash relative to the reference asset. When every asset (i.e. when all future cash flows) can be perfectly ranched, we get a type of Arrow-Debreu equilibrium and all asset prices fall. The depressing effect of CDS on asset prices is most dramatic when the asset is not ranched, but is held outright or levered, because in that case the buyers of the asset will divert their wealth into writing CDS, which is a perfect substitute for holding the asset (Fostel and Geanakoplos, 2008; Geanakoplos, 2010). According to Fostel and Genakoplos (2008), ranching increases the collateral value of the underlying asset. Leverage is an imperfect form of ranching and so raises the underlying asset value less than ideal ranching would. CDS is an imperfect form of ranching cash and so raises the relative value of cash, thus lowering the value of the reference asset.

There is also extensive theoretical research suggesting that the pricing of assets, including sovereign debt, may be nonlinear. Recent work stresses the importance of nonlinear effects and amplification dynamics through the price mechanism during financial crises (Brunnermeier and Oehmeke, 2009). On the one hand, the initial drop in asset prices will be exacerbated if it triggers fire-sale liquidations driven by the deterioration of the mark-to-market portfolio value. This theory suggests that relatively small shocks can imply large spillover effects (Brunnermeier and Pedersen, 2009). Moreover, Brock *et al.* (2009) show that proliferation of hedging instruments may produce nonlinear systems and destabilize markets.

The goal of this paper is to measure the effect of CDS prices on a number of asset prices in four heavily stressed European economies: Greece, Ireland, Italy and Spain. It has been generally claimed that the bust crisis of 2007–2009 might have been caused by financial innovation. We focus on assessing systemic sovereign credit risks, as the recent European debt crisis has highlighted that governments can be the main source of systemic risks, while these risks pose a serious threat to the international financial system. Our study differs from prior studies in the sense that the empirical analysis avoids a number of weaknesses associated with linear causality by employing nonlinear causality tests.

The empirical findings suggest that the presence of the CDS derivatives market aggravated the prices in a number of assets, especially in a number of economies that experienced the sovereign debt crisis and had to go through a dramatic reduction in market liquidity as well as strict consolidation programs that led these markets to crash.

Section 2 provides an overview of the literature. Section 3 discusses methodological issues, while Section 4 presents the data, the empirical analysis and the results. Section 5 concludes the paper.

2. Literature Review

This paper is part of the growing theoretical literature on CDS. Bolton and Oehmke (2011) study the effect of CDS on the debtor-creditor relationship. The proposition that CDS tend to lower asset prices is demonstrated in Geanakoplos (2010). Research by Ang and Longstaff (2013) on systemic sovereign credit risk documents that systemic risk arises from shared and simultaneous effects across countries as a response to major shocks. Their results receive empirical support from Adrian and Brunnermeir (2008), while the presence of systemic sovereign risk is closely associated with financial crises (Bekaert *et al.*, 2013).

Hilscher and Nosbusch (2009) show that sovereign default risks are closely related to country fundamentals, even after controlling for sovereign credit ratings and global factors. Their default risk implied credit spreads track observed market-based bond spreads fairly accurately in out-of-sample tests. However, their tests were restricted to emerging market debt where the focus on sovereign credit risks traditionally resided. However, a recent phenomenon noted by Longstaff *et al.* (2010) and Dieckmann and Plank (2012) is that the cross-section of CDS spreads across advanced economies also exhibits a strong degree of commonality that is not related to the country-specific fundamentals of sovereign obligors. Longstaff *et al.* (2010) reveal that CDS spreads are explained and predicted by US equity, volatility and bond market risk premia. Moreover, Dieckman and Planck (2012) provide empirical evidence on the private-to-public risk transfer phenomena arising from the exposures of the global banking sector and the government bail-outs that followed.

The concept of conditional value at risk (CoVaR), introduced by Adrian and Brunnermeier (2008) for measuring systemic risks within banking sectors, is also employed to provide evidence about the impact of systemic risks on asset prices. Specifically, CoVar can be used to measure a country's value at risk conditional upon that of another country. The authors find that based on weighted averages of the changes in CoVaR, Greece is the most vulnerable to sovereign distress within Europe, followed by Portugal, Ireland, Italy and Spain. Northern European countries like Finland, Germany and the Netherlands are the least vulnerable. Using a similar framework, Fong and Wong (2011) also assess sovereign systemic risk based on a small regional sample comprising the eleven largest Asia-Pacific economies over the 2004–2009 time period.

Previous empirical work identified the presence of nonlinearity in the spread determination model for euro-area peripheral sovereigns during the crisis period (Gerlach *et al.*, 2010; Aizenman *et al.*, 2011; Borgy *et al.*, 2011; Favero and Missale, 2011; Montfort and Renne, 2012). Two different regimes (crisis and non-crisis) have been described, with additional fundamental factors important in the crisis regime. These papers usually attribute nonlinearities to the fiscal situation: they find that yield spreads became much more sensitive to fiscal imbalances after 2008, with a deterioration of fiscal indicators generating a significant widening of the spreads after 2008.

Gennaioli *et al.* (2010) argue that sovereign risk affects banks through their exposure to sovereign bonds. Huizinga and Demirguc-Kunt (2013) provide evidence in a large cross-country sample that bank CDS spreads responded negatively to the deterioration of government finances over the period 2007–2008. Acharya and Steffen (2013) find that eurozone banks have actively engaged in a 'carry trade' process over the crisis period, thus, increasing their exposure to risky sovereign debt. By contrast, bank risk affects the sovereigns, which are expected to bail out systemically important institutions (Acharya *et al.*, 2011). That represents a significant risk given the size of banks compared to the size of the public backstop.

Nonlinearity in the spread determination model of peripheral members of the euro area during the crisis has been seen in previous work (Aizenman *et al.*, 2011; Montfort and Renne, 2011; de Grauwe and Ji, 2013). Montfort and Renne (2011) model the joint dynamics of euro-area sovereign yields with a Markov-switching specification and find a regime-switching feature at the origins of the large fluctuations during the crisis. In particular, they identify a crisis regime that captures the rise in volatility experienced by the sovereign bond market since 2009. Borgy *et al.* (2011) examine the macroeconomic determinants of risk premia in the sovereign yield spreads of six euro-area members and give special emphasis to fiscal sustainability measures. They show a structural break in the relationship between sovereign spreads and fiscal determinants in 2008.

3. Methodology

The linear Granger causality methodological approach is naturally attractive because the methodology simply requires determining whether the regression model coefficients, associated with past and current values, are significant. However, it is now common that the traditional Granger framework is exposed to two major drawbacks. First, the Vector Autoregressive (VAR) model used in Granger causality testing is an adequate approach only in cases when the processes to be modeled are stationary, i.e. the properties of the VAR model (expectation, variance, auto/cross-correlations) are invariant in time. These restrictions are not valid in many cases, since the system dynamics in real datasets exhibit changes depending on external factors (e.g. a crisis period, governmental interventions and multinational agreements). The second drawback is the absence of separation between the causal impact of positive and negative shocks, given that economic agents usually respond more to negative news than to good news in absolute terms.

In this paper, we address the first drawback by making use of the Sato *et al.* (2007) methodological approach, which introduces time-varying vector autoregressive modeling, i.e. the model parameters are considered as functions of time. To address the second drawback, we make use of the Hatemi-J (2012) asymmetric causality test.

3.1 Time-Varying Causality by Sato *et al.* (2007)

The time-varying vector autoregressive model (Sato *et al.*, 2007) for a multivariate time series $\mathbf{x_{t,T}} = \left(x_{1t,T}, x_{2t,T}, \ldots, x_{st,T}\right)'$, where s is the dimension and T is the number of observations, is described as:

$$\mathbf{x_{t,T}} = \mathbf{u(t/T)} + \sum_{l=1}^{p} \mathbf{A_l(t/T)x_{t-l,T}} + \boldsymbol{\varepsilon}_{\mathbf{t,T}} \tag{1}$$

where $\boldsymbol{\varepsilon}_{\mathbf{t,T}}$ is the error vector of independent random variables with zero mean and covariance matrix $\Sigma\left(\mathbf{t/T}\right)$, $\mathbf{u}\left(\mathbf{t/T}\right)$ is the vector with intercepts, and $\mathbf{A_l}\left(\mathbf{t/T}\right)$ are the autoregressive coefficient matrices with $l = 1, 2, \ldots, p$.

The time-varying vector autoregressive model is an extension of the conventional VAR model. In this model, each VAR coefficient is described as a function of time. Here, we propose to decompose these functions by using the B-splines decomposition (Eilers and Marx, 1996) because it is less restrictive than the wavelets. By using the B-splines time-function decomposition approach, the multivariate time-varying autoregressive model can be represented as:

$$\mathbf{x_t} = \sum_{k=0}^{\infty} \mathbf{u_k} \boldsymbol{\psi}_\mathbf{k}(\mathbf{t}) + \sum_{l=1}^{p} \sum_{k=0}^{\infty} \mathbf{A_k^{(l)}} \boldsymbol{\psi}_\mathbf{k}(\mathbf{t}) \mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_\mathbf{t} \tag{2}$$

where $\boldsymbol{\psi}_\mathbf{k}\left(\mathbf{t}\right)$ are the B-splines functions (obs: $\boldsymbol{\psi}_\mathbf{0}\left(\mathbf{t}\right) = \mathbf{1}$, constant for all $\mathbf{t}$, $\mathbf{u_k}$ are vectors and $\mathbf{A_k^{(l)}}$ $(l = 1, 2, \ldots, p; k = 0, 1, 2, \ldots)$ are matrices containing the B-splines expansion coefficients.

The basic idea of the estimation of the time-varying VAR is to represent the decomposition of the intercept and autoregressive time functions as an approximation using a finite linear combination of B-splines functions. In other words, each intercept and autoregressive function is described as a linear combination of M B-splines functions. By using this expansion, the model is approximated by a linear model with finite parameters, given by:

$$\mathbf{x_t} = \sum_{k=0}^{M} \mathbf{u_k} \boldsymbol{\psi}_\mathbf{k}(\mathbf{t}) + \sum_{l=1}^{p} \sum_{k=0}^{M} \mathbf{A_k^{(l)}} \boldsymbol{\psi}_\mathbf{k}(\mathbf{t}) \mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_\mathbf{t} \tag{3}$$

with the parameters of this model (i.e. the B-splines expansion coefficients) being estimated through the least squares method in a linear multiple regression, similarly to the estimation of the conventional VAR models. Then the time-varying Granger causality test can be carried out by testing whether there is at least one autoregressive time-function from y_{it} to y_{lt} which is different from zero at least in one time point.[1]

3.2 Asymmetric Causality by Hatemi-J (2012)

The asymmetric causality test of Hatemi-J (2012) is employed to investigate the asymmetric causality between CDS and the variable **X** is a vector, which represents the following variables: bank stock prices, insurance stock prices, total

[1] Further technical details about the estimation of the time-varying VAR and hypothesis testing can be found in Sato *et al.* (2007).

stock prices, bond prices and the exchange rate between the euro and the US dollar). Each of these is defined as a random walk process as below:

$$CDS_t = CDS_{t-1} + u_{1t} = CDS_0 + \sum_{i=1}^{t} u_{1i} = CDS_0 + \sum_{i=1}^{t} u_{1i}^{+} + \sum_{i=1}^{t} u_{1i}^{-} \tag{4}$$

and

$$X_t = X_{t-1} + u_{2t} = X_0 + \sum_{i=1}^{t} u_{2i} = X_0 + \sum_{i=1}^{t} u_{2i}^{+} + \sum_{i=1}^{t} u_{2i}^{-} \tag{5}$$

where $t = 1,2,\ldots, T$. CDS_0 and X_0 are constants representing the initial values. u_{1i} and u_{2i} indicate white noise error terms which are defined as the sum between positive and negative shocks, i.e. $u_{1i} = u_{1i}^{+} + u_{1i}^{-}$ and $u_{2i} = u_{2i}^{+} + u_{2i}^{-}$, where $u_{1i}^{+} = \max\left(u_{1i}, 0\right)$, $u_{2i}^{+} = \max\left(u_{2i}, 0\right)$, $u_{1i}^{-} = \min\left(u_{1i}, 0\right)$ and $u_{2i}^{-} = \min\left(u_{2i}, 0\right)$.

Hatemi-J (2012) defined positive and negative shocks of each variable in a cumulative form as $CDS^{+} = \sum_{i=1}^{t} u_{1i}^{+}$, $CDS^{-} = \sum_{i=1}^{t} u_{1i}^{-}$, $X^{+} = \sum_{i=1}^{t} u_{2i}^{+}$ and $X^{-} = \sum_{i=1}^{t} u_{2i}^{-}$. Then asymmetric causality between negative components, i.e. $y_t^{-} = (CDS^{-}, X^{-})$, can be implemented via the following vector autoregressive model (VAR model) with the length of the underlying dynamic equal to L[2]:

$$\mathbf{y_t^{-}} = \mathbf{v} + \mathbf{A_1 y_{t-1}^{-}} + \ldots + \mathbf{A_p y_{t-1}^{-}} + \boldsymbol{\varepsilon}_\mathbf{t}^{-} \tag{6}$$

where $\mathbf{y_t^{-}}$ is the vector of variables, $\mathbf{v}$ is the vector of intercepts, $\mathbf{A_T}$ is the vector of parameters for the lag order $r(r = 1,\ldots, p)$ and $\boldsymbol{\varepsilon}_\mathbf{t}^{-}$ is the vector of error terms.

The asymmetric causality test consists in testing under the null hypothesis if the *k*-th element of $\mathbf{y_t^{-}}$. does not Granger-cause the *z*-th element of $\mathbf{y_t^{-}}$. In this order, Hatemi-J (2012) proposed the following Wald test:

$$\mathbf{W} = \left(\mathbf{Cvec}\left(\mathbf{D}\right)\right)' \left[\mathbf{C}\left(\left(\mathbf{Z'Z}\right)^{\mathbf{-1}} \otimes \mathbf{V}_{\boldsymbol{\varepsilon}}\right)\mathbf{C}'\right]' \left(\mathbf{Cvec}\left(\mathbf{D}\right)\right) \tag{7}$$

where $\mathbf{C}$ is an indicator matrix with ones for restricted parameters and zeros for the rest. $\mathbf{D} := \left(\mathbf{v}, \mathbf{A_1}, \ldots, \mathbf{A_p}\right)$ and $vec\left(.\right)$ indicates the column stacking operator. $\mathbf{V}_{\boldsymbol{\varepsilon}}' = \hat{\delta}'_{\varepsilon}\hat{\delta}_{\varepsilon} / T - q$ is the estimated variance-covariance matrix of the unrestricted VAR model with $\hat{\delta} := \left(\hat{\delta}_1^{-}, \ldots, \hat{\delta}_T^{-}\right)$ and q is the number of parameters in each equation of the VAR model. The above Wald test statistic has an asymptotic χ^2 distribution with p degrees of freedom.

[2] The optimal lag order L is obtained based on the HJC information criterion suggested in Hatemi and Hatemi-J (2003, 2008).

However, financial time-series returns are characterized by volatility (the existence of ARCH effects) and usually are not normally distributed. To overcome this problem, Hatemi-J (2012) proposed a bootstrap simulation technique employing the following steps:

– Step 1: Estimate the restricted VAR(p) model.
– Step 2: Simulate the bootstrap data, $\mathbf{Y}_{\mathbf{t}}^{*}$.[3]
– Step 3: Estimate the Wald test statistic (equation 7) for each bootstrap simulation (100,000 times). The bootstrap generated critical value c_{α}^{*} for each α-level of significance is obtained by taking the α-th upper quantile of the distribution of the bootstrapped Wald test statistic.
– Step 4: Finally, we estimate the Wald test statistic using the original data. The null hypothesis of absence of Granger asymmetric causality is rejected at the α-level of significance if the Wald test statistic is larger than the bootstrap critical value at that significance level.

4. Empirical Results

4.1 Data and Preliminary Analysis

We use daily data spanning the period from January 2007 to September 2012 to capture any potential causality effect from CDS prices on four stressed European countries (Greece, Ireland, Italy and Spain) through the following variables: total stock prices, bank stock prices, insurance stock prices, bond prices and the exchange rate between the euro and the US dollar measured in US dollar per euro. We deliberately end our sample at the beginning of the Outright Monetary Transactions (OMT) program, which has successfully narrowed the spreads and blurred market signals. Data are obtained from Bloomberg. The empirical analysis was substantially assisted by using statistical software components written in the R language and Gauss for both the time-varying and asymmetric causality tests, respectively. The codes were kindly provided directly by the authors of each test (João R. Sato and Abdulnasser Hatemi-J).

Consistent with the extant literature, our empirical analysis is based on country CDS spreads, as it provides a more direct measure of sovereign credit risk than actual sovereign debt yield spreads, as the latter are influenced by interest rate movements, supply changes in sovereign bonds, illiquidity and other factors (Ang and Longstaff, 2013; Pan and Singleton, 2008; Remolona, Scatigna and Wu, 2008). Rodriguez-Moreno and Peria (2013) compare two groups of macro-based and micro-based measures and for both groups they find that measures based on market-determined CDS spreads perform better and are more straightforward to use than alternative measures.

Daily returns are calculated from daily price data by taking the natural logarithm of the ratio of two successive prices. *Table 1* presents the unit root test results of sample data using the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests. The results indicate that the null hypothesis of a unit root is

[3] Details about producing the bootstrapped residuals (δ^{*}) are available in Hatemi-J (2012).

Table 1 Unit Root Test Results

		Trend and Intercept		Intercept		Result
		Level	1st Difference	Level	1st Difference	
Greece						
CDS	ADF	0.3870	0.0000***	0.9153	0.0000***	I(1)
	PP	0.4478	0.0000***	0.9341	0.0000***	
Bank stocks	ADF	0.7073	0.0000***	0.9430	0.0000***	I(1)
	PP	0.6781	0.0000***	0.9430	0.0000***	
Insurance stocks	ADF	0.0987*	------	0.1123	0.0000***	I(1)
	PP	0.1107	0.0000***	0.1260	0.0000***	
Total stocks	ADF	0.6175	0.0000***	0.9444	0.0000***	I(1)
	PP	0.5915	0.0000***	0.9432	0.0000***	
Ireland						
CDS	ADF	0.4937	0.0000***	0.8355	0.0000***	I(1)
	PP	0.2310	0.0000***	0.5867	0.0000***	
Bank stocks	ADF	0.6092	0.0000***	0.7477	0.0000***	I(1)
	PP	0.7215	0.0000***	0.7929	0.0000***	
Insurance stocks	ADF	0.6042	0.0000***	0.7247	0.0000***	I(1)
	PP	0.7013	0.0000***	0.7672	0.0000***	
Total stocks	ADF	0.8328	0.0000***	0.7592	0.0000***	I(1)
	PP	0.9025	0.0000***	0.7802	0.0000***	
Italy						
CDS	ADF	0.5961	0.0000***	0.7827	0.0000***	I(1)
	PP	0.6220	0.0000***	0.8010	0.0000***	
Bank stocks	ADF	0.7931	0.0000***	0.6900	0.0000***	I(1)
	PP	0.7737	0.0000***	0.6830	0.0000***	
Insurance stocks	ADF	0.6823	0.0000***	0.7886	0.0000***	I(1)
	PP	0.5958	0.0000***	0.7679	0.0000***	
Total stocks	ADF	0.8371	0.0000***	0.6714	0.0000***	I(1)
	PP	0.8555	0.0000***	0.6811	0.0000***	
Spain						
CDS	ADF	0.5237	0.0000***	0.6539	0.0000***	I(1)
	PP	0.6404	0.0000***	0.6719	0.0000***	
Bank stocks	ADF	0.7257	0.0000***	0.5003	0.0000***	I(1)
	PP	0.7228	0.0000***	0.5032	0.0000***	
Insurance stocks	ADF	0.4688	0.0000***	0.5023	0.0000***	I(1)
	PP	0.5349	0.0000***	0.5552	0.0000***	
Total stocks	ADF	0.6490	0.0000***	0.5217	0.0000***	I(1)
	PP	0.7600	0.0000***	0.6019	0.0000***	
Euro index	ADF	0.7804	0.0000***	0.0000***		I(1)
	PP	0.7174	0.0000***	0.0000***		

Exchange rate between EUR and USD	ADF	0.6196	0.0000***	0.0000***	**I(1)**
	PP	0.6099	0.0000***	0.0000***	

Notes: The values in the table are *p*-values. ***, ** and * indicate the significance at the 1%, 5% and 10% levels, respectively.

rejected at the 1% level across all series. The stationarity property of the first log difference series is thus suitable for further statistical analysis.

4.2 Time-Varying Causality Results

We first test whether there are any time-varying relationships between the variables. The time-varying Granger causality test can be carried out by testing whether there is at least one autoregressive time function from y_{it} to y_{lt} which is different from zero at least in one time point. In our model representation (decomposing the function of interest as a linear combination of simpler functions), this is equivalent to testing whether there is at least one coefficient from the B-splines expansion of the autoregressive time functions that is different from zero. Since the model is linear, this test can be easily carried out by using a conventional Wald test in a linear multiple regression analysis. In addition, our model parameterization also allows testing of whether the Granger causality between two time series is time invariant (i.e. constant over time) or not. If the constant causality relationship cannot be rejected, the two series interact according to the conventional Granger causality framework (Sato *et al.*, 2007). The results, reported in *Table 2*, indicate that there is a significant time-varying relationship running from CDS to total stocks, the Euro index and the exchange rate between the euro and the US dollar in the case of Greece. In the case of Italy, we also note a significant time-varying relationship running from CDS to the Euro index and the exchange rate between the euro and the US dollar. For the remaining two countries, no such time-varying results are found. In this case, standard Granger causality tests are applied.

Next, we analyze the causal relationships across our panel of countries in a time-varying vs. time-constant context by using a Granger causality test which takes into account the time-varying properties, given that they are present. The time-varying Granger causality results are reported in *Table 3*. The empirical findings strongly document evidence of causality across all cases when the time-varying relationships between the variables are accepted. This result confirms the importance of this property when we analyze the Granger causality between CDS and a number of asset prices for stressed European countries.

4.3 Asymmetric Causality Results

The analytic results of these asymmetric causality tests are reported in *Table 4*, while *Table 5* provides a chart that summarizes them. We note that in the case of Greece the null hypothesis that positive CDS shocks do not Granger-cause positive and negative shocks in bank stocks prices, positive shocks in insurance stocks, negative shocks in total stocks, and negative shocks in the Euro index is rejected at the 5% and 10% significance levels. In the case of Ireland, either positive or negative shocks in CDS cannot Granger-cause either asset price. In the case of Italy, positive CDS shocks Granger-cause negative shocks across all four asset prices and, finally,

Table 2 Dynamic Granger Causality Test Results

Countries	Hypothesis	*p*-value
	CDS ≠> Bank stocks	0.2100
	CDS ≠> Insurance stocks	0.2301
Greece	*CDS* ≠> Total stocks	**0.0959***
	CDS ≠> Euro index	**0.0075*****
	CDS ≠> Exchange rate	**0.0591***
	CDS ≠> Bank stocks	0.4861
	CDS ≠> Insurance stocks	0.3091
Ireland	*CDS* ≠> Total stocks	0.9285
	CDS ≠> Euro index	0.5568
	CDS ≠> Exchange rate	0.3201
	CDS ≠> Bank stocks	0.8857
	CDS ≠> Insurance stocks	0.6638
Italy	*CDS* ≠> Total stocks	0.3619
	CDS ≠> Euro index	**0.0799***
	CDS ≠> Exchange rate	**0.0193****
	CDS ≠> Bank stocks	0.8170
	CDS ≠> Insurance stocks	0.6675
Spain	*CDS* ≠> Total stocks	0.7662
	CDS ≠> Euro index	0.2005
	CDS ≠> Exchange rate	0.2270

Notes: The dynamic Granger causality test allows testing of whether the Granger causality between two time series is time invariant or not (i.e. H_0: The causality from X to Y is constant over time vs. H_1: The causality from X to Y is not constant over time).

Figures denote *p*-values. *, **, *** denote statistical significance at 1%, 5% and 10%, respectively.

in the case of Spain, only negative CDS shocks can Granger-cause positive shocks in bank stocks and total stocks.

The empirical findings accept the presence of a nonlinear link between systemic sovereign risk and asset prices in our sample of distressed countries, except in the case of Ireland. In particular, the results highlight the validity of the hypothesis that the observed nexus between sovereigns and banks may have created a nonlinear relationship which goes both ways and features some amplification in the sovereign risk (Gennaioli *et al.*, 2010; Huizinga and Demirguc-Kunt, 2013; Acharya and Steffen, 2013). In addition, adverse liquidity effects on euro-area banks were documented during the crisis, including a significant fall of interbank loans after mid-2010 (Allen and Moessner, 2013). Finally, the findings provide statistical support to the hypothesis that derivatives produce nonlinear systems (Brock *et al.*, 2009; Simsek, 2013).

Our findings are similar to those reached by Coimbra (2014), who has explicitly modeled the resulting feedback loop. After a rise in sovereign risk, banks' VaR constraint binds, which reduces their demand for sovereign bonds, thereby raising the sovereign risk premium. This leads to adverse sovereign debt dynamics, which raise sovereign risk. The initial shock is exacerbated and feeds back to credit

Table 3 Time-Varying Granger Causality Test Results

Countries	Hypothesis	*p*-value
	CDS ≠> Bank stocks	0.1989
	CDS ≠> Insurance stocks	0.2003
Greece	*CDS* ≠> Total stocks	**0.0716***
	CDS ≠> Euro index	**0.0043*****
	CDS ≠> Exchange rate	**0.0932***
	CDS ≠> Bank stocks	0.5685
	CDS ≠> Insurance stocks	0.3823
Ireland	*CDS* ≠> Total stocks	0.9494
	CDS ≠> Euro index	0.6634
	CDS ≠> Exchange rate	0.3702
	CDS ≠> Bank stocks	0.8622
	CDS ≠> Insurance stocks	0.3654
Italy	*CDS* ≠> Total stocks	0.2988
	CDS ≠> Euro index	**0.0163****
	CDS ≠> Exchange rate	**0.0182****
	CDS ≠> Bank stocks	0.7971
	CDS ≠> Insurance stocks	0.7641
Spain	*CDS* ≠> Total stocks	0.7033
	CDS ≠> Euro index	0.1388
	CDS ≠> Exchange rate	0.3005

Notes: The dynamic Granger causality test allows to test whether the Granger causality between two time series is time-invariant or not (i.e., H_0: The causality from X to Y is constant over time vs. H_1: The causality from X to Y is not constant over time).

Figures denote p-values. *, **, *** denote statistical significance at 1%, 5% and 10%, respectively.

conditions. Borrowing costs deteriorate further, causing more credit restrictions. Highly leveraged investors are more vulnerable to initial shocks and forced into credit restrictions to a greater extent. In addition, our findings provide support for the hypothesis that initial shocks on sovereign bonds may trigger a liquidity spiral because they degrade the quality of collateral. Banks facing liquidity problems will be forced to sell off assets to regain liquidity or restore their capital ratio (Brunnermeier and Pedersen, 2009). The emergence of asymmetric information frictions also strengthens the dynamics (Brunnermeier *et al.*, 2009). The pricing of debt becomes more “information sensitive” and safe assets become less safe, so investors are more selective about the quality of assets they accept as collateral. Their demand for sovereign bonds perceived to be riskier declines, thereby raising the sovereign risk premium.

Table 4 Asymmetric Causality Test Results

Countries	Hypothesis	Test value	Bootstrap CV at 1%	Bootstrap CV at 5%	Bootstrap CV at 10%
	CDS^{+} ≠> Banks^{+}	**6.711****	12.886	6.473	4.464
	CDS^{-} ≠> Banks^{-}	0.883	13.060	6.717	4.756
	CDS^{+} ≠> Banks^{-}	**6.447****	9.718	5.795	4.468
	CDS^{-} ≠> Banks^{+}	0.031	10.397	3.964	2.724
	CDS^{+} ≠> Insurance^{+}	0.478	15.253	7.124	4.884
	CDS^{-} ≠> Insurance^{-}	0.276	14.792	3.553	2.192
	CDS^{+} ≠> Insurance^{-}	1.861	10.764	6.335	4.428
	CDS^{-} ≠> Insurance^{+}	**10.046****	20.005	5.876	3.768
	CDS^{+}≠>Stock index^{+}	**5.458***	11.860	6.396	4.609
Greece	*CDS^{-}*≠>Stock index^{-}	0.559	13.392	6.641	4.795
	CDS^{+}≠>Stock index^{-}	**8.418****	9.205	5.914	4.695
	CDS^{-}≠>Stock index^{+}	0.024	10.320	3.759	2.697
	CDS^{+} ≠> Euro index^{+}	4.105	10.960	6.059	4.550
	CDS^{-} ≠> Euro index^{-}	0.360	9.583	3.816	2.385
	CDS^{+} ≠> Euro index^{-}	**6.154****	10.207	6.126	4.695
	CDS^{-} ≠> Euro index^{+}	0.002	9.032	3.690	2.426
	CDS^{+} ≠> Exch. Rate^{+}	4.113	10.910	6.223	4.772
	CDS^{-} ≠> Exch. Rate^{-}	0.841	9.927	4.266	2.641
	CDS^{+} ≠> Exch. Rate^{-}	2.729	8.620	5.812	4.545
	CDS^{-} ≠> Exch. rate^{+}	0.006	8.389	3.532	2.255
	CDS^{+} ≠> Banks^{+}	0.100	12.234	7.704	4.913
	CDS^{-} ≠> Banks^{-}	0.300	28.995	12.579	8.121
	CDS^{+} ≠> Banks^{-}	0.042	14.127	6.691	4.749
	CDS^{-} ≠> Banks^{+}	0.822	18.047	10.927	8.307
	CDS^{+} ≠> Insurance^{+}	0.343	12.009	6.520	4.473
	CDS^{-} ≠> Insurance^{-}	0.904	21.683	13.268	8.443
	CDS^{+} ≠> Insurance^{-}	0.041	15.592	7.355	4.333
	CDS^{-} ≠> Insurance^{+}	1.973	17.265	11.362	8.425
	CDS^{+}≠>Stock index^{+}	0.153	8.083	3.563	2.476
Ireland	*CDS^{-}*≠>Stock index^{-}	0.477	17.795	10.856	8.467
	CDS^{+}≠>Stock index	0.001	10.489	3.774	2.617
	CDS^{-}≠>Stock index^{+}	2.240	15.696	10.560	7.649
	CDS^{+} ≠> Euro index^{+}	0.006	8.107	3.958	2.475
	CDS^{-} ≠> Euro index^{-}	0.157	17.314	10.032	7.536
	CDS^{+} ≠> Euro index^{-}	0.053	8.153	4.045	2.785
	CDS^{-} ≠> Euro index^{+}	1.591	15.642	9.850	7.896
	CDS^{+} ≠> Exch. Rate^{+}	0.177	9.156	4.235	2.472
	CDS^{-} ≠> Exch. Rate^{-}	0.289	17.127	10.421	8.083
	CDS^{+} ≠> Exch. Rate^{-}	0.166	10.635	4.089	2.504
	CDS^{-} ≠> Exch. rate^{+}	0.708	16.707	10.104	7.913

Italy	$CDS^+ \not\Rightarrow$ Banks$^+$	2.366	9.745	6.907	4.796
	$CDS^- \not\Rightarrow$ Banks$^-$	0.628	10.875	6.414	4.526
	$CDS^+ \not\Rightarrow$ Banks$^-$	**7.322****	10.415	6.451	4.651
	$CDS^- \not\Rightarrow$ Banks$^+$	0.009	8.357	3.987	2.828
	$CDS^+ \not\Rightarrow$ Insurance$^+$	4.032	10.164	6.849	5.185
	$CDS^- \not\Rightarrow$ Insurance$^-$	4.900	13.562	7.591	6.247
	$CDS^+ \not\Rightarrow$ Insurance$^-$	**7.782****	13.432	7.613	6.437
	$CDS^- \not\Rightarrow$ Insurance$^+$	0.262	7.918	4.154	2.708
	$CDS^+ \not\Rightarrow$ Stock index$^+$	3.240	10.800	6.391	5.005
	$CDS^- \not\Rightarrow$ Stock index$^-$	1.288	10.078	6.242	4.466
	$CDS^+ \not\Rightarrow$ Stock index$^-$	**6.771****	10.657	6.057	4.559
	$CDS^- \not\Rightarrow$ Stock index$^+$	0.018	8.810	3.859	2.583
	$CDS^+ \not\Rightarrow$ Euro index$^+$	3.416	9.206	5.776	4.496
	$CDS^- \not\Rightarrow$ Euro index$^-$	0.257	7.251	3.847	2.652
	$CDS^+ \not\Rightarrow$ Euro index$^-$	**10.633*****	9.262	6.024	4.779
	$CDS^- \not\Rightarrow$ Euro index$^+$	0.871	12.634	6.446	4.886
	$CDS^+ \not\Rightarrow$ Exch. Rate$^+$	3.985	9.347	5.833	4.900
	$CDS^- \not\Rightarrow$ Exch. Rate$^-$	0.405	6.797	4.133	2.761
	$CDS^+ \not\Rightarrow$ Exch. Rate$^-$	**5.718***	10.271	6.115	4.684
	$CDS^- \not\Rightarrow$ Exch. rate$^+$	0.174	6.513	3.503	2.554
Spain	$CDS^+ \not\Rightarrow$ Banks$^+$	0.286	8.595	3.843	2.306
	$CDS^- \not\Rightarrow$ Banks$^-$	0.536	12.456	5.855	4.477
	$CDS^+ \not\Rightarrow$ Banks$^-$	0.788	14.860	6.781	4.476
	$CDS^- \not\Rightarrow$ Banks$^+$	**3.468****	9.207	3.101	2.199
	$CDS^+ \not\Rightarrow$ Insurance$^+$	0.062	8.131	3.944	2.469
	$CDS^- \not\Rightarrow$ Insurance$^-$	0.001	8.052	3.534	2.268
	$CDS^+ \not\Rightarrow$ Insurance$^-$	0.008	7.598	3.543	2.249
	$CDS^- \not\Rightarrow$ Insurance$^+$	0.030	8.563	4.001	2.567
	$CDS^+ \not\Rightarrow$ Stock index$^+$	0.820	9.305	3.670	2.304
	$CDS^- \not\Rightarrow$ Stock index$^-$	0.026	8.094	3.751	2.547
	$CDS^+ \not\Rightarrow$ Stock index$^-$	0.214	8.133	3.322	2.415
	$CDS^- \not\Rightarrow$ Stock index$^+$	**3.399****	10.821	3.171	1.971
	$CDS^+ \not\Rightarrow$ Euro index$^+$	0.691	9.570	3.773	2.477
	$CDS^- \not\Rightarrow$ Euro index$^-$	0.133	7.881	4.128	2.579
	$CDS^+ \not\Rightarrow$ Euro index$^-$	0.683	9.336	3.888	2.750
	$CDS^- \not\Rightarrow$ Euro index$^+$	1.743	7.137	3.178	2.365
	$CDS^+ \not\Rightarrow$ Exch. Rate$^+$	0.269	8.789	3.834	2.491
	$CDS^- \not\Rightarrow$ Exch. Rate$^-$	1.045	6.849	3.141	2.236
	$CDS^+ \not\Rightarrow$ Exch. Rate$^-$	0.994	8.959	3.991	2.547
	$CDS^- \not\Rightarrow$ Exch. rate$^+$	0.722	7.219	3.205	2.147

Notes: $\not\Rightarrow$ denotes "does not cause", CV denotes the critical value, $^+$ and $^-$ represent positive and negative shocks, respectively.

Table 5 Summary of the Results in Table 4

Hypothesis	Greece	Ireland	Italy	Spain
$CDS^{+} \not\Rightarrow$ Banks^{+}	**R (5%)**	NR	NR	NR
$CDS^{-} \not\Rightarrow$ Banks^{-}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Banks^{-}	**R (5%)**	NR	**R (5%)**	NR
$CDS^{-} \not\Rightarrow$ Banks^{+}	NR	NR	NR	**R (5%)**
$CDS^{+} \not\Rightarrow$ Insurance^{+}	NR	NR	NR	NR
$CDS^{-} \not\Rightarrow$ Insurance^{-}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Insurance^{-}	NR	NR	**R (5%)**	NR
$CDS^{-} \not\Rightarrow$ Insurance^{+}	**R (5%)**	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Stock index^{+}	**R (5%)**	NR	NR	NR
$CDS^{-} \not\Rightarrow$ Stock index^{-}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Stock index^{-}	**R (5%)**	NR	**R (5%)**	NR
$CDS^{-} \not\Rightarrow$ Stock index^{+}	NR	NR	NR	**R (5%)**
$CDS^{+} \not\Rightarrow$ Euro index^{+}	NR	NR	NR	NR
$CDS^{-} \not\Rightarrow$ Euro index^{-}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Euro index^{-}	**R (5%)**	NR	**R (1%)**	NR
$CDS^{-} \not\Rightarrow$ Euro index^{+}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Exch. Rate^{+}	NR	NR	NR	NR
$CDS^{-} \not\Rightarrow$ Exch. Rate^{-}	NR	NR	NR	NR
$CDS^{+} \not\Rightarrow$ Exch. Rate^{-}	NR	NR	**R (10%)**	NR
$CDS^{-} \not\Rightarrow$ Exch. rate^{+}	NR	NR	NR	NR

Notes: $\not\Rightarrow$ denotes "does not cause". "R" indicates that the hypothesis is rejected, while "NR" indicates that the hypothesis is not rejected. $^{+}$ and $^{-}$ represent positive and negative shocks, respectively. (.) represents the level of significance.

5. Conclusions

Given the developments in both the derivatives markets and in the European sovereign credit crisis, this study investigated whether these types of developments worked to negatively affect asset prices within four economies that suffered dramatic deteriorations in their sovereign credit risk levels and thus enhanced their sensitivity to sovereign risk factors, which rapidly spread across their asset markets.

More specifically, this study explored the effect of sovereign risk (proxied by CDS prices) on a number of asset prices in the economies of Greece, Ireland, Italy and Spain. The paper is innovative in terms of making use of both the Sato *et al.* (2007) nonlinear causality approach and the Hatemi-J (2012) asymmetric causality test. The analysis also used daily data from January 1, 2007 to September 30, 2012 to capture any potential causality effect from CDS prices on four stressed European countries (Greece, Ireland, Italy and Spain) through the following variables: total stock prices, bank stock prices, insurance stock prices, bond prices and the exchange rate between the euro and the US dollar.

The empirical findings highlighted the fact that the presence of the CDS derivatives market aggravated the prices in a number of assets. These findings are consistent with the notion that negative stock price moves and worsening credit conditions are the causes of the observed feedback effect between the stock and CDS markets. Investors have priced the European sovereigns differently since the beginning of the European crisis.

The results from our study provide evidence in support of the financial theory that the stock market efficiently reflects the default probability of firms in stock prices. In contrast, the CDS market is empirically found to be the main venue for the price discovery of credit risk. Possible reasons that make the CDS market a better venue than the stock market include: (1) participants in the CDS market are typically large financial institutions and hedge funds with information advantages *vis-à-vis* retail investors in the stock market who have no information advantages, and (2) the CDS market has become very liquid due to the tremendous growth in demand for trading and hedging credit risk. Therefore, investors should examine more carefully the dynamic information flow between the stock market and the CDS index market in the price discovery process when the credit market is in a credit and liquidity crunch. The CDS market has provided good motivation for market participants to monitor both markets more closely. Market participants are advised to seek information in both markets when they are about to engage in trading and/or hedging.

Finally, the findings have important implications for the ongoing debate about how to reform the financial system so as to mitigate systemic risk in the future, given that asset prices, such as exchange rates and stock market returns, seem to depend crucially on the overall market sentiment indicated by the course of the derivatives markets. The most important, mostly regulatory, reforms that should be strictly followed involve: i) the adoption of Basel III capital requirements, including a countercyclical capital buffer and a surcharge for globally systemically important financial institutions, ii) substantial progress on reducing too-big-to-fail domestically systemically important banks, iii) higher capital adequacy requirements and more intense supervision, iv) reforms related to national resolution schemes (including bail-in instruments) so that failing institutions can be resolved without wider disruptions, v) adoption of principles for sound compensation practices to avoid perverse incentives for risk-taking, vi) agreement in principle on similar treatment of some types of financial transactions under the Generally Accepted Accounting Principles (GAAP) and International Financial Reporting Standards (IFRS), vii) some closure of data gaps, e.g. the beginning of harmonized collection of improved consolidated data on bilateral counterparty and credit risks of major systemic banks, viii) some over-the-counter (OTC) derivatives reforms, such as guidelines and minimum standards for centralized counterparties, ix) new "macro-prudential" policymaking, including better identification of risks, building of more robust institutional infrastructures, reduction of excessive procyclicality and risks, and designing of a new institutional framework for financial operations, x) reduction of risk to banks arising from shadow banking activities (this will remove a source of contagion to banks' balance sheets), and xi) a new set of incentives for better international financial integration.

REFERENCES

Acharya V, Steffen S (2013): The greatest carry trade ever? Understanding Eurozone bank risks. *CEPR Discussion Paper*, no. 9432.

Acharya V, Drechsler I, Schnabl P (2011): A Pyrrhic victory? Bank bailouts and sovereign credit risk. *CEPR Discussion Paper*, no. 8679.

Adrian T, Brunnermeier MK (2008): CoVar. *Federal Reserve Bank of New York Staff Report*, no. 348 (September).

Aizemann J, Hutchison MM, Jinjarak N (2011): What is the risk of European sovereign debt default? Fiscal space, CDS spread, and market pricing of risk. *NBER Working Paper*, no. 17407.

Allen WA, Moessner R (2013): The liquidity consequences of the euro area sovereign debt crisis. *BIS Working Paper*, no 1302.

Ang A, Longstaff FA (2013): Systemic sovereign credit risk: Lessons from the U.S. and Europe. *Journal of Monetary Economics*, 60:493–510.

Bekaert G, Ehrmann M, Fratzscher M, Mehl A (2013): Global crises and equity market contagion. *NBER Working Paper*, no. 17121.

Bolton P, Oehmke M (2011): Credit default swaps and the empty creditor problem. *Review of Financial Studies*, 24:2617–2655.

Borgy V, Laubach T, Mésonnier JS, Renne JP (2011): Fiscal sustainability, default risk and Euro area sovereign bond spreads markets. *Banque de France, Document de travail*, n◦350.

Brock WA, Hommes CH, Wagner FOO (2009): More hedging instruments may destabilize markets. *Journal of Economic Dynamics and Control*, 33:1912–1928.

Brunnermeier M, Crockett A, Goodhart C, Persaud A, Shin H (2009): The Fundamental Principles of Financial Regulation. *ICMB-CEPR Geneva Reports on the World Economy series*.

Coimbra N (2014): Sovereigns at risk: a dynamic model of sovereign debt and banking leverage. *London Business School, Department of Economics, Manuscript*.

Dieckmann S, Plank T (2012): Default risk of advance economies: an empirical analysis of credit default swaps during the financial crisis. *Review of Finance*, 16:903–934.

Eilers PHC, Marx BD (1996): Flexible smoothing with B-splines and penalties. *Statistical Science*, 11:89–121.

Favero C, Missale A (2012): Sovereign spreads in the Euro area: Which prospects for a Eurobond? *Economic Policy*, 27:231–273.

Fong T, Wong A (2011): Analysing interconnectivity among economies. *Emerging Markets Review*, 12:432–442.

Fostel A, Geanakoplos J (2008): Leverage cycles and the anxious economy. *American Economic Review*, 98:1211–1244.

Geanakoplos J (2010): Solving the present crisis and managing the leverage cycle. *Federal Reserve Bank of New York Economic Policy Review*:101–131.

Gennaioli N, Martin A, Rossi S (2010): Sovereign default, domestic banks and financial institutions. *CEPR Discussion Paper*, no. 7955.

Gerlach S, Schulz A, Wolff GB (2010): Banking and sovereign risk in the euro area. *Deutsche Bundesbank Discussion Paper*, no.◦09/2010.

Grauwe P de, Ji Y (2013): Self-fulfilling crises in the Eurozone: an empirical test. *Journal of International Money and Finance*, 34:15–36.

Hatemi-J A (2003): A new method to choose optimal lag order in stable and unstable VAR models. *Applied Economics Letters*, 10:135–137.

Hatemi-J A (2008): Forecasting properties of a new method to choose optimal lag order in stable and unstable VAR models. *Applied Economics Letters*, 15:239–243.

Hatemi-J A (2012): Asymmetric causality tests with an application. *Empirical Economics*, 43: 447–456.

Hilscher J, Nosbusch Y (2010): Determinants of sovereign risk: Macroeconomic fundamentals and the pricing of sovereign debt. *Review of Finance*, 14:235–262.

Huizinga H, Demirguc-Kunt A (2013): Are banks too big to fail or too big to save? International evidence from equity prices and CDS spreads. *Journal of Banking & Finance*, 37: 875–894.

Longstaff FA, Pan J, Pedersen LH, Singleton KJ (2010): How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics*, 3:75–103.

Montfort A, Renne JP (2011): Credit and liquidity risks in euro-area sovereign yield curves. *Banque de France, Document de travail*, n◦352.

Pan J, Singleton K (2008): Default and recovery implicit in the term structure of sovereign CDS spreads. *Journal of Finance*, 63:2345–2384.

Remolova E, Scatigna M, Wu E (2008): The dynamic pricing of sovereign risk in emerging markets: Fundamentals and risk aversion. *Journal of Fixed Income*, 17:57–71.

Rodriguez-Moreno M, Peria J (2013): Systemic risk measures: The simpler the better? *Journal of Banking and Finance*, 37:1817–1831.

Sato JR, Morettin PA, Arantes PR, Amaro JE (2007): Wavelet based time-varying vector autoregressive modelling. *Computational Statistics & Data Analysis*, 51:5847–5866.

Simsek A (2013): Speculation and risk sharing with new financial assets. *Quarterly Journal of Economics*, 128:1365–1396.