"Quantifying sovereign risk in the euro area"

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Abstract

The choice of the optimal sovereign risk indicator is crucial in the context of the euro area (EA) countries, which faced a fierce sovereign debt crisis. Traditional indicators of sovereign risk (CDS, bond yields, and credit rating) do not take into consideration the priority structure of creditors and are highly influenced by market sentiment. We propose a new indicator (DtD) to quantify sovereign risk for eleven EA countries over the period 2004Q1-2019Q4. Using contingent claims' methodology, DtD incorporates the seniority structure of creditors in an existing theoretical model. Our results suggest that (1) DtD is a leading indicator of sovereign risk and (2) adding information from the public sector's balance sheet structure to market information, helps better incorporate macroeconomic fundamentals in the sovereign risk measure, overcoming some of the weaknesses documented in the traditional indicators.

JEL classification: E62, H3, C11.

Keywords: Sovereign default risk, Euro area countries, Contingent claims, Distance-to- default.

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1. Introduction

Sovereign credit risk indicators are measures of governments' ability to repay their debt. In the context of the euro area (EA) countries, which have recently faced a fierce sovereign debt crisis, the choice of the optimal indicator is crucial. The level of credit risk directly affects the behaviour of financial market participants when diversifying the risk of their global debt portfolios and may have major implications for financial stability (see, e.g., Mallick and Sousa (2013)). They also play a key role in determining the financing costs of the public sector since higher perceived risk implies higher long-term domestic interest rates, which in turn increase debt servicing costs and future government deficits. A decade after the 2008 global financial crisis and the European sovereign debt crisis, the recent Covid-19 pandemic and its economic consequences are causing a major increase in fiscal deficits and public debt ratios across EA countries. Fiscal policy actions have gone to an unprecedented level amid pre-existing government debt-to-GDP ratios still above their pre-crisis levels. There is an urgent and pressing need to understand the sovereign's credit risk to gauge the room for manoeuvre and vulnerability of the public sector, making the construction of a robust indicator of sovereign risk of paramount importance.[1]

Empirical researchers also find it difficult to reconcile the evolution of traditional market-based indicators of sovereign risk in EA countries with their economic fundamentals (see De Grauwe (2012), De Grauwe and Ji (2013), Favero and Missale (2012), Aizenman et al.(2013), Beirne and Fratzscher (2013), among others). The most commonly used measures of sovereign risk are the credit default swap (CDS) spreads and sovereign yields. CDS is a direct measure of sovereign's default risk while the yield measures the expected funding cost for a sovereign. Even though both CDS and yields are market-based measures, both are prone to political interference. For example, in the past European sovereign debt crisis, the authorities banned naked/uncovered purchases of sovereign CDS based on EA countries (International Monetary Fund (2013)).

[1] The Spring 2020 European Commission (EC)'s Economic Forecast predicts that the eurozone economy will suffer "a recession of historic proportions this year," with soaring national debts entrenching economic

Also, in times of crises, central banks provide price support to sovereign bonds in both primary and secondary markets. Thus, CDSs and bond yields are no longer indicative of what investors think about the credit risk but reflect more a mix of default risk expectations and forecasts of rescue measures. This is yet another instance of Goodhart's Law - *'a variable that becomes a policy target soon loses its reliability as an objective indicator'* (Goodhart (1975a), Goodhart (1975b)). An additional widely used measure is credit rating of sovereigns, but studies examining their determinants also suggest the pro-cyclical nature of credit ratings and their inadequate treatment of the domestic fiscal stance (see Soudis (2016)). Besides, credit rating agencies systematically under- or over-estimate risks (see, e.g., Amstad and Packer (2015)), raising concerns about the information content of credit ratings and their association with sovereign spreads and default risk (see Binici et al. (2018)).

Moreover, since most sovereign debt contracts offer no explicit seniority to particular groups of creditors, the traditional sovereign credit risk measures do not differentiate between the bond holdings of different types of creditors. However, in survey analysis, Steinkamp and Westermann (2014) showed that almost 90% of the market participants expect at least one of the multilateral official creditors' holding to be senior to private investors.[2] These authors also document the reactions of rating agencies, which justified their downgrades explicitly pointing to the seniority issue. The Greek debt restructuring in 2012 also validated this differentiation since asymmetrical losses were observed across creditors and across debt instruments based on the seniority of creditors and maturity of different bonds (see, e.g., Zettelmeyer et al. (2013)).

In this context, this paper makes two important contributions to the existing literature. First, it presents a new framework to measure and analyse sovereign credit risk in currency union countries using the structural model of Merton (1974), which was extended towards

divisions between countries. According to the EC, the eurozone is projected to contract 7.7% this year, however the hit will be particularly hard in its southern members, with Greece, Spain and Italy projected to contract by close to 10% in 2020 and unemployment rising sharply in Spain in particular. Moreover, it forecasts that by this year's end, seven eurozone economies will have debts exceeding 100% of their gross domestic product, with Greece's ratio near 200% and Italy's rising to 159% from 135%. That of the eurozone as a whole is expected to increase above 100%.

[2]They considered the European Central Bank (ECB), the European Financial Stability Facility (EFSF), the European Stability Mechanism (ESM), the International Monetary Fund (IMF), ad the European Investment Bank (EIB) as multilateral official creditors.

sovereign credit risk by Gapen et al. (2005).[3] Unlike traditional indicators of sovereign risk, the sovereign distance-to-default (*DtD*) indicator that we propose, not only uses market-based measures but offers the best possibility for incorporating the seniority structure of creditors in an already existing theoretical model. To the best of our knowledge, this paper is the first that adapts the existing CCA-based methodology for countries which are members of a monetary union (EA) and lack the ability to inflate away its debt in a distressed situation. Based on creditors' seniority, we define a unique priority structure of debt holders and incorporate it into the theoretical model to calculate the credit risk for all EA countries. Secondly, the paper contributes to the existing literature by comparing the proposed indicator with the traditional vulnerability indicators (*CDS*, sovereign bond yields and credit rating), by means of Granger-causality tests and regression analysis, to assess the forward-looking nature of the proposed indicator and to identify its main drivers.

Our results suggest that the addition of this idiosyncratic component for individual sovereigns which is primarily linked to the sectoral distribution of their creditors, especially the debt held by multilateral lenders and domestic banks, increases the information content of the sovereign credit risk measure. By analysing and comparing the behaviour of sovereign *DtD* with three of the most relevant market based sovereign credit risk indicators, our results indicate that sovereign *DtD* indicator is the leading indicator. The Granger causality test reveals a clear unidirectional causality relationship running from sovereign *DtD*s to sovereign bond yield, CDSs, and credit ratings (and only bidirectional Granger-causality relationships between *DtD* and *CDS* and between *DtD* and sovereign bond yield in a few instances), suggesting that the *DtD* series contains useful information that is not present in the traditional sovereign risk indicators.

Moreover, the regression analysis suggests that macroeconomic fundamentals are the main drivers of sovereign risk measured by the proposed sovereign *DtD* indicator, while market sentiment variables are the key determinants of the traditional measures of credit risk. As most sovereign debt contracts offer no explicit seniority to a particular group of creditors, the traditional market-based sovereign risk measures might be increasingly reflecting the risk for the junior claim holders, thus creating a bias in all credit risk measures. This can help us to partially reconcile the increasing deviation between our proposed *DtD* and other traditional risk indicators.

The rest of the paper is organized as follows. Section 2 provides a review of the empirical literature on the main drivers of the traditional sovereign credit risk indicators. In Section 3, we give a conceptual overview of the Merton model, with an explanation of the basic features of the quantitative model. This is followed by a discussion of the challenges facing the direct application of this model to the EA setting. Section 4 shows how this model can be modified and used to quantify the credit risk for EA countries. Section 5 enumerates

[3]The basic approach rests on the generalization of the option pricing theory pioneered by Black and Scholes (1973) and Merton (1974). The principle underlying the model is that if the liabilities of a legal entity have different priority (e.g., senior and junior), then the junior claims can be modelled as a call option on the asset value of the legal entity with senior claims as the strike price. 'Senior status' means that the preferred lender is the first to recover its money in case of insolvency. The subordinated creditor, or junior creditor, on the other hand, receives only what is left after senior claim holders have been paid.

the databases used and the practical considerations in sovereign credit risk calculations. We also illustrate the application of our modified model to the actual data of EA countries for the period 2004Q1-2019Q2. Section 6 explores the forward-looking nature of sovereign *DtD* indicators over the traditional ones by means of Granger-causality and uses regression analysis to disentangle their potential drivers. Finally, Section 7 offers some concluding remarks.

2. Literature review on traditional sovereign credit risk measures

The sovereign debt crisis in Europe, which began in late 2009, revived the literature on EA sovereign yield spread drivers and has attributed increasing importance to uncertainty and variables reflecting investment confidence and perceptions for the upcoming economic activity (see, among others, Georgoutsos and Migiakis (2013) and Beirne and Fratzscher (2013)). Many authors have also stressed the importance of other fundamental variables beyond the country's fiscal position to explain yield spread behaviour after the outbreak of the crisis (see, e.g., Acharya et al. (2014)). In particular, Gomez-Puig et al. (2014) empirically investigate the determinants of EA sovereign bond yield spreads with respect to the German bund from January 1999 to December 2012, using panel data techniques and examining the role of a very exhaustive set of potential drivers. Their results stress that the rise in sovereign risk during the crisis can only partially be explained by the evolution of local macroeconomic variables. Specifically, they find that the relevance of the variables that measure global market sentiment increased during the crisis, especially in peripheral EA countries.

These results have been corroborated by many other authors. Aristei (2014), who also investigate sovereign spreads drivers in ten EA countries during the 2000-2012 period, show that proxies of consumer and market sentiment and expectations strongly affect spreads behaviour, especially during the crisis. Silvapulle et al. (2016), whose analysis focuses on peripheral EA countries during the 1999-2013 period, find that market sentiment variables (the stock returns or the VIX index, among them) had a significant impact on bond yield spreads in the crisis period. Boysen-Hogrefe (2017) argue that, since the announcement of the outright monetary transactions program (OMT), the debt-to-GDP ratio has become less relevant as a determinant for government bond spreads, while financial markets have become more concerned about the willingness and capability to cooperate with the institutions that conduct the adjustment programs. Finally, the analysis of Paniagua et al. (2017) also provides empirical evidence suggesting that not only fiscal indebtedness, but also a shift in global risk aversion and the worsening of other fundamentals, have played a significant role in explaining the evolution of long term yield spreads in peripheral EA countries.

The nature of sovereign credit risk using *CDS* data has been studied by Longstaff et al. (2011) for a sample of 26 developed and emerging countries during the 2000-2010 period by conducting a principal component analysis of the changes in sovereign *CDS*. Their results show that sovereign credit risk measured by *CDS*s tends to present much higher correlations across countries than equity index returns for the same countries, due to the dependence of sovereign credit spreads on a common set of global market factors (see also Ang and

Longstaff (2013)). Specifically, they find that a single principal component accounts for 64% of the variation in sovereign credit spreads. Badaoui et al. (2013) also try to isolate default risk from the sovereign risk premium in a sample of emerging market countries during the period 2005-2010; their decomposition exercise puts forward the idea that the increase in sovereign *CDS*s observed during the crisis period was mainly due to a surge in liquidity rather than to an increase in the default intensity. Broto and Perez-Quiros (2015), who analyse the sovereign *CDS*s of ten OECD countries with a dynamic factor model, conclude that although the *CDS* premium contains highly relevant information on sovereign risk, it must be previously corrected by the portion of the premium related to overall risk aversion and qualified by the contagion effects that may be present in it. Blommestein and Qia (2016) also find that contagion from the global financial market is an important factor affecting the pricing of *CDS*s in their sample of peripheral EA countries.

Another interesting result is that, in contrast to previous studies which focused on pre-crisis periods, Blommestein and Qia (2016) find that domestic and economic financial developments have little impact on sovereign credit risk in Greece, Ireland, Portugal and Spain during the crisis. The causality is in fact the other way round: sovereign credit risk significantly affects domestic economic and financial developments in crisis times. Fabozzi and Tsu (2016) introduce a novel technique of factor decomposition (independent component analysis) to investigate the behaviour of EA sovereign *CDS*s during the debt crisis. Their results identify three important factors: the risk associated with the peripheral countries, the global risk, and the EA common risk. They also show how the main source of risk changes over time: in 2009, it was the global factor, in 2010 the peripheral factor, and finally in 2012 the EA common factor. Finally, Aizenman et al. (2013) and Rubia et al. (2016) agree that if sovereign *CDS*s are wrongly assumed to solely reflect default risk, the severity of the underlying market conditions may be substantially overestimated, particularly during periods of distress. Specifically, according to Rubia et al. (2016) the case of peripheral EA countries in the midst of the debt crisis might illustrate this point accurately, since sovereign *CDS* contracts were traded at prices that were too high to reflect solely the credit default risk premium.

Finally, credit rating agencies (CRA) have played a prominent role in the recent financial crisis. They assign a credit rating to sovereign and private sector borrowers which indicates the probability of their failing to fulfil their obligations in their debt issues. Specifically, understanding the dynamics of sovereign credit ratings is highly relevant given their implications for capital flows and their strong link with private ratings. Despite their importance, the CRA do not provide enough detail about the ratings' determinants or their rating procedures (Mora (2006)), in spite of some recent regulatory initiatives to improve transparency. Some empirical literature has examined the main determinants of ratings and most papers state that CRA do not adjust adequately to domestic indicators. For instance, Soudis (2016), who applies the extreme bounds analysis technique to approximately 30 factors proposed by the literature as determinants of the ratings, finds that variables such as rule of law, openness to economic flows, central bank independence, and market-friendly policies are more robustly correlated with the ratings than foreign reserves, fiscal deficit, sovereign bond yields, and economic growth. Likewise, Boumparis and Panagiotidis (2017), who examine ratings determinants for EA countries during the 2002-2015 period, find that economic policy uncertainty impacts negatively on credit rating, especially in the lower rated countries. In other words, the creditworthiness of low rated countries takes a much bigger 'hit' than that of high rated countries when uncertainty rises. Other authors conclude that there is a certain amount of lag in the agencies' response to domestic variables and the debate revolves around the procyclical or sticky nature of ratings. Some authors (Ferri et al. (1999) and Monfort (2000), among them) point out that ratings are procyclical, meaning that in downgrade phases CRA are oversensitive to fundamentals and this, in turn, contributes to exacerbating the existing crisis. Other authors, such as Mora (2006) state that ratings are sticky rather than procyclical (they are adjusted only when there is a sufficiently large divergence between predicted and assigned ratings). More recently, Broto and Molina (2016) present mixed conclusions, as the reaction of the agency to macroeconomic developments differs during downgrade and upgrade periods: downgrade phases would have a procyclical nature, with a certain amount of lag, whereas upgrade periods would tend to be sticky.

All in all, the existing empirical literature on the determinants of traditional sovereign credit risk measures (bond yield spreads, *CDS* and ratings) suggests that those indicators are driven by factors other than the fiscal position, especially in times of crisis. In other words, since they are market based indicators and do not solely reflect default risk, they may substantially overestimate the difficulties of governments in repaying their debt, especially in periods of distress. In this context, the sovereign *DtD* indicator proposed in this paper - which includes both accounting metrics and market-based measures - aims to isolate sovereign credit risk by using information from the public sector balance sheets to build it up.

3. An overview of CCA

Consider a legal entity (firm, bank or sovereign) whose capital structure consists of only two types of liabilities (both due at time T), differing only in terms of their seniority.[4] For simplicity let's call them - senior and junior claims. Also, assume that the entity promises to pay a fixed amount S to the senior creditors, and the remainder to the junior creditors. Therefore at maturity T, if the total value of assets of the entity is $A(T)$, then the pay-off for the senior claim holder 'P_S' will be, $P_S = min\{S, A(T)\}$, while the pay-off for the junior claim holder 'P_J' will be $P_J = max\{A(T) - S, 0\}$.

This pay-off for the junior creditors is analogically similar to the pay-off for the buyer of a typical call option. For a given strike price K, the pay-off for the buyer of the call option depends on the firm's equity price E, and is given by $P_C = max\{E - K, 0\}$, where E is the firm's equity value at the maturity of the option. CCA exploits this analogy and the fundamental relationships between the value of an entity's assets and the dependent contingent claim (the call option). The junior claims are modelled as an implicit call option on the value of the entity's assets while considering the senior claims as the strike price.

[4]By seniority, we mean that the senior creditors are the first to recover their money in case of insolvency while the junior creditor receives only what is left once the senior creditors have been paid.

So if the entity's future senior claims are known and its junior claims are tradable in the marketplace, then CCA uses this information to derive the value of the entity's asset (A) and asset volatility (σ_A). The methodology is well established in the literature (see, e.g., Black and Scholes (1973), Merton (1974, 1977), Gray and Malone (2008), Gray et al. (2011)). For a detailed presentation, please see Appendix A.

Distress occurs when the market value of an entity's assets declines relative to its contractual obligations (S in this case) or when asset volatility increases such that the value of assets becomes highly uncertain and the probability of the value falling below the contractual obligation increases. Default occurs when the value of an entity's assets falls below its contractual obligation known as the 'default point' in the literature. One way to define this concept is through the calculation of "Distance-to-default (DtD)" which is defined as the number of standard deviation the entity's asset value is away from its contractual obligation.

$$Distance - to - default \ (DtD(t)) = \frac{A(t) - S}{A(t)\sigma_A(t)} \tag{1}$$

An alternate way is to define a risk-adjusted Distance-to-default (DtD^{RA}) as

$$DtD^{RA}(t) = \frac{log(\frac{A(t)}{S}) + (r - 0.5\sigma_A^2)(T - t)}{\sigma_A\sqrt{T - t}} \tag{2}$$

Here r denotes the risk-free rate. If substituted in the normal cumulative density function, we can calculate the probability of default ($PD(t)$) as,

$$PD(t) = P[A(t) \leq D] = \Phi(-DtD^{RA}(t)) \tag{3}$$

Conceptually there is not much difference between these risk indicators. The level and variation vary numerically but the change always points in the same direction for the entity's health. Given this, from now on, we will document all our analysis based on the DtD calculated using equation (1).

3.1. Application of CCA balance-sheet approach for firms

The typical liability structure of a firm has two basic components: debt and equity contracts. A formal insolvency regime for corporate debt restructuring sets out, in general terms, how these different types of claimants on a distressed firm will be treated in a restructuring process and establishes the order of payment in the event of outright liquidation. As the contracts suggest, the bankruptcy laws consider debt holders as senior claimants compared to shareholders. Debt gets paid first, and whatever remains is paid to the shareholders. As shareholder claims are junior compared to creditors, the value of the firm's equity can be modelled as a call option on its assets in which the outstanding debt is considered as the strike price. If the firm is publicly traded then CCA can use their debt and equity price data to derive a set of credit risk indicators. Moreover, although a firm's liability structure usually involves debt and equities of many different kinds with different priorities, an extensive survey of the literature suggests that for corporate credit risk measurement the distress barrier can be calculated as the sum of short-term debt, interest payments due within a year, and 50% of the long-term debt (see Singh et al. (2015)).

3.2. Application of CCA balance-sheet approach for emerging market sovereigns

In the case of emerging market sovereigns, in order to apply the CCA, we must first understand their liability structure. For the systematic presentation, Table 1 shows a simplified version of the sovereign accounting balance sheet.[5] On the asset side, Foreign reserves measure the net international reserves of the public sector. Net fiscal asset is the present value of the primary fiscal surplus over time (the present value of fiscal surplus minus interest payments) while Other public assets include the government's equity in public enterprises.

[Table 1 about here.]

On the liability side, Base money is a liability of the monetary authorities and consists of the total currency in circulation and bank reserves (required bank reserves, excess reserves, vault cash). Local-currency debt of the government and monetary authorities are the total government-issued debt held outside the monetary authorities and the government. Foreign-currency debt is the part of the sovereign debt which is denominated in foreign currency. It is usually held by foreigners. Guarantees compose of the implicit or explicit financial guarantees provided by the government to banks, financial institutions or contingent pension/social obligations.

The CCA approach ignores the asset side of the balance sheet and works only with the liability side. It circumvents the problems of assessing the market value of all sovereign assets by estimating sovereign asset value and volatility indirectly with information on observable values of the liability side of the balance sheet.[6]

Given that liabilities (foreign and local currency debt) are claims on current and future assets, this approach yields an 'implied' estimate for a sovereign's assets value and volatility. However, since seniority is not defined by legal status, as in the case of corporate liabilities, it must be inferred from observed government behavior. The emerging countries debt default and restructuring experiences of the last four decades suggest that governments often make strenuous efforts to remain current on their foreign-currency debt. These efforts effectively

[5]This section borrows heavily from Gray et al. (2011).

[6]The problem can also be approached from the asset side of the sovereign balance sheet. Foreign reserves can be directly measured. For the Net fiscal assets, a reasonable value can be estimated by discounting all future expected cash flow (such as primary surplus) with an appropriate discount rate. Other public assets value can be determined from the observed market prices of all or part of the assets. This can be a market price quote, direct observation, bid-ask quote or other similar direct measures. In the case of illiquid securities for which no direct market price is available, a comparable or adjustable comparable security can be used as a proxy. Different expected future scenarios can then be generated to gauge the individual asset volatility (a procedure very similar to Debt Sustainability Analysis used by World Bank and IMF). The sovereign asset volatility can then be computed by aggregating the volatility of the individual assets using a weighting function. The method looks straightforward but in fact is very difficult to apply. The tradable financial assets have direct or comparable observable market prices, but the implicit assets are extremely difficult to measure as this requires projecting the future cash flows, deciding the appropriate discount rate, and determining all the relevant components that underlie the cash flow projections for tangible and intangible items included in the asset value estimation.

make foreign currency debt senior to domestic currency debt when governments show flexibility in issuing, repurchasing, and restructuring (see Eichengreen et al. (2002) and Sims (1999)).[7]

Thus, sovereign local currency debt can be modelled as an implicit call option on a sovereign's asset value. The market value of local currency debt and its price volatility is then used to derive the implied market value and volatility of sovereign assets. While the promised payments, or distress barrier, are known with a fair degree of certainty over a time horizon based on the maturity profile of foreign currency debt, the literature defines the "distress barrier" as the present value of the promised payments on foreign-currency debt (see Gray et al. (2011)). Sovereign distress occurs when the sovereign assets are insufficient to cover the promised payments on the foreign-currency debt.

We are assuming that the junior lenders' pay-off is $P_J = \max\{A - S_S, 0\}$, where, S_S represents the senior creditors claim on government assets. However, being the junior creditor is not exactly the same as being a equity holder here. As a junior creditor, the maximum claim on the government assets is limited by the amount of the junior loans (S_J). Analytically, in these circumstances, the pay-off should be

$$P_J = \max\{A - S_S, 0\} - \max\{A - (S_S + S_J), 0\}$$

The cap on the maximum pay-off renders the junior creditors a writer of another call option with strike price $S_S + S_J$. This second component clearly doesn't matter much in times of elevated default risk, but it will change the dynamics of the DtD measure in calmer periods.

The probability of sovereign distress is higher when a bigger fraction of debt is denominated in a foreign currency, or when most of the foreign currency liabilities are short-term (rollover risk is high). Sovereigns can also sometimes trade below their contractual liabilities for a significant period of time if most of the liabilities are long-term, if most of the debt is denominated in the domestic currency or if the expected future fiscal position looks bright (higher implicit asset value).

4. The modified approach: Application to EA countries

The most prominent feature of the EA is that, unlike emerging countries or other developed economies (e.g., US, UK, and Japan), individual EA countries are part of a monetary union. As part of the union, they do not have the possibility to inflate/dilute local currency debt in a distress situation before defaulting on foreign currency debt (for a detailed discussion, refer to Cochrane (2005) and De Grauwe (2012)). This effectively makes all EA sovereign debt 'foreign currency' debt, since their own central banks cannot print the currency in which their debt is denominated. Thus a case cannot be made that foreign currency debt holders are senior to local currency debt holders.

[7]Note that the underlying reason for this flexibility is the unlimited capacity of governments to print their own currency.

Also under the current institutional arrangement in the EA, the assets and liabilities of the monetary authority (the ECB) are independent of the sovereigns. In a practical sense, the monetary authority is just another lender to the sovereigns. The standard government view that credit from monetary authorities is the most junior obligation breaks down, and failing to honour this commitment can have serious consequences. This also exposes EA governments to the bouts of fear and distrust in the ECB's function as the lender of last resort. These fears can trigger a liquidity crisis, which can easily turn into a solvency crisis; higher interest rates and worsening debt dynamics can be self-fulfilling and sovereigns can effectively end up in default (see Saka et al. (2015)).

The loss of control over domestic currency for EA countries, however, does not place all creditors of a EA sovereign at par with each other. To assess the seniority status of different creditors and their precise place in the pecking order, we study the central episode of the European debt crisis - the restructuring and near-elimination of Greece's sovereign bonds held by private investors, comprising a face value of more than 100% of Greek GDP in March/April 2012 - together with the debt restructuring experience of multitude of emerging countries (for a detailed overview, refer to Roubini and Setser (2004)). The Greek sovereign debt default, first agreed in summer 2011 and implemented in spring 2012, is specially relevant here. It was the first sovereign default in the postwar period in an advanced economy and, despite regular claims to the contrary, it has set a precedent that members of the euro area might default if their sovereign debt burden becomes unsustainable. Thus, it has shown that a country default or a debt restructuring can take place for a EA country without triggering that country's exit from the eurozone. While no other euro area member has restructured its sovereign debt to date, according to Whelan (2013), the institutional structures that were put in place are consistent with the likelihood of future defaults. For example, the European Stabilization Mechanism (ESM), was put on a permanent statutory basis and its underlying treaty clearly states that "*In accordance with IMF practice, in exceptional cases an adequate and proportionate form of private sector involvement (PSI) shall be considered in cases where stability support is provided accompanied by conditionality in the form of a macro-economic adjustment programme.*"

We start our analysis here with the classification of different sovereign creditors. Instead of focusing solely on the place of residence (foreign vs domestic), we also consider their institutional characteristics. Specifically, we follow the guidelines established by the World Bank (WB) and the International Monetary Fund (IMF) to understand institutional characteristics.[8] We define the institutional unit as an economic entity that is capable, in its own right, of owning assets, incurring liabilities, and engaging in economic activities and in transactions with other entities.

4.1. Classification of creditors according to their place of residence

The place of residence -domestic or foreign- of a sovereign creditor is important since the public debt owed to foreigners is quite different from debt owed to domestic residents, both

[8] To see institutional characteristics in detail, refer to the (Quarterly Public Sector Debt Statistics (QPSD) dataset

from the political and economic point of view. From a political point of view, the foreign creditors of a sovereign cannot vote for the higher taxes or lower expenditure needed to service the debt. It is therefore much less likely that a highly indebted government would obtain a majority for these politically difficult measures if the debt service was destined for foreigners. From a purely economic point of view, a higher interest rate or risk premium just leads to more internal redistribution (from taxpayers to bondholders) in the case of domestic debt. By contrast, in case the debt is owed to foreigners, higher interest rates lead to a welfare loss for the country as a whole because the government has to transfer resources abroad.

According to some authors (see Gross (2013) among them), the euro crisis was not really about sovereign debt in general, but about foreign debt which constitutes the underlying problem for the solvency of a sovereign in the euro area.[9] Indeed, it is widely agreed that the euro debt crisis at its heart is a balance-of-payments crisis. It started with a 'sudden stop' to capital which used to flow within the euro area from the surplus countries in the north (principally Germany and the Netherlands) to countries in the periphery of the euro zone (such as Spain, Ireland, Greece, and Portugal) who had been growing rapidly thanks to those capital inflows. Nevertheless, the counterpart of the latter were large current account deficits.[10] When the flows of capital dried up then both the governments and the private sector in these countries had difficulties financing ongoing deficits and rolling over the existing stocks of debt.

4.2. Classification of creditors according to their institutional characteristics

Why institutional characteristics matter? In general, government bonds come with a *pari passu* clause. However, the history of default and restructuring experiences in the context of sovereign lending makes it unclear what *pari passu* really means (see Weidemaier et al. (2013)). For instance, the IMF, which has proven its seniority in the financial crises of the past decades, is *de jure* not senior - it awards its credit lines without any corresponding clauses in its contracts or institutional by-laws. Nevertheless, its seniority is widely accepted and has never been challenged in the course of the financial crisis, by any of the creditors. Even bilateral official creditors have always respected the IMF's privilege position. Indeed, the historical willingness of bilateral creditors to restructure their claims in order to ensure

[9] This difference between the economic effects of foreign and domestic debt had been particularly important in the context of the past euro debt crisis. In some countries (Italy) the debt was mainly domestically held, whereas in others (Greece) it was mainly foreign. The case of Belgium was particularly interesting because the risk premium on Belgian government debt remained modest throughout most of the euro crisis period, although the debt ratio of the country was above the euro-area average (around 100 per cent of GDP)-and it went without government for over a year. But Belgium, in contrast to Portugal or Spain, had run current account surpluses for a long time and thus accumulated a large stock of foreign assets.

[10] Chisiridis et al. (2020) have recently shown that an expansionary policy of northern EA countries and increased competitiveness in the southern EA countries could alleviate trade imbalances of the debtor EA economies and that, from the southern EA perspective, internal devaluation decreases output but at the same time reduces current account deficits.

payment to the IMF has been central to the idea of the fund's preferential status.[11] Even during the Greek debt restructuring, the most favourable treatment achieved by other institutional lenders were at par with the treatment of the IMF. This makes the IMF *de facto* the senior lender of all (see Roubini and Setser (2004) and Steinkamp and Westermann (2014), among others).

In the similar vain, other multilateral lending facilities like the first Greek loan facility, the temporary rescue fund (EFSF), and the permanent rescue fund (ESM) are *de jure* not senior. However, they constitute multilateral claims of institutions-the Eurogroup or the Eurosystem of Central Banks-which are widely accepted as preferred creditors. A sovereign's desire to maintain its future access to emergency financing and a good working relationship with the other governments that provide this is a powerful incentive to follow the convention of paying multilateral creditors even if it defaults on its other debts. Sometimes the lending clauses explicitly give them preferred creditor status, junior only to the IMF loan. So even if *de jure* the preferred creditor status of multilateral institutions is often ambiguous, their seniority was accepted by market participants.[12]

For the case of EA countries, the most challenging task is to understand the role of ECB as a sovereign creditor. The ECB became an important creditor of countries in crisis via its Securities Markets Programme (SMP), collateralized lending to financial institutions and, later, the Outright Monetary Transactions (OMT) in order to stabilize sovereign bond yields in secondary markets. As all government bonds bought in the open (secondary) market contain the same legal clauses, it became unclear how these bonds would be treated in case of restructuring. In some cases (like the OMT), the ECB explicitly acknowledged that it accepts the same priority as other private creditors in accordance with the terms of those bonds, while in other cases (like the Public Sector Purchase Program (PSPP)), it was holding bonds on a risk sharing basis with the sovereign or national central bank. However, accepting *pari passu* treatment did not mean that the ECB was open to participating in voluntary debt restructuring, such as the Greek PSI in March/April 2012. The Greek debt restructuring proposal excluded the bond holdings of the ECB - the single largest holder by far, with 42.7 billion euros (16.3% of total Greek debt).[13]

Another interesting group of creditors is the domestic deposit-taking corporations (the banks). Markets believe that governments implicitly or explicitly undertake to honour the liabilities of *too-important-to-fail* banks.[14] In many cases, we can think of these guarantees to *too-important-to-fail* banks as senior claims. The reason for this is that a sovereign's cred-

[11] There is surprisingly little *de jure* evidence that multilateral lenders are indeed senior to other creditors. It is primarily a convention and follows from the idea that, in future crises, this lender of last resort may be needed again in order to borrow further resources. Kletzer and Wright (2000) show in a formal analysis that this reason is actually sufficient and that no external enforcement is required.

[12] The Greek debt restructuring proposal excluded the bond holdings of other national central banks (5% of the total) and the European Investment Bank (EIB). For more details, please refer to Zettelmeyer et al. (2013) and Steinkamp and Westermann (2014)).

[13] For detailed restructuring process, refer to Zettelmeyer et al. (2013) and Steinkamp and Westermann (2014)).

[14] Grande et al. (2013) show that these guarantees help reduce risk premium on banks' liabilities and that their effect is proportional to the sovereign's creditworthiness. Implicit guarantees are harder to measure,

itworthiness depends heavily on the creditworthiness of its domestic banks. A deterioration in the creditworthiness of banks, as perceived by the market, can drastically increase the sovereign's contingent liabilities. This may cause the government's own creditworthiness to deteriorate. Since the asset side of the bank's balance sheet typically consists of substantial holdings of domestic government debts, a deterioration in the government's creditworthiness can cause huge losses in its banks' portfolios. Sovereign fiscal strains can also impact banks' funding conditions since government securities are typically used as collateral to obtain short-term funding in debt markets.[15] Thus a self-fulfilling vicious loop develops in which deterioration in banks' health can increase the sovereign's contingent liability and fiscal strain which in turn has a negative impact on the banks' health.[16]

Banks are also locked into a long-term relationship with the government. During times of crisis, domestic banks in fiscally stressed countries increase their holdings of domestic sovereign debt considerably relative to foreign banks. This effect is stronger for state-owned banks and for banks with low initial holdings of domestic sovereign debt. This practice complies with the moral suasion argument[17] where banks choose to respond to pressure from their government on the understanding that current favours will be reciprocated in the future (for the presentation of the idea, refer to Horvitz and Ward (1987)). Ongena et al. (2019) provide evidence of this behaviour during the European sovereign debt crisis. This entails a natural collusion between two parties that have an equal interest, and so governments have an incentive to bail-out certain creditors more than others. Further uses of the bailout funds also indicate the priority banks receive over any other credit institution.[18]

In summary, past experiences, survey responses and credit rating agencies' decisions have all suggested that a certain group of institutional creditors are *de facto* senior to other

but Angelini et al. (2011) provide suggestive evidence that they may be among the reasons why on average large banks borrow at a discount.

[15]For example, in repo markets, a fall in the price of the sovereign bond can trigger margin calls or increase the haircut requirements, thus reducing the liquidity that can be obtained via a given nominal amount of sovereign paper. In an extreme scenario, a sovereign's rating downgrade below investment grade status disqualify it as collateral in funding operations, or as investments suitable for certain categories of investors such as pension and insurance funds.

Sovereign ratings also represent a ceiling for the ratings assigned to all other domestic borrowers. Increasing sovereign stress can lead to a ratings downgrade for a sovereign as well as its domestic banks, which in turn will increase the funding cost for banks.

[16]As suggested by a referee, the European Banking Union (EBU) is designed to cut the sovereign-bank nexus and, if credible, could lead to a lower correlation between sovereign and bank default risks. The first two pillars of the banking union are a Single Supervisory Mechanism (SSM) and a Single Resolution Mechanism (SRM) for banks (see, e.g., Howarth and Quaglia (2014)). The SSM took up its authority on 4 November 2014, and the SRM entered into full force on 1 January 2015. We plan to extend our research using a longer sample in order to evaluate the effect of the establishment of the EBU.

[17]The term *moral suasion* originally refers to an appeal to 'morality' or 'patriotic duty' to induce behaviour by the persuaded agency that is not necessary profit-maximizing for it. This appeal can be combined with a threat of a more repressive regime, as in the case of banking - intensified supervision, a revocation of banking license, or limited access to central bank funding (Horvitz and Ward (1987)).

[18]Gross (2013) presents a small stylized model where he shows that it is not possible to impose a large haircut on holdings of government bonds by the financial system without risking a collapse of the economy and thus the capacity of the government to service its debt

market creditors (preferred creditor status), even if this is not formalized *de jure*. The large increase in the share of sovereign debt holding by these senior *de facto* creditors in the peripheral EA countries total debt outstanding and its observed co-movement with the interest rate spreads (refer to Figure 4 in Steinkamp and Westermann (2014)) makes the question addressed in this paper extremely timely and policy relevant. As a result, we focus here on the *de facto* rather than *de jure* classification.

4.3. Application to EA

Based on the discussion above, we classify sovereign's creditors in two braod categories based on place of residence - domestic vs foreign. Domestic creditors are further re-classified into the following three categories based on institutional characteristics:

(a) *Domestic central bank*;
(b) *Domestic banks*: deposit-taking corporations except the central bank comprising all resident public deposit-taking corporations, except the central bank, that are controlled by general government units or other public corporations; and
(c) *Domestic non-banks*: It consists of all resident non-deposit taking financial corporations, non-financial corporations (corporations whose principal activity is the production of market goods or nonfinancial services), households, and non-profit institutions serving households.

The foreign creditors are further classified into:

(a) Foreign officials - Multilateral creditors outside the EU - the IMF, the World Bank (WB), the ECB, Other multilateral creditors - EFSF/ESM, EIB (the European Investment Bank), Other national central banks within the EU;
(b) Foreign banks; and
(c) Foreign non-banks.

Based on the discussion in the previous section, we define the priority structure of sovereign debt based on creditors' location and institutional classification, as shown in Table 2 (in decreasing order of priority).[19] We extend to the existing literature in three different ways: (1) Diverging away from the previous literature, we define a unique seniority status of domestic and foreign creditors based on their institutional characteristics (instead of currency, legal jurisdiction or other bond covenants); (2) We define the pecking order based on the *de facto* treatment of sovereign creditors instead of the *de jure* order; and (3) By classifying domestic banks holdings as senior, we are able to integrate and quantify the risk emanating from the sovereign-bank nexus observed in times of crises as part of the sovereign risk measure.

[Table 2 about here.]

[19] Another way to classify the priority structure of sovereign liabilities could be based on the laws under which the contractual agreement is signed. Debt agreements signed under foreign jurisdiction would have a higher priority than debt agreements signed under domestic law, as governments during the time of crisis can change the terms of the agreement by a legislative fiat. But due to limited data accessibility, we prefer not to use this classification.

5. Data and methodology

5.1. DtD Data description

In this subsection, we enumerate the datasets used in building our sovereign distance-to-default (DtD) - an alternative indicator of sovereign credit risk.

1. *Risk-free interest rate:* We consider the 10-year benchmark German bund yields as the risk-free rate (Source: Eurostat).[20]
2. *Value of sovereign debt:* We use the comprehensive investor base dataset for advanced economies created by Arslanalp and Tsuda (2014). The advantage of using this dataset is multifold: First, it creates a common definition of sovereign debt (general government gross debt on a consolidated basis). Second, a common estimation methodology is used to ensure cross-country comparability based on harmonized international data sources, such as the Bank for International Settlements (BIS), IMF, and World Bank. Third, all data are compiled either at face value or adjusted for valuation changes, where appropriate, to track investor transactions as well as holdings.
3. *Volatility of sovereign debt:* The quarterly volatility is calculated as the standard deviation of the daily sovereign 10-year bond yield. The yields are based on the long-term interest rate as defined by the Maastricht criteria and is provided by the Eurostat.[21]
4. *Sectoral sovereign bond holdings:* We use Arslanalp and Tsuda (2014) dataset for sectoral sovereign bond holdings. To compliment our analysis and to provide robust evidence, we also use the cross-country sectoral sovereign bond holdings data developed in Merler and Pisani-Ferry (2012) (available at Bruegel website) which gathers publicly available data provided by national authorities on a country-by-country basis for 12 countries (Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, UK and US).
   Note that Arslanalp and Tsuda (2014) classifies foreign investor holdings separately into the foreign official sector, foreign banks, and foreign non-banks, in contrast to Merler and Pisani-Ferry (2012) that classify them under one category (- non-resident holdings). However, the coverage in terms of time period is slightly limited. Merler and Pisani-Ferry (2012) data goes back to the late 1990s while Arslanalp and Tsuda (2014) data starts from 2004Q1.[22]

[20]Note that German bond yield is not always the lowest in EMU countries but during the time-frame of our study this was usually the case. We also used US government 10-year bond yields as risk-free rate and our results are robust to both these specifications.

[21]To check the robustness of our results, we also used the data from the National Securities Market Commission (Comisión Nacional del Mercado de Valores (CNMV)), the agency responsible for the financial regulation of the securities markets in Spain. These are daily data on bond market volatility which is calculated as the annualized standard deviation of daily changes in 40-day sovereign bond prices. The quarterly value is then computed as the average of the last three months daily volatility.

[22]We did the analysis based on both datasets and our results are robust to changing sample period.

We also consider other traditional sovereign credit risk measures in order to analyse and compare our sovereign *DtD* indicator with them. Since a large number of credit risk indicators are available in the marketplace, we stay selective and narrow our analysis to sovereign bond yields (*YIELD*), *CDS*s and the credit ratings (*RAT*). For *YIELD*, we use the Maastricht criterion bond yields (the long-term interest rates). The series relates to interest rates for long-term government bonds denominated in national currencies. The data are based on central government bond yields on the secondary market, gross of tax, with a residual maturity of around 10 years, collected from Eurostat.[23]

For CDS, we use the five-year benchmark sovereign *CDS* daily mid-quotes from Datastream as the second measure of the sovereign credit risk. These data are available from 2007Q4 until 2016Q4. Following previous studies, we focus on the 5-year maturity, as these contracts are regarded as the most liquid in the market. As for credit ratings, we follow Blanco (2001) and build a credit rating variable (*RAT*) averaging the ratings assigned to sovereign debt by Standard & Poor's, Moody's and Fitch. Using data compiled from Bloomberg, 21 different categories are considered. The first category is made up of the highest-rated debts, while the twenty-first category includes the lowest-rated debts. Therefore, by construction, the higher the value of *RAT*, the worse the rating categories.

Figure 1 shows the country-wise evolution of the sovereign *DtD* index together *YIELD*, *CDS* and *RAT*, while Table 3 provides summary information.

[Figure 1 about here.]

[Table 3 about here.]

5.2. Methodology

Based on our discussion in Section 4, we consider the priority structure of creditors shown in Table 2. We use the market value of sovereign debt in the hands of junior creditors as the equity value. The value of junior claims is calculated by multiplying the market value of the sovereign's total debt as provided by the Arslanalp and Tsuda (2014) database together with the fraction of the total debt in the hands of junior creditors. Whenever the sovereign debt is held under the risk-sharing clause, we proportionally divide the portfolio into senior and junior claims. For example, PSPP bond holdings are based on the 80% no-risk sharing clause. So we classify only 20% of the bond holdings as senior claims.[24] The default barrier is then calculated as the sum of debt holdings of all external creditors and domestic banks.[25]

[23] Given that Germany is considered in our empirical analysis, we do not use yield spreads calculated as the difference between the ten-year benchmark sovereign bond yield of each individual country and that of Germany.

[24] We would like to thank an anonymous referee for correcting our early misspecification.

[25] We also use (1) the sum of the general government's short-term debt and long-term debt where the payment is due in one year or less in nominal terms; and (2) the sum of part one and 50% of the long-term debt where payment is due in more than one year in nominal terms - to check the robustness of our results. Our results are robust to all these alternative specifications. However, to save space, we document results only on the basis of the third one.

Once the equity value, equity volatility and distress barriers are calculated, we use the procedure as documented in Appendix A to calculate the quarterly time series of sovereign *DtD* for individual EA countries.[26]

Table 4 provides summary information for the sovereign *DtD* indicators. The measurement does not include units of account as it represents the number of standard deviation the sovereign's asset value is away from its distress barrier. The average value of the sovereign *DtD*s ranges widely across countries: the lowest average is 3.82 for Greece, and the highest is 8.84 for Germany. Both the standard deviations and the minimum-maximum values indicate that there is a significant time-series variation in the sovereign *DtD* indices. For example, in the cases of Greece and Ireland, it ranges from -1.32 to 12.43 and -0.09 to 18.80 respectively. Note also that even though the core countries display a higher mean, the standard deviation is very similar across all countries.

[Table 4 about here.]

6. Econometric analysis

Taking stock of the potential commonality and differences with other credit risk measures, in this section we apply two different econometric methodologies to try to assess both the information content of the sovereign DtD indicators and its relative performance compared with other credit risk measures. To that end, we make use of Granger-causality and regression analysis.[27]

6.1. Granger-causality analysis

Granger causality is a measurable concept of causality or directed influence for time series data, defined using predictability and temporal precedence (Granger (1969) and Sims (1972)). According to Granger, X causes Y if the past values of X can be used to predict Y more accurately than simply using the past values of Y. In other words, if past values of X statistically improve the prediction of Y, then we can conclude that X Granger-causes Y. The results of the Granger causality test critically depend on the lag length choice. Most often,

[26] To understand the gains for using this default barrier, we also compare the sovereign *DtD* with three alternative specifications - (1) the sum of debt holdings to all external debt holders; (2) the sum of debt holdings of all external multilateral creditors and domestic banks; and (3) the sum of debt holdings of all external creditors, domestic banks together with domestic central bank. The results are not shown here but is available upon request.

[27] To get a sense whether our proposed sovereign *DtD* indicator is a leading indicator, we first examined the co-movement. Following common practice, we calculated the cross correlation $\rho(j)$ between DtD_{t-j} and other sovereign risk indicators (X_t) by varying j. We say that the *DtD* indicator is leading, synchronous or lagging X as $\rho(j)$ reaches a maximum for $j < 0, j = 0, j > 0$.

Results from correlation analysis (which are not shown here in order to save space, but are available from the authors upon request) reveal in most of the cases a strong negative leading relationship between *DtD* and the traditional sovereign risk indicators, given further support to the looking nature of sovereign *DtD*.

the lag length choice is done in an ad hoc arbitrary manner.[28] Additionally, these Granger causality tests are estimated using symmetric lags (i.e., the same lag length is used for all variables in all equations of the model); however, economic theory provides no compelling reason that lag lengths must be symmetric.

To overcome these problems, in this subsection we use Hsiao (1979)'s sequential procedure for identifying and estimating bivariate time series models in order to establishing causal links between the proposed *DtD* indicator and the traditional measures of sovereign risk. Hsiao (1979)'s sequential method combines Akaike's final predictive error (FPE, from now on) and the definition of Granger-causality, allowing that the lag length on each variable in each equation can differ.[29] Essentially, the FPE criterion trades off bias that arises from under-parametrization of a model against a loss in efficiency resulting from over-parametrization of the model, removing us from the ambiguities of the conventional procedure.[30]

We first test whether *DtD, CDS, RAT* and *YIELD* are stationary. We found *DtD, CDS, RAT* and *YIELD* as first-difference stationary[31] [i.e., they are I(1) variables], raising the possibility that some of them could be cointegrated (see Engle and Granger (1987)). Therefore, to investigate the existence of a Granger causal relationships from ΔDtD_t to ΔY_t ($Y_t = CDS,\ RAT,\ or\ YIELD$) and from ΔY_t to ΔDtD_t, we use the following error correction model:

$$\Delta DtD_t = \alpha + \sum_{i=1}^{m} \delta_i \Delta DtD_{t-1} + \epsilon_t \tag{4}$$

$$\Delta DtD_t = \alpha + \beta \hat{Z}_{t-1} + \sum_{i=1}^{m} \delta_i \Delta DtD_{t-1} + \sum_{j=1}^{n} \gamma_j \Delta Y_{t-j} + \epsilon_t \tag{5}$$

where $\hat{Z}_t$ is the estimated OLS residual of the cointegrating regression ($DtD_t = \mu + \lambda Y_t +$

[28]More specifically, a too-short lag length results in estimation bias while a too-long lag length causes a loss of degrees of freedom and, thus, estimation efficiency (see, e. g., Lee (1997)).

[29]An exhaustive study by Thornton and Batten (1985) have found Hsiao's method to be superior to arbitrary lag length selection and several systematic procedures for determining lag length.

[30]The Hsiao's Granger causality test has been applied in many studies (see, e.g., Chang and Lai (1997) and Gómez-Puig and Sosvilla-Rivero (2013), among others) with robust results and preferred in relation to other causality methods.

[31]These results (not shown here in order to save space, but available from the authors upon request) are initially based on traditional Augmented Dickey-Fuller (Dickey and Fuller (1981)) tests, where the null is a unit root against the alternative of stationary process and the more efficient alternatives proposed by Phillips and Perron (1998), Elliott et al. (1996) and Ng and Perron (2001), being further validated by using the Kwiatkowski et al. (1992) (KPSS) tests, where the null is a stationary. In this respect, we are very grateful to an anonymous referee for suggesting us that interest rates could be governed by near unit roots as argued by Lanne (2000). Nevertheless, given the large empirical work suggesting that very persistent series with a root very close (if not equal) to unit are better approximated by I(1) processes than by stationary ones (e.g., Stock (1997), Diebold and Kilian (2000)), it is reasonable to consider that our sovereign risk indicators are characterised by non-stationarity.

Z_t), known as the error-correction term.[32] The following steps are used to apply Hsiao's procedure for testing Granger-causality:

i) Treat ΔDtD_t as a one-dimensional autoregressive process (4), and compute its FPE with the order of lags m varying from 1 to m.[33] Choose the order which yields the smallest FPE, say m, and denote the corresponding FPE as $FPE_{\Delta X}(m, 0)$.
ii) Treat ΔDtD_t as a controlled variable with m number of lags, and treat ΔY_t as a manipulated variable as in (5). Compute again the FPE of (5) by varying the order of lags of ΔY_t from 1 to n, and determine the order which gives the smallest FPE, say n, and denote the corresponding FPE as $FPE_{\Delta X}(m, n)$.[34]
iii) Compare $FPE_{\Delta X}(m, 0)$ with $FPE_{\Delta X}(m, n)$ [i.e., compare the smallest FPE in step (i) with the smallest FPE in step (ii)]. If $FPE_{\Delta X}(m, 0) > FPE_{\Delta X}(m, n)$, then ΔY_t is said to cause ΔDtD_t. If $FPE_{\Delta X}(m, 0) < FPE_{\Delta X}(m, n)$, then ΔDtD_t is an independent process.
iv) Repeat steps i) to iii) for the ΔY_t variable, treating ΔDtD_t as the manipulated variable.

Engle and Granger (1987) and Phillips and Ouliaris (1990) residual-based tests for cointegration reject the null hypothesis of no cointegration at conventional levels between *CDS* and *DtD* for Austria, Greece, Ireland, Italy and Spain and between *YIELD* and *DtD* for Austria, Finland, France, Greece, Italy and Spain.[35] Therefore, for these pairs we test for Granger-causality in first differences of the variables, with an error-correction term added [i. e., equations (4)) and (5)],[36] whereas for the remaining cases, we test for Granger-causality in first differences of the variables, with no error-correction term added [i. e., equations (4)) and (5) with $\beta = 0$]. The resulting FPE statistics are reported in Table 5.[37]

[32]Granger causality can be estimated using single equation methods as proposed by Granger (1969), Sims (1972), Hsiao (1979) and others, as well as simultaneous equations procedures as in a VAR/VECM system of Johansen (1988, 1995). This paper uses the latter approach controlling for the presence of cointegration applying the Engle and Granger (1987)'s two-step estimations methodology. As Zietz (2000) shows, when a spurious relationship actually exists, the Engle-Granger procedure appears to be quite good at identifying it, being appreciably better than the Johansen cointegration technique.

[33]$FPE_X(m, 0)$ is computed using the formula: $FPE_{\Delta X}(m, 0) = \frac{T+m+1}{T-m-1} . \frac{SSR}{T}$, where T is the total number of observations and SSR is the sum of squared residuals of OLS regression (4).

[34]$FPE_X(m, n)$ is computed using the formula: $FPE_{\Delta X}(m, n) = \frac{T+m+n+1}{T-m-n-1} . \frac{SSR}{T}$, where T is the total number of observations and SSR is the sum of squared residuals of OLS regression (5).

[35]Due to constraints of space, these results are not shown here but they are available from the authors upon request. They were validated using the Johansen (1991) trace for the presence of cointegration. Furthermore, in light of potential near unit root problems, we also test for long run exclusion. Specifically, according to Hjälmarsson and Österholm (2010), in case no time series are found to be excluded from the cointegration space, the specification of the system is correct, both in the case of unit roots and near unit roots.

[36]In this procedure, X Granger cause Y in the short-run if the estimated coefficients on lagged values of X and X Granger cause Y in the long-run if the estimated coefficient on lagged value of error term from cointegrated regression is statistically significant (see, e. g., Banerjee et al. (1998)).

[37]These results were confirmed using both Wald statistics to test the joint hypothesis $\hat{\gamma_1} = \hat{\gamma_2} = ... = \hat{\gamma_n} = 0$ in equation (5) and Williams-Kloot test for forecasting accuracy (Williams (1959)). Besides, the highly significant estimated error correction terms provide further support for the existence of the identified Granger-causality relationships based on equations (4) and (5). These additional results are not shown here to save space, but they are available from the authors upon request.

[Table 5 about here.]

As can be seen, in all of the cases our results suggest unidirectional Granger-causality running from the proposed *DtD* sovereign indicator to the traditional sovereign indicators. We also find evidence of bidirectional Granger-causality relationships between *DtD* and *CDS* for Austria, Ireland and Italy, and between *DtD* and *YIELD* for Greece. Note that, even though the results of the cointegration tests mostly reject (except for eleven out of thirty three cases) a long-run relationship between the risk indicators under study, we find evidence of strong Granger-causal linkages between *DtD* the traditional sovereign indicators. Therefore, each *DtD* series contains useful information that is not present in the traditional sovereign indicators which in each country can help to explain the short-run evolution of *CDS*, *YIELD* and *RAT*.

6.2. Regression analysis

Finally, in this last subsection, we empirically evaluate the relevance of the variables that have been proposed in the recent theoretical and empirical literature as potential drivers of sovereign risk.

The dependent variables in our empirical analysis are the proposed *DtD* indicator and the three traditional measures of sovereign risk (sovereign bond yield, *CDS*, and rating). With regard to the independent variables (Table 6), we consider both macroeconomic fundamentals and market sentiment variables (see, e.g., Gomez-Puig et al. (2014) and references within). Three fundamental variables are used to measure the country's fiscal position; the government debt-to-GDP ratio ($DEBT$), the government deficit-to-GDP (DEF) and the index of the fiscal stance (FSI) suggested by Polito and Wickens (2011, 2012). An increase in DEF and DEBT would signal an intensification in the sovereign risk, while a rise in the *FSI* would indicate a need for higher fiscal consolidation to achieve a pre-specified debt target at any future time horizon, and therefore would have a positive relationship with sovereign risk. Moreover, the inflation rate (INF) is used as a proxy of the appreciation of the real exchange rate and, thus, the country's loss of competitiveness. A rise in inflation represents a deterioration of competitiveness; therefore, it should increase sovereign risk. The same sign is expected for the unemployment rate (U) which proxies the country's growth potential, while a negative effect might be expected between an increase in the current account balance-to-GDP (CAC) and the sovereign risk.

[Table 6 about here.]

Turning to the market sentiment variables, we used the implied volatility in the Standard and Poor's 500 index options (VIX) and a synthetic measure of financial market uncertainty in the EA (FMU) as indicators of uncertainty in the global financial and EA financial markets. We also consider national indices of economic policy uncertainty (EPU), built following Baker et al. (2016), to assess whether policy uncertainty has influenced sovereign risk, and a country-level index of financial stress ($CLIFS$) to evaluate the degree of financial stress in national financial markets. A positive sign is expected for their respective coefficients.

Finally, the consumer confidence indicator (*CCI*) is used to gauge economic agents' perceptions of future economic activity. It seems reasonable to expect a negative relationship between this and sovereign risk, since an increase in consumer confidence may lead to a rise in investor confidence in the economy's potential for growth.

As most macroeconomic data exhibit non-stationary, we tested for the order of integration of the potential explanatory variables under study by means of the standard Augmented Dickey-Fuller test and the more efficient alternatives proposed by Phillips and Perron (1998), Elliott et al. (1996) and Ng and Perron (2001). The results decisively reject the null hypothesis of a unit root at conventional significance levels for *CAC, U, DEF, DEBT, FSI, EPU* and *CLIFS* (suggesting that these variables can be treated as first-difference stationary), while we do not reject the null for *CCI, VIX, FMU* and *INF* (indicating that they are stationary in levels). Then, following i Silvestre et al. (2001) suggestion, we confirm these results using the Kwiatkowski et al. (1992) (KPSS) tests, where the null is a stationary process against the alternative of a unit root.[38]

Given the time series properties of our variables, we transform the non-stationary variables into stationary variables by differencing them[39] and use a data-based method for obtaining a parsimonious representation of the data-generating process: the general-to-specific approach (for detail, see Hendry (1995)). In this approach, the modeller specifies an initial general model that adequately characterizes the empirical evidence within his or her theoretical framework.[40] Starting from a general unrestricted model that captures the essential characteristics of the underlying dataset and contains all relevant variables and sufficient lags, this general model is reduced in complexity by eliminating statistically insignificant variables, checking the validity of the reductions at each stage to ensure the congruence of the finally selected model (via lag-order selection, F-tests on successively shorter lag groups, and F-type tests for sequentially increasing blocks of omitted variables (see Faust and Whiteman (1997) for detailed explanation)).[41] This method has proved useful in practice for selecting empirical economic models (see Hendry (2000)). Table 7 reports the empirical results.[42]

[Table 7 about here.]

[38] The results are not shown here due to space restrictions but are available from the authors upon request.

[39] The first difference operator is denoted as D(.) in the text and in the tables.

[40] The basic idea of the general-to-specific methodology is to derive a simplified representations of the complex and unknown data generating process. Therefore, the aim is to obtain a congruent empirical model with the following properties: the residuals are innovations, the conditioning variables are weakly exogenous with respect to the parameters of interest, the parameters are stable over the estimation sample, the model is economically founded, and it is data-admissible (Hendry (1995)).

[41] We consider two lags of each variable in the initial general specification.

[42] In order to address the potential problem of simultaneity or reverse causality between the sovereign risk indicators and the explanatory variables, we use two-stage least squares (2SLS) instrumental variable techniques to estimate the finally selected model. Following common practice with macroeconomic data, we use lagged terms of regressors as instruments.

As can be seen,[43] the signs of the selected explanatory variables are in accordance with the literature: a deterioration in the fiscal indicators (*DEF*, *DEBT* and *FSI*), an increase in the inflation or unemployment rates (*INF* and *U*), a rise in market expectations of future volatility (*VIX*) and an augmentation of EA market uncertainty and of country financial stress (*FMU* and *CLIFS*) are associated with a surge in sovereign risk, while an improvement of economic agents' perceptions of future economic activity (*CCI*) and an expansion in the net position of the country towards the rest of the world (*CAC*) reduce sovereign risk. The results are in line with previous studies that point out the sovereign risk drivers in the EA are a mixture of fundamental-based and perception-based factors (see, e.g., Gomez-Puig et al. (2014)). Nevertheless, it is worth to mention that, while market sentiment variables seem to play a dominant role in determining traditional measures of sovereign risk, macroeconomic fundamentals are identified as the main drivers of sovereign risk, as measured by the proposed DtD indicator. Indeed, *D(CAC), D(U), D(DEF), D(DEBT), D(FSI)* and *INF* appear more frequently as a relevant explanatory variable in *DtD*, while *D(EPU), CCI, D(CLIFS), VIX* and *FMU* are more significant when determining the evolution of *CDS, YIELD* and *RAT*. These results suggest that the *DtD* indicator isolates the fundamental and fiscal situation of the country better than the other three risk indicators, which are influenced much more by market sentiment and uncertainty.

Finally, it is worth mentioning that the estimated models pass diagnostic tests such as normality of error term, second-order residual autocorrelation and heteroskedasticity.[44] The overall regression fit is satisfactory, as measured by the adjusted R^2 value (ranging from 0.8330 to 0.8963). Therefore, our econometric modelling seems to have identified sensible and interpretable relationships between the economic variables under study.

In order to gauge the predictive power of our basic model and to assess how each selected explanatory variable contributes to the explanation of the dependent variable, we perform stochastic dynamic simulations. Table 8 reports the results for each sovereign risk indicator under study. Column 2 represents the actual values of the dependent variables averaged over the period of the analysis, while column 3 shows the averaged predicted values. The remaining columns present the contribution of the explanatory variables across countries. As can be seen, our model delivers high level of forecast accuracy. Moreover, our results suggest that while macroeconomic fundamentals are the main drivers of sovereign risk measured by the proposed *DtD* indicator (explaining an average of 68.44%), market sentiment variables are identified as the key determinants of the traditional measures of credit risk (contributing to explain, on average, 64.58% of the *CDS* risk indicator in the sample, 64.79% of the sovereign bond yields and 63.42% of the credit ratings). Interestingly, the average contribution of the macroeconomic variables in explaining the behaviour of *DtD* is higher in the central countries than in the peripheral ones (70.54 and 65.92%, respectively), while the average contribution of market perceptions to the evolution of *CDS* and *RAT* are higher in

[43] We focus our comments on general, summarizing the results by pointing out the main regularities. The reader is asked to browse through Tables 7 and 8 to find evidence for a particular country of her/his interest and for a detailed account of the impact of other explanatory variables on the sovereign risk indicators under study.

[44] The results are not shown here due to space restrictions but are available from the authors upon request.

the peripheral EA countries than in the central ones (64.66% vs. 64.51%, and 63.69% vs. 63.20%, respectively).

[Table 8 about here.]

6.3. Robustness analysis[45]

The results presented hitherto are based on estimates over the period 2004-2019. Since this period covers sub-periods with potential dissimilar perceptions on the determinants of sovereign credit risk for Eurozone member countries, we have checked the validity of the results presented in the paper over different time periods. To that end, and following a common practice in the literature, we first divide the sample in two sub-periods: before and after the European debt crisis (taking 2009-Q4 as the start of the crisis). Furthermore, given that during the estimation sample the ECB intervened heavily in the sovereign bonds market in order to stabilize it, we have also re-estimated our models before and after the asset purchase programme (quantitative easing or QE program). The selection of the break point reflects the decision taken by the ECB in October 2014 to conduct net purchases of securities under one or more of the asset purchase programmes to reduce the dispersion of the cost of debt across euro area countries (see, e.g., Hartmann and Smets (2019)).

Table 9 summarises the results by offering the relative contribution of macroeconomic fundamental variables and market sentiment variables to the explanation of the dependent variable during the different sub-period considered. Regarding the effect of the European debt crisis, we can observe a general increase in the average relevance of the macroeconomic fundamentals in explaining the evolution of all sovereign risk indicators during the crisis period: 3.04 percentage points for *DtD*, 2.88 for *CDS*, 3.01 for *YIELD* and 3.03 for *RAT*. Nevertheless, the *DtD* continues to be mainly driven by fundamental-based variables while perception-based factors continued to be the central determinants *CDS*, *YIELD* and *RAT*. It is worth to note that detected contribution of the macroeconomic variables in explaining the behaviour of *DtD* is higher in the central countries than in the peripheral ones (3.24 and 2.79 percentage points, respectively), while the average increase in such contribution are higher the peripheral EA countries than in the central ones in the traditional sovereign risk indicators (3.02 vs 2.76 percentage point in *CDS*, 3.11 vs 2.92 in *YIELD* and 3.42 vs 2.70 in *RAT*). The latter could be associated to a greater re-assessment during the crisis period of the importance of macroeconomic imbalances that had been largely ignored during the period of stability when market-based risk indicators seemed to underestimate the possibility that governments might default.[46] These results are in line with De Grauwe and Ji (2013)'s hypothesis that government bond markets in a monetary union are more vulnerable to negative market sentiments and therefore are more fragile and more susceptible to self-fulfilling liquidity crises than in stand-alone countries.

[45]We are grateful to an anonymous referee for suggesting this additional analysis.

[46]It is worth to note that the countries affected and that needed some form of adjustment program with financial assistance were precisely Ireland (2010), Portugal, Cyprus (both 2011) and Spain (2012). Over time Italy became also seriously distressed but never to the point that it had to take a rescue program.

[Table 9 about here.]

Turning to the case of the possible impact of the ECB QE programme, some authors (see, e.g., Afonso and Jalles (2019)) present empirical evidence that suggest that some non-conventional measures of the ECB contributed to reduce sovereign risk. However, we also detect a general increase in the average relevance of the macroeconomic fundamentals in explaining the evolution of all sovereign risk indicators (3.03 percentage points for *DtD*, 2.55 for *CDS*, 2.88 for *YIELD* and 2.97 for *RAT*). So, after the non-standard measures implemented by the ECB, although sovereign risk was lower, our results suggest that it was mainly driven by fundamental-based variables. It is interesting to note that the average increase in such contribution is higher in the peripheral EA countries than in the central ones (3.31 vs. 2.79 percentage point in *DtD*, 2.88 vs. 2.28 in *CDS*, 3.44 vs. 2.41 in *YIELD* and 3.41 vs. 2.60 in *RAT*). This greater relative sensitivity of the periphery is in line with its higher public debt, reinforcing the need of strengthening convergence among EA counties and solving its weaknesses in the prudential and fiscal fields in order to become increasingly credible. Once again, we observe a primary role of fundamental-based variables in explaining the behaviour of *DtD* after the QE programme, being *CDS*, *YIELD* and *RAT* mainly driven by perception-based factors.

7. Concluding remarks

The European sovereign debt crisis and the recent Covid-19 pandemic with its associated increased fiscal deficits and public debt ratios has brought public debt management to the forefront of the media and the public debate, as have showed the need to have an appropriated indicator for quantifying and monitoring sovereign risk. So, in the present environment of extreme uncertainty in the European economy and financial markets, the main objective of this paper has been to contribute to the existing literature by building up a new sovereign risk indicator for EA countries that might overcome some of the weakness we have detected in the traditional indicators (they are more influenced by the evolution of variables that capture "market sentiment" rather than by the evolution of the fundamental variables about the country's solvency and do not take into account the priority structure of creditors in their construction).

Concretely, based on the theory and practice of modern contingent claims methodology, this paper proposes a modified contingent claims model that incorporates the priority structure of creditors in measuring sovereign credit risk for the euro area countries. These new risk indicators model an important element - the total debt held by multilateral creditors (i.e., the ECB, IMF, ESM etc.), which provides additional information and helps to reconcile the country's credit risk with its underlying economic fundamentals. The approach is particularly useful as it incorporates the adverse market sentiments by taking the sovereign bond prices and volatility as input in the measurement of the sovereign risk.

By analysing and comparing the behaviour of sovereign *DtD* with three of the most relevant market-based sovereign credit risk indicators (i.e., *CDS*, sovereign bond yield and credit rating), our results indicate that sovereign DtD is a leading indicator and contains useful information that is not present in the traditional sovereign risk indicators. Moreover, the regression analysis suggests that macroeconomic fundamentals are the main drivers of sovereign risk measured by the proposed sovereign *DtD* indicator, while market sentiment variables are the key determinants of the traditional measures of credit risk.

All in all, our results show that the alternative sovereign credit risk measure proposed has a meaningful signalling power in assessing sovereign vulnerabilities, suggesting a potential role in the policy makers' tool box for diagnosis, evaluation and monitoring risks and vulnerabilities. This is relevant given the recent trend among policy makers to give a greater focus to financial stability analysis, financial system resilience and crisis prevention, as well as to face the challenge raised for sovereign debt managers by the Covid-19 crisis since in many countries, debt stresses are likely to exceed past experience across a number of dimensions (see Balibek et al. (2020)).

There are several natural extensions to our analysis. Policies aimed at reducing sovereign risk should be explored in detail in future work. Going forward, the *DtD* framework could be extended beyond the sovereign context. In addition, given the flexibility of this framework, the financial sector and sovereign risk analysis could be integrated with macro-financial feedbacks in order to design monetary and fiscal policies.

Funding

This work was supported by the Spanish Ministry of Economy and Competitiveness [grant PID2019- 105986GB-C21] and by Instituto de Estudios Fiscales [grant IEF151/2017].

Acknowledgements:

The authors wish to thank three anonymous referees for their insightful comments and suggestions on a previous draft of this paper and the Editor for guidance and encouragement. They are also very grateful to seminar participants at the University of Barcelona for helpful comments and suggestions, to the Comisión Nacional del Mercado de Valores for kindly providing the sovereign debt volatility dataset and to Vito Polito and Michael R. Wickens for providing the datasets of their Fiscal Stability Indicator. Simon Sosvilla- Rivero thanks the Department of Economics at the University of Barcelona for their hospitality. The opinions expressed in this paper are those of the authors, and they do not reflect in any way those of the institutions to which they are affiliated. Responsibility for any remaining errors rests with the authors.

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Appendix A. Merton model equations for pricing contingent claims

Let us denote the observable value of the junior claims and its volatility by V_J and σ_J respectively and the fixed payment due at the end of the period T as S. If we assume this simple capital structure for the entity and ignore market imperfections (like dividend payouts, short selling restrictions, etc.), then at time t $(0 \leq t \leq T)$, the value of the entity's assets will be,

$$A(t) = S(t) + V_J(t) \tag{A.1}$$

If we assume that the entity's asset value follows geometric Brownian motion, then

$$dA(t) = \mu_A(t)\ A(t)\ dt + \sigma_A(t)\ A(t)\ dW$$

where A is value of the asset, σ_A its volatility, μ_A drift and dW is a Wiener process.

Because at the end of the period, senior creditors will receive their payment first while whatever remains will go to junior claim holders, junior claims can be seen as a call option on the entity's asset. Therefore, using the Black-Scholes option pricing theory analogically, the value of junior claims will be

$$V_J(t) = A(t)\ N(d_1) - S\ e^{-r(T-t)}\ N(d_2) \tag{A.2}$$

Using Ito's formula one can show

$$\sigma_J(t) = (\frac{A(t)}{V_J(t)})\ (\frac{\partial V_J(t)}{\partial A(t)})\ \sigma_A(t) \tag{A.3}$$

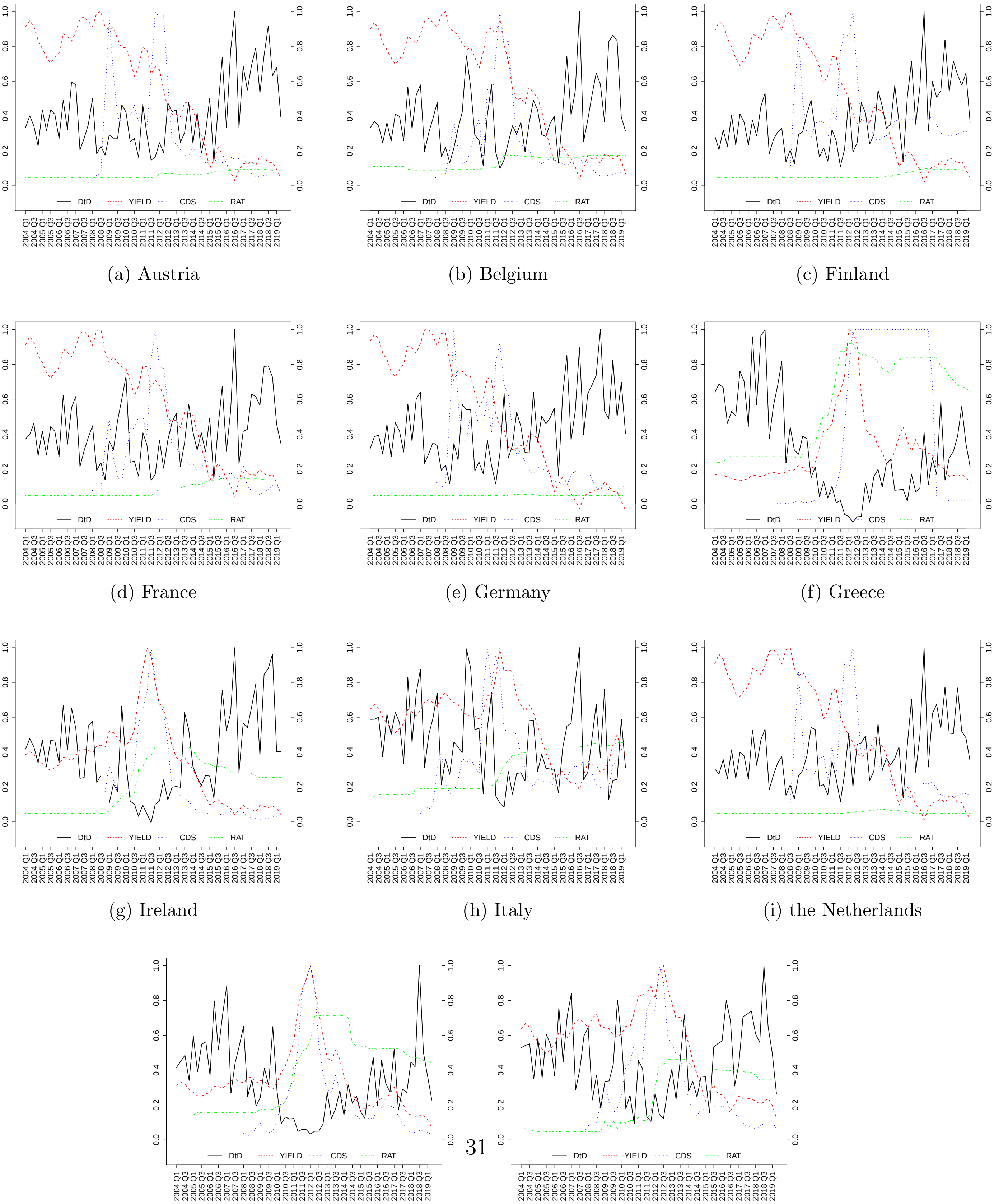
where $d_1 = \frac{log(\frac{A(t)}{S}) + (r + 0.5\sigma_A(t)^2)(T-t)}{\sigma_A(t)\sqrt{T-t}}$, $d_2 = d_1 - \sigma_A(t)\sqrt{T-t}$ and r is the risk-free interest rate at time t.

Thus, to find the unobservable value and volatility of the asset, we solve the non-linear system of equations A.4 and A.5. The system offers a single value for $A(t)$ and $\sigma_A(t)$.

$$f_1(V_J(t), \sigma_J(t)) = A(t)\ N(d_1) - S\ e^{-r(T-t)}\ N(d_2) - V_J(t) = 0 \tag{A.4}$$

$$f_2(V_J(t), \sigma_J(t)) = \frac{A(t)}{V_J(t)}\ N(d_1)\sigma_A(t) - \sigma_J(t) = 0 \tag{A.5}$$

Figure 1: *DtD* with other sovereign risk indicators



(a) Austria (b) Belgium (c) Finland

(d) France (e) Germany (f) Greece

(g) Ireland (h) Italy (i) the Netherlands

(j) Portugal (k) Spain

Note: DtD, YIELD, and CDS are normalized for each individual country between 0 and 1 by dividing the country-level DtD, YIELD, and CDS with the highest value of country level DtD, YIELD, and CDS achieved in the study period. RAT is normalized by diving it with 21 (the total number of credit rating categories considered in our analysis).

Table 1: Accounting balance sheet for the sovereign (combined government and monetary authorities)

Assets	**Liabilities**
Foreign reserves	Base money
Net fiscal assets	Local currency debt
Other public assets	Foreign currency debt
	Guarantee

Table 2: Priority structure of sovereign liabilities

Senior claims	
1.	Foreign official creditors: Multilateral creditors outside the EU - the IMF, the World Bank (WB), the ECB, Other multilateral creditors - EFSF/ESM, EIB (the European Investment Bank), Other national central banks within the EU.
2.	Domestic creditor: Domestic banks
3.	Foreign banks
4.	Foreign non-banks
Junior claims	
1.	Domestic creditor: Domestic central bank
2.	Domestic creditor: Domestic non-banks

Table 3: Descriptive statistics for other comparable sovereign risk indicators

Country	Mean	Standard Deviation	Minimum	Median	Maximum	Skewness	Kurtosis	Standard Error	N
Part I: Sovereign CDS									
Austria	51.79	48.68	3.61	30.61	181.81	1.42	1.09	7.10	47
Belgium	71.04	70.56	6.18	43.38	310.63	1.86	2.67	10.29	47
Finland	30.85	16.22	3.49	29.43	80.11	1.23	1.72	2.37	47
France	37.74	31.31	7.45	27.12	139.57	1.48	1.66	4.57	47
Germany	19.29	15.54	5.11	12.33	65.29	1.24	0.70	2.27	47
Greece	6878.37	7056.35	20.32	1524.16	14904.36	0.20	-1.94	1029.27	47
Ireland	175.46	213.89	12.49	78.85	841.86	1.53	1.23	32.62	43
Italy	139.84	86.96	19.58	121.06	415.01	1.59	2.21	12.30	50
Netherlands	39.68	27.44	11.60	28.94	120.51	1.51	1.45	4.14	44
Portugal	266.31	289.90	28.99	161.56	1170.30	1.84	2.55	42.74	46
Spain	116.71	98.60	18.79	73.51	402.16	1.23	0.56	14.38	47
Part II: Sovereign bond yield									
Austria	2.51	1.50	0.14	2.99	4.58	-0.22	-1.57	0.19	62
Belgium	2.71	1.50	0.17	3.36	4.67	-0.36	-1.54	0.19	62
Finland	2.40	1.48	0.08	2.61	4.56	-0.11	-1.58	0.19	62
France	2.55	1.40	0.17	3.02	4.49	-0.27	-1.49	0.18	62
Germany	2.16	1.52	-0.16	2.09	4.35	-0.04	-1.58	0.19	62
Greece	7.81	5.30	3.16	5.60	25.90	1.90	3.26	0.67	62
Ireland	3.67	2.44	0.43	3.82	10.65	0.75	0.39	0.31	62
Italy	3.66	1.27	1.22	4.03	6.62	-0.22	-0.76	0.16	62
Luxembourg	2.44	1.64	-0.03	2.47	4.88	-0.06	-1.58	0.21	62
Netherlands	2.38	1.49	0.05	2.54	4.48	-0.15	-1.55	0.19	62
Portugal	4.65	2.63	0.93	4.06	13.23	1.57	2.15	0.33	62
Spain	3.45	1.48	0.79	3.88	6.44	-0.18	-1.11	0.19	62
Part III: Sovereign credit ratings									
Austria	1.33	0.39	1.00	1.02	2.00	0.66	-1.21	0.05	62
Belgium	2.80	0.75	1.89	2.54	3.67	-0.01	-1.88	0.10	62
Finland	1.26	0.41	1.00	1.00	2.11	1.05	-0.73	0.05	62
France	1.79	0.87	1.00	1.15	3.11	0.38	-1.65	0.11	62
Germany	1.01	0.03	1.00	1.00	1.11	2.51	4.56	0.00	62
Greece	12.01	5.53	5.00	14.02	19.33	-0.14	-1.82	0.70	62
Ireland	4.59	3.05	1.00	5.33	9.00	0.02	-1.56	0.39	62
Italy	6.26	2.57	3.00	5.17	9.55	0.07	-1.89	0.33	62
Netherlands	1.07	0.14	1.00	1.00	1.52	1.67	1.45	0.02	62
Portugal	8.01	4.43	3.00	9.39	15.00	0.16	-1.52	0.56	62
Spain	4.84	3.57	1.00	3.00	9.67	0.09	-1.87	0.45	62

Notes: Part I of the table reports summary statistics for the quarterly average five-year sovereign *CDS*s. The data for most countries starts in 2007 (Source: Bloomberg). Part II reports summary statistics for the quarterly sovereign bond yields for the period 2004Q1 to 2019Q2. The yield are measured in percentage terms (Source: Eurostat). Part III of the table reports summary statistics for the quarterly average sovereign credit rating indicators for the 2004Q1 to 2019Q2 period. The rating is the average of sovereign credit rating available from S&P's, Moody's and Fitch rating agencies (Source: Bloomberg).

Table 4: Descriptive statistics for sovereign Distance-to-Default (DtD) indicators

Country	Mean	Standard Deviation	Minimum	Median	Maximum	Skewness	Kurtosis	Standard Error	N
Austria	8.14	3.94	2.74	7.41	19.88	0.90	0.26	0.50	62
Belgium	8.65	4.26	2.17	7.95	21.88	1.00	0.75	0.54	62
Finland	8.18	3.92	2.37	7.31	21.41	0.90	0.78	0.50	62
France	8.79	3.86	2.86	8.58	21.28	0.75	0.45	0.49	62
Germany	8.84	3.97	2.30	8.10	20.18	0.63	-0.02	0.50	62
Greece	3.82	3.48	-1.32	3.05	12.43	0.68	-0.38	0.44	62
Ireland	7.33	4.52	-0.09	6.38	18.80	0.58	-0.36	0.58	61
Italy	7.62	3.75	1.38	7.31	16.57	0.44	-0.58	0.48	62
Netherlands	8.71	3.92	2.62	8.10	22.46	0.93	1.11	0.50	62
Portugal	5.62	3.57	0.55	5.07	16.71	0.82	0.47	0.45	62
Spain	7.28	3.39	1.48	6.99	16.11	0.27	-0.67	0.43	62

Notes: The table reports summary statistics for the quarterly sovereign DtD index for the period 2004Q1 to 2019Q2.

Table 5: FPE statistics

Notes: The figures in brackets are the optimum order of lags in each pair of countries. Bold italics values indicate presence of Granger-causality.

Country		$FPE_{\Delta X}(m,0)$	$FPE_{\Delta X}(m,n)$	Causality		$FPE_{\Delta X}(m,0)$	$FPE_{\Delta X}(m,n)$	Causality
Austria	DtD →YIELD	0.0775 (3,0)	0.0727 (3,1)	**YES**	YIELD →DtD	11,88 (2,0)	12.27 (2,1)	NO
Austria	DtD →CDS	1312.32 (2,0)	1072.23 (2,1)	**YES**	CDS →DtD	18.72 (1,0)	17.83 (2,1)	**YES**
Austria	DtD →RAT	0.0059 (1,0)	0.0054 (1,2)	**YES**	RAT →DtD	11,88 (2,0)	12,14 (2,3)	NO
Belgium	DtD →YIELD	0.0954 (1,0)	0.0915 (1,1)	**YES**	YIELD →DtD	18.74 (2,0)	20,84 (2,1)	NO
Belgium	DtD →CDS	2149.14 (1,0)	2117.32 (1,2)	**YES**	CDS →DtD	22.42 (2,0)	22.74 (2,1)	NO
Belgium	DtD →RAT	0.0028 (1,0)	0.0023 (1,2)	**YES**	RAT →DtD	18.74 (2,0)	20.65 (2,1)	NO
Finland	DtD →YIELD	0.0724 (2,0)	0.0711 (2,1)	**YES**	YIELD →DtD	10.73 (2,0)	11.17 (2,1)	NO
Finland	DtD →CDS	186.26 (1,0)	184.45 (1,2)	**YES**	CDS →DtD	11.11 (2,0)	11.70 (2,1)	NO
Finland	DtD →RAT	0.0030 (4,0)	0.0023 (4,1)	**YES**	RAT →DtD	10.73 (2,0)	11.71 (2.1)	NO
France	DtD →YIELD	0.0857 (2,0)	0.0835 (2,1)	**YES**	YIELD →DtD	17.59 (2,0)	19.21 (2,1)	NO
France	DtD →CDS	384.18 (1,0)	373.88 (1,2)	**YES**	CDS →DtD	21.21 (2,0)	22.83 (2,1)	NO
France	DtD →RAT	0.0125 (1,0)	0.0117 (1,2)	**YES**	RAT →DtD	17.59 (2,0)	18.17 (2,1)	NO
Germany	DtD →YIELD	4.38 (1,0)	4.27 (1,1)	**YES**	YIELD →DtD	13.96 (2,0)	14.54 (2,1)	NO
Germany	DtD →CDS	142.41 (2,0)	138.12 (2,2)	**YES**	CDS →DtD	11.19 (2,0)	11.59 (2,1)	NO
Germany	DtD →RAT	0.0007 (1,0)	0.0004 (1,1)	**YES**	RAT →DtD	13.96 (2,0)	14.45 (2,1)	NO
Greece	DtD →YIELD	408.36(1,0)	375.33 (1,3)	**YES**	YIELD →DtD	4.94 (2,0)	4.71 (2,1)	**YES**
Greece	DtD →CDS	50.22 (1,0)	48.16 (1,2)	**YES**	CDS →DtD	3.19 (1,0)	3.45 (1,1)	NO
Greece	DtD →RAT	0.5685 (1,0)	0.5344 (1,2)	**YES**	RAT →DtD	4.94 (2,0)	5.11 (1,1)	NO
Ireland	DtD →YIELD	0.2905 (1,0)	0.2754 (1,1)	**YES**	YIELD →DtD	14.81(3,0)	16.57 (3,1)	NO
Ireland	DtD →CDS	70.02 (1,0)	64.11 (1,2)	**YES**	CDS →DtD	11.56 (3,1)	11.03 (3,1)	**YES**
Ireland	DtD →RAT	0.2704 (1,0)	0.2423 (1,2)	**YES**	RAT →DtD	14.81(3,0)	15.93 (3,1)	NO
Italy	DtD →YIELD	0.1545 (1,0)	0.1443 (1,1)	**YES**	YIELD →DtD	17.93 (2,0)	18.51 (2,1)	NO
Italy	DtD →CDS	34.65 (1,0)	31.88 (1,1)	**YES**	CDS →DtD	15.62 (2,0)	14.75 (2,1)	**YES**
Italy	DtD →RAT	0.0690 (2,0)	0.0587 (2,1)	**YES**	RAT →DtD	17.93 (2,0)	18.93 (2,1)	NO
Netherlands	DtD →YIELD	0.0749 (2,0)	0.0656 (2,1)	**YES**	YIELD →DtD	14.54 (2,0)	15.09 (2,1)	NO
Netherlands	DtD →CDS	4.38 (1,0)	4.28 (1,2)	**YES**	CDS →DtD	17.92 (2,0)	18.99 (2,1)	NO
Netherlands	DtD →RAT	0.0019 (1,0)	0.0014 (1,1)	**YES**	RAT →DtD	14.54 (2,0)	15.12 (2,1)	NO
Portugal	DtD →YIELD	0.4447 (1,0)	0.4176 (1,1)	**YES**	YIELD →DtD	7.83 (2,0)	7.91 (2,1)	NO
Portugal	DtD →CDS	11.63 (1,0)	10.14 /1,1)	**YES**	CDS →DtD	5.38 (2,1)	5.74 (2,1)	NO
Portugal	DtD →RAT	0.6757 (2,0)	0.5924 (2,1)	**YES**	RAT →DtD	7.83 (2,0)	8.11 (2,1)	NO
Spain	DtD →YIELD	0,1342 (1,0)	0.1234 (1,1)	**YES**	YIELD →DtD	11.92 (2,0)	12.51(2,1)	NO
Spain	DtD →CDS	20.91 (1,0)	20.17 (1,1)	**YES**	CDS →DtD	12.40 (2,0)	12.79 (2,1)	NO
Spain	DtD →RAT	0.4954 (3,0)	0.4751 (1,1)	**YES**	RAT →DtD	11.92 (2,0)	12.42 (2,1)	NO

Table 6: Variables that measure macroeconomic fundamentals and market sentiments

Variable	Description	Source
Variables that measure macroeconomic fundamentals		
Net position towards the rest of the world (CAC)	Current-account-balance-to-GDP	OECD
Growth potential (U)	Unemployment rate	Eurostat
Competitiveness (INF)	Inflation rate. Quarterly average of HICP monthly inter-annual rate of growth	Eurostat
Fiscal position (DEF)	Government deficit-to-GDP	Eurostat
Public debt (DEBT)	Government debt-to-GDP	Eurostat
Index of the Fiscal stance (FSI)	This indicator compares a target level of the debt-GDP ratio at a given point in the future with a forecast based on the government budget constraint. It was created by Polito and Wickens (2011, 2012)	Provided by Polito and Wickens for the 1999-2011 period and updated by the authors
Variables that measure market sentiment		
Variable	Description	Source
Index of economic policy uncertainty (EPU)	This index reflects the frequency of newspaper references to policy uncertainty and was built by Baker et al. (2013)	http://www.policyuncertainty.com
Consumer confidence indicator (CCI)	This index is built by the European Commission which conducts regular harmonised surveys of consumers in each country	European Commission (DG ECFIN)
Global risk (VIX)	A measure of implied volatility of the Standard & Poor's 500 Index	www.cboe.com
Country-Level Index of Financial Stress (CLIFS)	A composite indicator proposed by Duprey et al. (2017)	European Central Bank
Financial market uncertainty (FMU)	A synthetic measure of financial market uncertainty in the EA, calculated from bond markets, equity markets and the exchange rate (ECB (2016))	European Central Bank

Table 7: Regression results

Part I: Difference of sovereign *DtD*s as dependent variable

	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSI)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	Adj R2	DW
Austria	0.821 (2.84)			-0.146 (-2.98)	-35.267 (-3.11)	-0.151 (-2.96)	-1.288 (-2.88)				-1.017 (-2.86)	0.88	2.36
Belgium			-0.166 (-2.94)	-0.534 (-2.86)		-0.063 (-2.85)		0.023 (2.92)	-1.343 (-2.94)		-0.056 (-2.93)	0.87	2.36
Finland			-0.231 (-2.97)	-0.401 (-2.97)	-12.515 (-3.12)	-0.025 (-2.92)	-0.033 (-2.99)				-0.464 (-2.95)	0.88	2.32
France				-0.957 (-2.98)	-42.292 (-3)	-0.177 (-2.86)	-2.191 (-2.98)		-6.606 (-3.14)			0.88	2.32
Germany			-0.358 (-2.94)	-0.087 (-3.02)	-21.395 (-2.95)	-0.139 (-2.89)			-0.915 (-2.89)		-0.171 (-2.94)	0.88	2.32
Greece		-0.105 (-2.93)	-0.07 (-2.93)	-0.133 (-2.88)					-11.104 (-2.97)		-0.862 (-2.92)	0.88	2.32
Ireland	0.199 (2.94)	-2.169 (-2.91)	-0.183 (-2.89)		-28.181 (-3.02)			0.015 (2.86)			-0.428 (-2.84)	0.9	2.33
Italy		-0.487 (-2.88)		-0.302 (-2.91)	-15.407 (-2.88)			0.008 (2.88)	-33.783 (-3.1)		-0.671 (-2.89)	0.83	2.34
Netherlands			-0.291 (-2.92)	-0.759 (-2.92)		-0.174 (-3.1)	-0.014 (-2.9)	0.143 (2.92)			-0.744 (-2.93)	0.88	2.33
Portugal		-0.604 (-2.93)	-0.078 (-2.88)		-61.854 (-2.97)		-0.443 (-2.92)		-58.761 (-2.95)		-0.05 (-2.9)	0.88	2.34
Spain		-1.241 (-2.98)	-0.158 (-2.92)	-0.522 (-2.99)	-5.313 (-2.96)				-20.201 (-2.93)		-0.221 (-2.88)	0.89	2.34

Part II: Difference of sovereign *CDS* as dependent variable

	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSIS)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	Adj R2	DW
Austria			1.109 (3.15)	1.666 (2.88)	1.639 (3.12)			-2.88 (-2.84)		1.675 (2.95)	2.669 (2.85)	0.87	2.39
Belgium			0.934 (3.01)	4.867 (2.91)	1.498 (2.93)			-4.757 (-2.87)		1.983 (2.93)	7.702 (2.91)	0.87	2.32
Finland				1.912 (2.88)	1.413 (2.88)		0.398 (2.85)	-3.967 (-2.9)	25.63 (3.11)	0.289 (2.95)		0.87	2.32
France				2.514 (2.76)		2.788 (2.72)			899.751 (3.42)	0.3 (3.11)	1.814 (2.73)	0.87	2.23
Germany			3.472 (2.87)	3.025 (2.86)	1.402 (2.94)				0.653 (2.92)	0.11 (2.89)	5.231 (3.54)	0.9	2.32
Greece		450.653 (2.99)		61.452 (2.89)				-7.255 (-2.94)	149.542 (2.83)	15.666 (2.85)	193.154 (2.97)	0.88	2.32
Ireland			1.468 (2.92)		5.387 (2.97)	1.638 (2.96)		-0.826 (-2.98)		0.821 (2.88)	10.572 (2.96)	0.88	2.3
Italy				4.372 (3.01)			9.242 (2.88)	-0.313 (-2.96)	119.712 (2.98)	1.313 (2.97)	7.018 (2.86)	0.9	2.3
Netherlands				1.853 (3)		3.812 (2.88)	0.127 (2.87)	-0.87 (-2.94)	84.007 (2.96)		9.216 (2.88)	0.88	2.31
Portugal	-0.571 (-2.84)				4.373 (2.83)		6.792 (2.94)	-1.371 (-2.91)		4.413 (2.9)	12.914 (2.93)	0.88	2.32
Spain		6.398 (2.91)		8.501 (2.96)	7.365 (2.89)	2.151 (3.23)					9.317 (2.91)	0.87	2.34

Part III: Difference of sovereign bond yields as dependent variable

	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSIS)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	Adj R2	DW
Austria				0.135 (2.84)	0.256 (2.92)	0.068 (2.97)	0.285 (2.84)	-0.146 (-2.93)		0.273 (2.8)	0.178 (2.91)	0.87	2.32
Belgium			0.083 (2.88)	0.338 (2.92)		0.079 (2.89)		-0.386 (-2.94)	1.076 (2.87)	0.004 (2.91)		0.87	2.33
Finland			0.02 (2.88)		1.724 (2.95)		0.154 (2.83)	-0.21 (-2.91)	0.83 (2.87)	0.006 (3.02)		0.87	2.33
France			0.071 (2.82)			0.041 (2.98)	0.177 (2.83)		0.937 (2.82)	0.007 (2.83)		0.89	2.32
Germany		0.257 (2.81)		0.048 (2.83)			0.329 (3.1)			0.005 (2.84)	0.04 (2.82)	0.88	2.31
Greece				0.105 (2.85)		0.2 (2.82)	0.589 (2.83)		9.576 (2.91)	0.027 (2.8)		0.89	2.31
Ireland			1.385 (2.82)		9.28 (2.82)	2.423 (2.81)		-3.276 (-3.14)		10.121 (2.86)	0.37 (2.81)	0.87	2.32
Italy		0.122 (2.8)		0.028 (2.94)			0.04 (2.86)		0.03 (2.84)	0.031 (2.8)	0.069 (2.81)	0.87	2.34
Netherlands			0.224 (2.83)			0.2 (3.11)	0.036 (2.98)	-0.194 (-3.01)		0.077 (3)		0.88	2.32
Portugal		0.282 (2.8)	0.012 (2.8)		7.843 (2.92)			-0.005 (-2.95)	0.033 (2.86)		0.024 (2.83)	0.86	2.31
Spain			0.024 (3.11)		8.321 (2.82)		0.057 (2.85)		1.767 (2.82)	0.007 (2.82)		0.87	2.32

Part IV: Difference of sovereign credit ratings as dependent variable

	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSIS)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	Adj R2	DW
Austria	-0.015 (-2.92)		0.002 (2.95)				0.434 (2.91)		0.128 (2.92)	0.003 (2.92)	0.017 (2.87)	0.85	2.32
Belgium			0.001 (2.94)	0.004 (2.93)		0.016 (2.91)		-0.013 (-2.88)		0.006 (2.9)	0.042 (2.88)	0.86	2.33
Finland	-0.007 (-2.91)			0.007 (2.88)		0.016 (2.89)		-0.006 (-2.87)		0.003 (3.12)	0.014 (2.84)	0.85	2.34
France	-0.012 (-3.11)		0.015 (2.97)		0.469 (3.1)				0.491 (2.98)	0.001 (2.92)	0.026 (2.91)	0.84	2.32
Germany	-0.003 (-2.86)			0.001 (2.96)	0.037 (2.81)				0.011 (2.79)		0.004 (2.8)	0.89	2.31
Greece		0.13 (2.91)		0.008 (2.8)	8.457 (2.82)		0.352 (2.83)	-0.002 (-2.82)	1.112 (2.83)			0.9	2.31
Ireland		0.144 (2.8)	0.004 (2.91)		8.273 (2.99)			-0.001 (-2.8)	1.778 (2.8)		0.082 (2.8)	0.89	2.31
Italy			0.011 (2.8)		9.51 (2.87)	0.029 (2.92)			0.269 (2.8)		0.02 (2.78)	0.89	2.32
Netherlands			0.019 (2.86)		0.004 (2.86)	0.01 (2.94)		-0.185 (-2.8)	0.087 (2.85)	0.002 (3.1)		0.89	2.32
Portugal			0.042 (2.79)		10.21 (3.1)	0.104 (2.93)		-0.009 (-3)	1.531 (2.78)		0.017 (2.77)	0.86	2.33
Spain				0.109 (2.82)	1.569 (2.79)					0.001 (28671)	0.053 (2.72)	0.84	2.32

Notes: In the ordinary brackets next to the parameter estimates, the corresponding t-statistics are shown, based on the small-sample degree of freedom corrected, heteroskedasticity and autocorrelation consistent standard errors proposed by Newey and West (1987)

Table 8: Predictive power and relative contributions of the explanatory variables

Country	Actual	Predicted	Individual Contributions (%)											Aggregate contribution (%)	
Panel I: Sovereign *DtD* model														Macroeconomic	Market
	D(DtD)	D(DtD)	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSI)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	fundamentals	sentiments
Austria	-0.0017	-0.0016	18.31	0	0	14.62	35.08	9.23	12.75	0	0	0	10.01	77.24	22.76
Belgium	-0.0334	-0.033	0	0	27.63	24.31	0	19.01	0	6.46	20.99	0	1.6	70.95	29.05
Finland	0.0117	0.0115	0	0	19.48	18.47	19.73	10.17	10.53	0	0	0	21.62	67.85	32.15
France	-0.0596	-0.0594	0	0	0	54.47	10.4	6.17	3.9	0	25.06	0	0	71.04	28.96
Germany	0.0322	0.0318	0	0	29.07	29.23	8.81	2.22	0	0	14.5	0	16.17	69.33	30.67
Greece	-0.1293	-0.1276	0	19.71	23.36	22.21	0	0	0	0	10.64	0	24.08	65.28	34.72
Ireland	-0.1198	-0.1194	5.43	23.02	0	32.91	8.44	0	0	6	0	0	24.2	69.8	30.2
Italy	-0.1127	-0.1124	0	28.79	0	19.66	16.55	0	0	5.14	12.26	0	17.6	65	35
Netherlands	0.0052	0.0048	0	0	24.9	24.39	0	17.54	4.53	4.24	0	0	24.4	66.83	33.17
Portugal	-0.0468	-0.0464	0	11.75	25.64	0	27.89	0	7.69	0	14.22	0	12.81	65.28	34.72
Spain	-0.0692	-0.0699	0	11.9	22.34	23.81	6.2	0	0	0	26.61	0	9.14	64.25	35.75
Panel II: Sovereign *CDS* model														Macroeconomic	Market
	D(*CDS*)	D(*CDS*)	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSI)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	fundamentals	sentiments
Austria	0.688	0.6789	0	0	9.53	11.32	13.12	0	0	26.73	0	16.37	22.93	33.97	66.03
Belgium	0.9259	0.9148	0	0	3.89	15.35	12.81	0	0	15.32	0	28.34	24.29	32.05	67.95
Finland	0.6823	0.6802	0	0	0	20.01	19.42	0	8.99	17.78	24.84	8.96	0	39.43	60.57
France	0.3785	0.3588	0	0	0	21.2	0	17.62	0	0	43.4	4.94	12.85	38.82	61.18
Germany	0.1462	0.145	0	0	12.04	11.14	7.97	0	0	0	46.84	5.97	16.04	31.15	68.85
Greece	425.2584	422.0479	0	19.65	0	16.75	0	0	0	5.4	37.59	6.1	14.51	36.41	63.59
Ireland	-3.2329	-3.2009	0	0	16.29	0	19.12	3.25	0	15.92	0	13.57	31.85	38.66	61.34
Italy	2.446	2.429	0	0	0	34.78	0	0	0	5.07	20.82	23.14	16.19	34.78	65.22
Netherlands	0.4521	0.4518	0	0	0	12.28	0	25.27	14.1	7.09	26.56	0	14.7	37.55	62.45
Portugal	5.4567	5.4171	0	0	20.96	0	10.54	0	7.4	20.41	0	22.45	18.25	31.5	68.5
Spain	1.2743	1.2694	0	5.51	0	25.14	4.7	0	0	0	46.43	0	18.21	35.36	64.64
Panel III: Sovereign bond yields model														Macroeconomic	Market
	D(yields)	D(yields)	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSI)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	fundamentals	sentiments
Austria	-0.0735	-0.0737	0	0	0	10.09	19.07	5.08	21.27	10.93	0	20.27	13.29	34.24	65.76
Belgium	-0.0727	-0.073	0	0	3.89	15.35	12.81	0	0	15.38	0	28.33	24.24	32.05	67.95
Finland	-0.0728	-0.0718	0	0	17.08	0	17.62	0	14.45	17.22	18.54	15.09	0	34.7	65.3
France	-0.0689	-0.0663	0	0	26.94	0	0	8.55	5.39	0	39.09	20.03	0	35.49	64.51
Germany	-0.0766	-0.0745	0	14.16	0	17.81	0	0	7.68	0	0	15.12	45.23	31.97	68.03
Greece	0.0634	0.0616	0	18.52	0	9.53	0	6.01	16.41	0	29.16	20.37	0	34.06	65.94
Ireland	-0.0662	-0.0642	0	10.95	0	11.07	16.15	0	0	0	39.43	22.4	0	38.17	61.83
Italy	-0.0492	-0.0478	0	16.21	0	17.52	0	0	0	0	20.93	40.43	4.91	33.74	66.26
Netherlands	-0.0734	-0.0722	0	0	17.28	12.97	0	8.74	0	16.61	21.76	22.64	0	38.99	61.01
Portugal	-0.012	-0.0109	0	6.31	12.31	0	19.38	0	0	21.55	23.1	0	17.35	38	62
Spain	-0.0549	-0.0515	0	0	23.12	0	12.77	0	5.61	0	34.74	23.76	0	35.89	64.11
Panel IV: Sovereign credit ratings model														Macroeconomic	Market
	D(Rating)	D(Rating)	D(CAC)	D(U)	D(DEF)	D(DEBT)	D(FSI)	INF	D(EPU)	CCI	D(CLIFS)	VIX	FMU	fundamentals	sentiments
Austria	0.0196	0.0191	17.44	0	13.43	0	0	0	26.88	0	34.27	3.49	4.49	30.87	69.13
Belgium	0.0232	0.0219	0	0	6.38	10.61	0	14.55	0	29.75	27.79	10.92	0	31.54	68.46
Finland	0.0196	0.0195	16.25	0	0	17.8	0	5.37	0	15.64	0	22.8	22.14	39.42	60.58
France	0.0392	0.0357	4.66	0	15.47	0	19.05	0	0	0	27.08	9.84	23.9	39.18	60.82
Germany	0	0.0001	24.54	0	0	11.93	4.32	0	0	0	26.34	0	32.87	40.79	59.21
Greece	0.24	0.2218	0	20.18	0	17.07	0	0	0	4.63	38.3	5.34	14.48	37.25	62.75
Ireland	0.1	0.0909	0	3.44	9.98	0	21.61	0	0	23.26	26.06	0	15.65	35.03	64.97
Italy	0.12	0.1091	0	0	13.2	0	13.97	12.1	0	0	39.05	0	21.68	39.27	60.73
Netherlands	0.0009	0.0008	0	0	17.28	12.97	0	8.74	0	16.61	21.76	22.64	0	38.99	61.01
Portugal	0.16	0.1457	0	15.95	0	0	4.89	17.1	0	27.88	17	0	17.18	37.94	62.06
Spain	0.14	0.1282	0	0	0	32.07	0	0	0	0	23.3	2.94	41.7	32.07	67.93

Notes: The results are obtained based on the models presented in Table 7.

Table 9: Predictive power and relative contributions of the explanatory variables: Sub-samples

Country	Aggregate contribution (%) **Pre-crisis period**		Aggregate contribution (%) **Crisis period**		Aggregate contribution (%) **Pre-QE period**		Aggregate contribution (%) **QE-period**	
	Macroeconomic fundamentals	Market sentiments	Macroeconomic fundamentals	Market sentiments	Macroeconomic fundamentals	Market sentiments	Macroeconomic fundamentals	Market sentiments
Panel I: Sovereign *DtD* model								
Austria	77.15	22.85	77.33	22.67	77.2	22.8	77.36	22.64
Belgium	68.16	31.84	73.26	26.74	70.4	29.6	73.48	26.52
Finland	65.64	34.36	69.46	30.54	68.32	31.68	73.21	26.79
France	67.05	32.95	70.02	29.98	64.52	35.48	68.19	31.81
Germany	68.18	31.82	71.73	28.27	69.77	30.23	71.8	28.2
Greece	63.57	36.43	64.66	35.34	63.65	36.35	66.32	33.68
Ireland	67.56	32.44	71.25	28.75	68.95	31.05	72.34	27.66
Italy	62.77	37.23	65.07	34.93	63.44	36.56	66.66	33.34
Netherlands	63.65	36.35	67.47	32.53	65.87	34.13	70.03	29.97
Portugal	63.18	36.82	66.86	33.14	64.71	35.29	67.45	32.55
Spain	62.46	37.54	65.67	34.33	63.6	36.4	66.88	33.12
Panel II: Sovereign *CDS* model								
Austria	31.07	68.93	36.27	63.73	33.17	66.83	37.33	62.67
Belgium	30.77	69.23	33.07	66.93	31.4	68.6	34.78	65.22
Finland	37.97	62.03	40.59	59.41	39.14	60.86	40.65	59.35
France	36.42	63.58	40.72	59.28	38.55	61.45	39.95	60.05
Germany	30.67	69.33	31.53	68.47	30.79	69.21	32.66	67.34
Greece	35.15	64.85	37.41	62.59	36.1	63.9	37.71	62.29
Ireland	37.35	62.65	39.7	60.3	38.11	61.89	40.97	59.03
Italy	32.41	67.59	36.66	63.34	33.5	66.5	40.16	59.84
Netherlands	36.84	63.16	38.11	61.89	37.29	62.71	38.64	61.36
Portugal	30.24	69.76	32.5	67.5	31.22	68.78	32.68	67.32
Spain	33.15	66.85	37.11	62.89	35.01	64.99	36.83	63.17
Panel III: Sovereign yields model								
Austria	33.12	66.88	35.13	64.87	33.82	66.18	36	64
Belgium	30.12	69.88	33.58	66.42	31.34	68.66	35.03	64.97
Finland	37.97	62.03	40.57	59.43	38.77	61.23	42.15	57.85
France	33.21	66.79	37.3	62.7	35.19	64.81	36.76	63.24
Germany	30.12	69.88	33.44	66.56	31.71	68.29	33.06	66.94
Greece	32.45	67.55	35.34	64.66	33.41	66.59	36.79	63.21
Ireland	36.45	63.55	39.53	60.47	37.44	62.56	41.24	58.76
Italy	32.01	67.99	35.11	64.89	34.22	65.78	37.13	62.87
Netherlands	36.41	63.59	38.45	61.55	37.11	62.89	39.4	60.6
Portugal	36.17	63.83	39.45	60.55	37.31	62.69	40.9	59.1
Spain	34.11	65.89	37.3	62.7	35.21	64.79	38.75	61.25
Panel IV: Sovereign credit ratings model								
Austria	30.12	69.88	31.46	68.54	30.54	69.46	32.26	67.74
Belgium	30.41	69.59	32.44	67.56	31.14	68.86	33.22	66.78
Finland	36.7	63.3	39.68	60.32	37.89	62.11	40.33	59.67
France	37.6	62.46	40.43	59.57	38.71	61.29	41.15	58.85
Germany	38.71	62.2	42.44	57.56	39.88	60.12	44.61	55.39
Greece	35.43	68.07	38.69	61.31	36.78	63.22	39.22	60.78
Ireland	32.99	68.09	36.65	63.35	34.17	65.83	38.64	61.36
Italy	37.71	63.43	40.51	59.49	38.61	61.39	42.02	57.98
Netherlands	37.16	62.84	40.44	59.56	38.57	61.43	40.75	59.25
Portugal	35.77	64.03	39.66	60.34	37.31	62.69	40.59	59.41
Spain	30.12	68.88	33.62	66.38	31.41	68.59	34.84	65.16