# Data-Driven Approach for Systemic Risk
## A Macroprudential Perspective

Barsotti, Flavia

**DOI**
10.1007/978-3-031-11818-0_68

**Publication date**
2022

**Document Version**
Final published version

**Published in**
Progress in Industrial Mathematics at ECMI 2021

# Data-Driven Approach for Systemic Risk: A Macroprudential Perspective

**Flavia Barsotti**

**Abstract** This paper proposes a sovereign CDS analysis for systemic risk, assuming a macroprudential perspective and building on the modelling framework proposed by Baglioni and Cherubini (J. Econ. Dynam. Control 37:1581–1597, 2013). A data-driven approach applied to CDS quotes is considered to estimate a reduced form model for the marginal intensity of defaults at country level and investigate the presence of common factors. Results show a systematic effect on default intensities, rank correlation and common factors for countries in the sample with specific geographic differences. This is an important empirical evidence to further investigate how to model, measure and assess the drivers explaining heterogeneity in impacts across countries and build early warning indicators to support strategic decision making.

## 1 Introduction

From a macroprudential perspective, policy decision makers have faced challenging times all over the world to contain and manage the unprecedented effects caused by Covid-19 pandemic and build trust. Some countries have taken the decision of strict lockdown measures which in turns might have caused contraction in the economy for different sectors. As the economic fundamentals weaken, risk aversion begins to play a predominant role for agents [3]. The increased uncertainty affecting

The views expressed in this paper are solely those of the author and do not necessarily represent those of her current or past employers.

F. Barsotti (✉)
ING Analytics, Amsterdam, The Netherlands

IAS (Institute for Advanced Study), University of Amsterdam, Amsterdam, The Netherlands

DIAM (Delft Institute of Applied Mathematics), TU Delft, Delft, The Netherlands
e-mail: Flavia.Barsotti@ing.com; f.barsotti@uva.nl; F.Barsotti@tudelft.nl



M. Ehrhardt, M. Günther (eds.), *Progress in Industrial Mathematics at ECMI 2021*,
The European Consortium for Mathematics in Industry 39,
https://doi.org/10.1007/978-3-031-11818-0_68

the world since 2019 is reflected in impacts on CDS spreads, as market-implied measure embedding default risk. This economic situation could potentially trigger cascading defaults for sovereigns. In order to build a preliminary empirical evidence at EU level, this paper entails an empirical study to investigate the dynamics of sovereign CDS and systemic risk from a macroprudential perspective, focusing on the credit risk component captured by CDS quotes and potential joint default effects. The paper proposes a data-driven approach to analyse the dynamics of sovereign CDS and systemic risk. Starting from the works by [1] and [6], a data-driven approach applied to CDS quotes is considered to estimate a reduced form model for the marginal intensity of defaults at country level. This information is then used to investigate the presence of common factors across economies for 8 European countries. Results show a systematic impact on pair-wise rank correlations and co-movements of the series for CDS sovereign market-implied indicators and marginal probabilities estimates. This is an important empirical evidence suggesting to build more extensive analysis to identify the factors explaining heterogeneity across countries by disentangling the default risk components and assessing the specific role of both systematic and non-systematic drivers [2].

## 2 Macroprudential Perspective: Risk Decomposition

The paper proposes a data-driven approach to investigate the implications on CDS market indicators in terms of credit quality and default risk of sovereigns close to the pandemic event outbreak. A key factor for macroprudential policy is building an holistic view on the financial system. This is fundamental to prevent overlooking the dependencies and impacts of its inner working mechanism and manage potential costs, instability and systemic risk patterns. From a mathematical point of view, this paper tackles the problem of estimating a reduced form approach for the drivers underlying the probability of a systemic risk event by leveraging on the marginal default probabilities of a set of obligors (e.g. sovereign), the pair-wise correlation of intensities and the identification of a common factor. The analysis of non-systematic components is beyond the scope of the present paper.

### 2.1 A Reduced Form Model for Sovereign Default Risk

As in [1], the paper considers a reduced form model where the default probability of each obligor $i$ follows a Poisson process with intensity $\hat{\lambda}_i$. The intensity captures the instantaneous relative increase in the probability of an event, namely

$$dP_i(t) = \hat{\lambda}_i P_i(t), \tag{1}$$

with $P_i(t)$ being the probability of default at time $t$. The survival probability of a generic obligor $i$ at time $T$ is

$$P_i(\phi_i > T) = \exp\big(-\hat{\lambda}_i(T-t)\big), \tag{2}$$

with $\phi_i$ indicating the default time and $\{\hat{\lambda}_i, \hat{\lambda}_j\}$ the marginal sovereign default intensities of obligors $\{i, j\}$. Following the modelling dependence framework in [1, 6], we consider a *common factor* $F$ and estimate its intensity $\bar{\lambda}_{F,ij}$ as

$$\bar{\lambda}_{F,ij} = \frac{2\hat{\rho}_{ij}(\hat{\lambda}_i + \hat{\lambda}_j)}{3(1-\hat{\rho}_{ij})}, \tag{3}$$

with $\hat{\rho}_{ij}$ being an estimate of the pair-wise correlation $\rho_{ij}$. For each rank correlation, we can then have an estimate of the common factor intensity[1] and analyze the impacts per geographic location.

### 2.2 Data

The analysis considers a sample of weekly observations of the most liquid 5Y CDS quotes for European sovereign CDS over the period Jan-2016/Jan-2021. Based on the financial nature of CDS contracts, their quotes enable to isolate the credit risk associated to its reference entity. In the case of sovereign, this plays a fundamental role for systemic risk measurement and assessment. In line with [6], this paper considers 8 European countries belonging to Northern Europe (e.g. Germany, France, Netherlands, UK—*Northern EU*) and Southern Europe (e.g. Greece, Italy, Portugal, Spain—*Southern EU*). As in [1], following the standard market approximation, the generic marginal intensity (e.g. hazard rate) $\hat{\lambda}_{C_{jt}}$ for sovereign $C_j$ at time $t$ is estimated as

$$\hat{\lambda}_{C_{jt}} = \frac{CDS_{jt}}{LGD}, \tag{4}$$

with $CDS_{jt}$ denoting the CDS quote for obligor $j$ at time $t$ and $LGD$ the loss given default. Figure 1 reports the time series of hazard rates for CDS sovereign obligors in the sample and Table 1 the associated descriptive statistics.

## 3 Empirical Evidence

The empirical evidence deriving from the estimation results highlights a certain degree of heterogeneity in the impacts of the pandemic outbreak in the sample.

---

[1] As estimate of the common factor $F$, this first empirical analysis considers a $30\%-$quantile measure over the set of estimates.

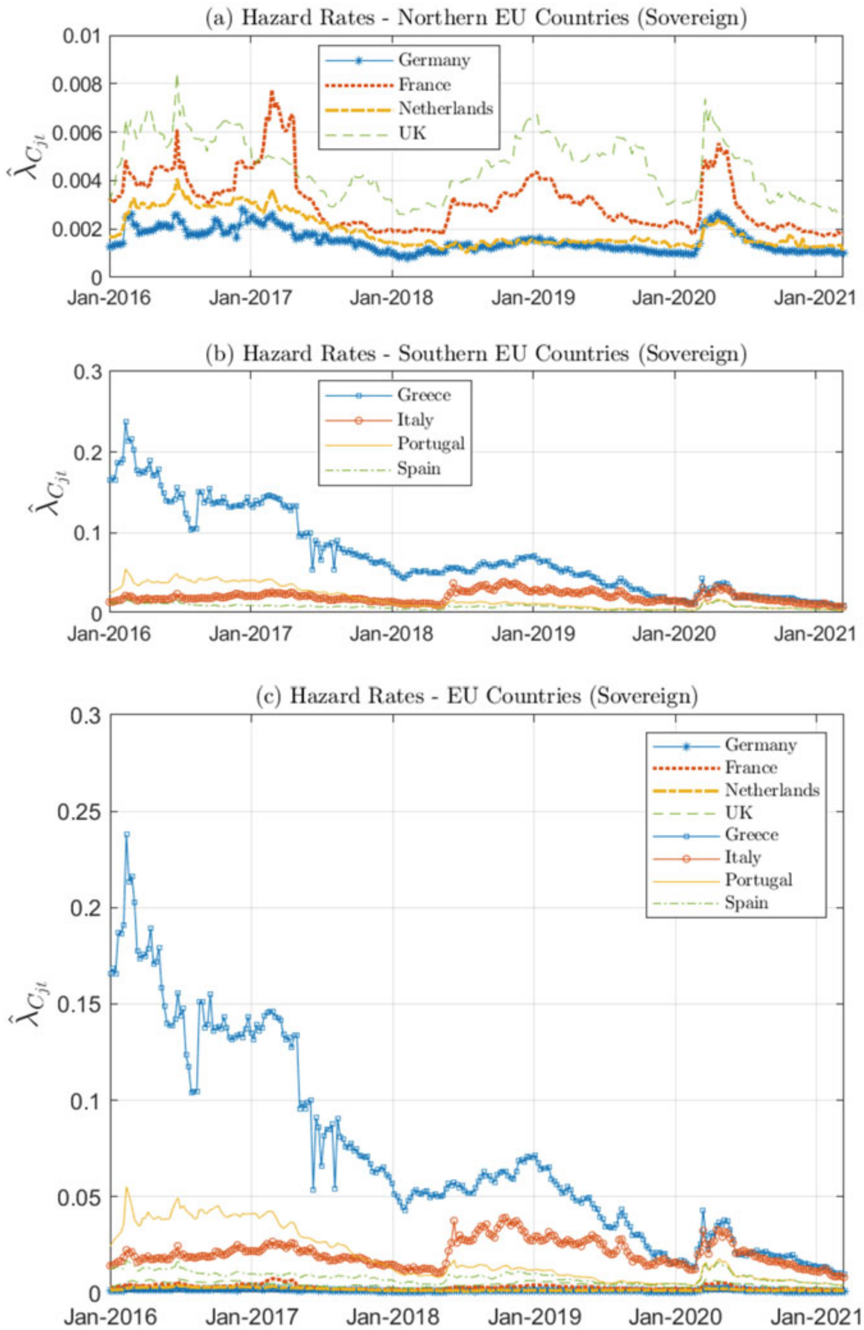


**Fig. 1** Sovereign hazard rates. The plots report the hazard rates implied by CDS quotes for 8 EU Sovereign entities over the period Jan-2016/Jan-2021: Germany, France, Netherlands, UK, Greece, Italy, Portugal, Spain. The marginal intensity for Sovereign $C_j$ at time $t$ is measured via the hazard rate $\hat{\lambda}_{C_{jt}}$ defined in Eq. (4). Plots (**a**)–(**b**) report the hazard rates with a split by region, e.g. Northern EU Countries (**a**), Southern EU Countries (**b**). Plot (**c**) reports the comprehensive overview for all countries. Table 1 reports the corresponding descriptive statistics

**Table 1** Descriptive statistics. Sovereign hazard rates implied by CDS quotes. Time window: Jan-2016/Jan-2021

| *Northern EU Sovereign* | *Mean* | *Std dev* | *Min* | *Max* |
|---|---|---|---|---|
| Germany | 0.0015 | 0.0005 | 0.0008 | 0.0028 |
| France | 0.0031 | 0.0012 | 0.0017 | 0.0078 |
| Netherlands | 0.0019 | 0.0007 | 0.0010 | 0.0041 |
| UK | 0.0046 | 0.0012 | 0.0025 | 0.0084 |
| *Southern EU Sovereign* | *Mean* | *Std dev* | *Min* | *Max* |
| Greece | 0.0717 | 0.0520 | 0.0098 | 0.2379 |
| Italy | 0.0207 | 0.0067 | 0.0082 | 0.0392 |
| Portugal | 0.0185 | 0.0139 | 0.0039 | 0.0551 |
| Spain | 0.0083 | 0.0030 | 0.0036 | 0.0175 |

Figure 1 reports the marginal intensities representing instantaneous probabilities of default at sovereign level and Table 1 the corresponding descriptive statistics. The economic impact of the outbreaks and its persistence are evident from the results. Looking at the whole time window Jan 2016/Jan 2021, Southern EU Countries show a systematic higher intensity level, if compared to Northern EU Countries. Table 1 highlights the presence of differences in the order of magnitude for specific descriptive statistics on the intensity levels $\hat{\lambda}_{C_{jt}}$, reflecting the corresponding difference in the embedded riskiness[2]: $\hat{\lambda}_{C_{jt}} \in [0.0008, 0.0084]$ for Northern EU Countries, while $\hat{\lambda}_{C_{jt}} \in [0.0036, 0.2379]$ for Southern EU Countries. Regarding Northern EU Countries, UK is ranked first (e.g. riskiest) over most of the time window[3]. The ranking among these intensities is: UK, France, Netherlands and Germany. By directly comparing the average intensity levels on Dec-2019 and Mar-2020, empirical evidence shows increases driven by scaling factors ranging from 1.4 (Netherlands) to 2.48 (Portugal). Regarding Southern EU Countries, results show Italy and Greece even more affected than Portugal and Spain since the start of the pandemic in 2019. To further investigate the impacts, focusing on Q1 2020 and considering relative changes in the intensity level enable a comprehensive comparison around the beginning of the pandemic event outbreak. When computing relative changes in the intensity levels in Q1 2020 across EU Countries, results show a peak for all countries, with relative increases[4] lying in the interval [38 %, 96 %]. Figure 2 and Table 2 suggest an interesting economic evidence from the pair-wise rank correlation estimates at country level in terms of co-movements. For Northern EU Countries, while Germany-France (France-Netherlands) correlation has the highest (lowest) values until Q3 2020 (Q4 2020), data points are located

[2] Observe also the column “Mean”, reporting the average intensity levels over the period.

[3] Exception for Q1 2017 where France shows a higher peak. From an economic perspective, disentangling the impacts deriving from Brexit would be an interesting topic to analyze for UK: this is beyond the scope of the present paper and left as extension for future research.

[4] The relative changes in the intensity levels are computed by considering the absolute variation in $\hat{\lambda}_{C_{jt}}$ (variation over one time step) divided by the initial intensity level $\hat{\lambda}_{C_{jt}}$. The highest relative changes are reported for Portugal, Spain, France and Greece, within the interval [67 %, 96 %].

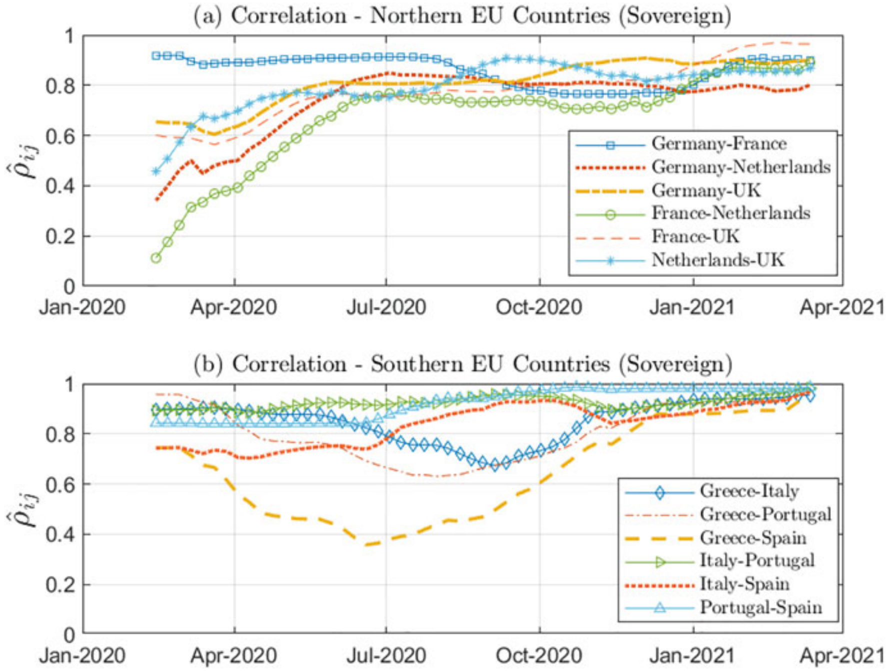


**Fig. 2** Sovereign rank correlation. The plots report the pair-wise rank correlation computed based on CDS quotes for 8 EU Sovereign entities over the period Mar-2020/Mar-2021. The plot at the top provides the pair-wise rank correlations for 4 Northern EU Countries, e.g. UK, Germany, France, Netherlands. The plot at the bottom provides the pair-wise rank correlations for 4 Southern EU Countries, e.g. Greece, Italy, Portugal, Spain

**Table 2** Descriptive statistics. Rank correlation. Time window: Mar-2020/Mar-2021

| *Northern EU Sovereign* | *Mean* | *Std dev* | *Min* | *Max* |
|---|---|---|---|---|
| Ger-Fra | 0.8583 | 0.0587 | 0.7638 | 0.9192 |
| Ger-Ned | 0.7375 | 0.1324 | 0.3408 | 0.8493 |
| Ger-UK | 0.8108 | 0.0900 | 0.6045 | 0.9085 |
| Fra-Ned | 0.6737 | 0.1848 | 0.1118 | 0.8902 |
| Fra-UK | 0.7791 | 0.1111 | 0.5634 | 0.9694 |
| Ned-UK | 0.7955 | 0.0938 | 0.4569 | 0.9065 |
| *Southern EU Sovereign* | *Mean* | *Std dev* | *Min* | *Max* |
| Gre-Ita | 0.8522 | 0.0835 | 0.6742 | 0.9542 |
| Gre-Por | 0.8069 | 0.1138 | 0.6305 | 0.9680 |
| Gre-Spa | 0.6437 | 0.1910 | 0.3583 | 0.9441 |
| Ita-Por | 0.9249 | 0.0240 | 0.8845 | 0.9817 |
| Ita-Spa | 0.8374 | 0.0829 | 0.7034 | 0.9666 |
| Por-Spa | 0.9219 | 0.0629 | 0.8409 | 0.9861 |

**Table 3** Descriptive statistics. EU common factor estimates

| Sovereign | Mean | Std dev | Min | Max |
|---|---|---|---|---|
| Northern EU | 0.0128 | 0.0035 | 0.0038 | 0.0184 |
| Southern EU | 0.1222 | 0.0425 | 0.0588 | 0.2625 |

above a correlation value of 0.6 from Q2 2020 onward for all cases. Overall, the rank correlation has an increasing trend until Q2 2020 for all countries and then a more stable behaviour around a high correlation value. For Southern EU Countries, the same initial increasing trend before Q2 2020 is not a common feature. This is strengthened after Q3 2020 and reaches its maximum in Q1 2021, when all series are above 0.9, thus reflecting the interconnectedness of the economies, the associated riskiness and strong co-movement behaviour[5]. The estimates of the common factor in Table 3 highlight a difference of one order of magnitude between Northern EU and Southern EU Countries. The estimates would need further investigation to disentangle the underlying components, both from an economic and mathematical perspectives. A Marshall-Olkin copula model [5] could be used to further explore the interplay between the sovereign default risk and the dynamics of the banking sector, as in [6], together with non-systematic components. Moreover, a comparison with alternative benchmark models for the dependence structure would be desirable. This is beyond the scope of this first empirical investigation and is left for future research on systemic risk attribution.

## 4 Conclusion

Building on the work by [1], this paper focuses on a sovereign CDS analysis of systemic risk assuming a macroprudential perspective. The paper proposes a data-driven approach applied to CDS quotes to estimate a reduced form model for the marginal intensity of defaults at country level. It considers 8 European sovereign obligors to assess the pandemic implications on the economies. According to results, a systematic effect in default intensities, rank correlation and common factor is observed in the sample. However, geographical differences in terms of macroeconomic perspective (e.g. rank correlation) and credit risk perspective (e.g. marginal intensity, common factor) are present. Empirical evidence highlights a strong co-movement on pair-wise correlations between sovereign default intensities. These preliminary results suggest the basis for a deeper analysis to identify the factors driving heterogeneity across countries. Future research should focus on developing a comprehensive mathematical framework to simultaneously asses: i) the interplay between sovereign-banking system defaults and non-systematic components, ii) the interconnectedness of the banking system, by means of complex

[5] Rank-correlations associated to Greece have a U-shaped behaviour, with a minimum for Q2-Q3 2020. The interplay between financial and non-financial effects could be a relevant driver.

theory and specific dependence metrics (as alternative to [5]). From a macroprudential perspective, designing a formal framework enabling to identify early warning economic indicators would be important to support policy-makers decisions on systemic risk and financial stability.

**Acknowledgments** The author would like to thank two anonymous referees, the editor and Cees Dicks for comments and feedback.

## References

1. A. Baglioni, U. Cherubini, Within and between systemic country risk. Theory and evidence from the sovereign crisis in Europe, Journal of Economic Dynamics & Control, 37 (2013), 1581–1597.
2. BIS (2011), The impact of Sovereign Credit Risk on Bank Funding Conditions, CGFS Papers, 43.
3. S. Cevik, B. Öztürkkal, Contagion of Fear: is the Impact of COVID-19 on Sovereign Risk Really Indiscriminate?, IMF Working Paper, WP/20/263
4. G. Farina, R. Giacometti, M.E. De Giuli, Systemic risk attribution in the EU, Journal of the Operational Research Society, 70(7) (2018), 1115–1128
5. Marshall A.W., Olkin I., A multivariate exponential distribution, Journal of American Statistical Association, 62(317) (1967), 30–44.
6. R. Giacometti, G. Torri, G. Farina, M.E. De Giuli, Risk attribution and interconnectedness in the EU via CDS data, Computational Management Science, 17 (2020), 549–567.