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From SMP to PEPP: a further look at the risk endogeneity of the Central Bank

by Marco Fruzzetti, Giulio Gariano, Gerardo Palazzo and Antonio Scalia*

Abstract

This paper examines the evolution of credit risk arising from monetary policy operations and ELA on the Eurosystem balance sheet over the last decade. We employ a dynamic, market-driven risk model relying on the expected default frequencies for sovereigns, banks and corporates provided by Moody's Analytics. Dependence between defaults is modeled with a multivariate Student *t* distribution with time-varying parameters. We find that at the end of 2020, risk is slightly above its average value in 2010 and approximately equal to one quarter of the value measured at the peak of the sovereign debt crisis in 2012, notwithstanding the threefold increase in the Eurosystem monetary policy exposure occurred since then. This is due to the launch of the OMT and PEPP, which succeeded in quelling market turmoil, thereby reducing the Eurosystem's own balance sheet credit risk. The OMT in particular has had a long lasting effect in lowering sovereign risk in the euro area. Our findings support the view that, in periods of severe financial distress, risk for a central bank is largely endogenous.

JEL Classification: E58, E52, C15.

Keywords: financial risk measurement, unconventional monetary policy, ELA, sovereign risk, Eurosystem financial risk.

Sintesi

Il lavoro esamina l'evoluzione nell'ultimo decennio del rischio di credito derivante dalle operazioni di politica monetaria e dall'ELA per il bilancio dell'Eurosistema. Si utilizza un modello di rischio dinamico che si basa sulle frequenze di insolvenza previste per emittenti pubblici, banche e aziende fornite da Moody's Analytics. La dipendenza tra le insolvenze è modellata con una distribuzione *t* di Student multivariata i cui parametri variano nel tempo. Si mostra che alla fine del 2020 il rischio è leggermente al di sopra del suo valore medio nel 2010 e pari a circa un quarto del valore misurato al culmine della crisi del debito sovrano nel 2012, nonostante l'esposizione di politica monetaria dell'Eurosistema sia triplicata da allora. Ciò è dovuto al lancio dell'OMT e del PEPP, che sono riusciti a placare le tensioni di mercato, riducendo così il rischio di credito del bilancio dell'Eurosistema. L'OMT, in particolare, ha avuto un effetto duraturo nel ridurre il rischio sovrano nell'area dell'euro. I nostri risultati avvalorano l'idea che, in periodi di grave difficoltà finanziaria, il rischio per una banca centrale è in gran parte endogeno.

* Bank of Italy, Financial Risk Management Directorate.

CONTENTS

1. Introduction[1]

Over the last decade the Eurosystem and other major central banks have adopted unprecedented programmes of long-term lending and large-scale asset purchases, which have stemmed the threats to price stability and financial stability.[2] The *'whatever it takes'* statement by President Draghi and the ECB's decision on the Outright Monetary Transactions (OMT) programme in 2012 have clearly shown that the central bank's commitment to act as a potential buyer of last resort is in itself capable of shifting expectations in the economy (Altavilla, Giannone and Lenza, 2016). These unconventional measures, though, have raised some criticism and concerns that their costs and side effects may be sizeable.[3]

While the effectiveness of the unconventional measures in terms of the achievement of the price stability mandate is the subject of a large body of empirical literature, their consequences for the financial risk borne by the Eurosystem are less explored, owing also to the confidential nature of central bank exposures. Nevertheless, this risk is a key indicator of the macroeconomic and institutional cost of the unconventional measures, as future capital losses may hinder the independence of the central bank and hence its effectiveness in the pursuit of the price stability mandate (BIS, 2013).[4]

The credit risk component of the Eurosystem's balance sheet has received increasing attention since the global financial crisis, owing to the absence of an area-wide fiscal authority that can be considered truly risk free (Buiter and Rahbari, 2012; Hall and Reis, 2013; Reis, 2015). The financial risk borne by the Eurosystem following the launch of the Securities Market Programme (SMP) and the OMT is the subject of a recent study by Caballero, Lucas, Schwaab and Zhang (2020).

We draw from the latter study and investigate the evolution of credit risk on the monetary policy and emergency liquidity assistance (ELA) operations of the Eurosystem over the last decade, from the SMP

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1 The views expressed in this paper are those of the authors and do not involve the responsibility of Banca d'Italia. For their helpful comments the authors would like to thank Michele Leonardo Bianchi, Luigi Cannari, Diego Caballero, Alberto Locarno, Fernando Monar, Franco Panfili, Stefano Siviero, Jonas Willequet, seminar participants at Banca d'Italia and at the IFABS 2021 Oxford Conference "Financial system(s) of tomorrow".

2 For the Eurosystem, the full list includes the Securities Market Programme (SMP), the Very Long-Term Refinancing Operations (VLTROs; see the glossary at the end of the paper), the Targeted Longer-Term Refinancing Operations (TLTROs), the Asset Purchase Programme (APP), and, most recently, the Pandemic Emergency Longer-Term Refinancing Operations (PELTROs) and the Pandemic Emergency Purchase Programme (PEPP). In addition, the Eurosystem has provided USD swap facilities to euro area banks on a regular basis and euro liquidity to non-euro area central banks (EUREP). In the sample period, the Governing Council of the ECB also introduced 'forward guidance' on monetary policy decisions in the communication to the public. For a cross-country analysis of the unconventional monetary policy tools, see BIS (2019). For a survey of the literature on the effectiveness of the non-standard monetary policy measures of the ECB, see Neri and Siviero (2019) and Rostagno *et al.* (2019).

3 Recurring concerns relate to the following issues: i) unconventional policies (UPs) may reduce bank profitability (Borio, Gambacorta and Hofmann, 2015); ii) they may lead to the build-up of asset-price deviations from their fundamentals and trigger a sharp asset-price correction (Borio, 2014); iii) UPs may induce financial intermediaries to move toward riskier assets (Rajan, 2005; Borio and Zhu, 2012); iv) UPs expose monetary authorities to political interference (Taylor, 2016); v) they have undesirable income and wealth redistribution effects (Lenza and Slacalek, 2018); vi) they may increase wage pressure, inflation and undermine the competitiveness of the industry sector (Sinn, 2019 and 2021); vii) UPs may cause a slowdown of consolidation and structural reforms on the part of sovereign issuers (Bundesbank, 2016). Extreme critics deem the sovereign purchases illegal.

4 Financial results may be important for a central bank even though it can always create money to pay its bills, it cannot be declared bankrupt by a court, and it does not exist to make profits. Losses or negative capital may raise doubts – however misplaced – about the central bank's ability to deliver on policy targets, and expose it to political pressure.

to the Pandemic Emergency Purchase Programme (PEPP) of 2020.[5] We thus aim to contribute to the empirical literature on the impact and costs of the unconventional measures. We focus on the notion of risk endogeneity for monetary policy, whereby the central bank itself, with its own monetary policy measures, generates spillover risk elsewhere in its balance sheet. In addition to external shocks, risk effects can materialize following the adoption of conventional or unconventional measures. While this notion is not new, and it goes all the way back to the lender-of-last-resort concept discussed by Thornton (1802) and Bagehot (1873), it is admittedly very difficult to appraise with accuracy.

Our methodological approach bears some similarity with Caballero *et al.* (2020). We employ a dynamic, market-driven risk model and we use probabilities of default (PDs) over a 1-year horizon inferred from real-time market data, through the Credit Edge platform provided by Moody's Analytics. Such PDs are available for private issuers (as their expected default frequency, or EDF) as well as sovereign issuers (CDS-Implied EDF, or CDS-I-EDF; see the Appendix, Section A). Moody's EDFs are widely used within the financial sector and, in particular, Moody's CDS-I-EDFs for sovereign issuers – when compared with PDs inferred from CDS premia, like those employed by Caballero *et al.* (2020) – seem more effective at filtering out the noise inevitably associated with market data, thus reducing volatility in the estimates. From a statistical viewpoint, we model dependence between issuers/obligors using a multivariate Student *t* distribution with time-varying parameters. This copula captures the varying degree of fatness in the tails of the joint distribution of asset values. We use the model as an engine to simulate scenarios of possible losses from lending operations and asset holdings at the end of a 1-year period. The risk metric is the expected shortfall at the 99 percent (ES99) confidence level, i.e. the average loss occurring in the worst one percent of the scenarios. We track the risk of the Eurosystem at a weekly frequency.

We extend the work of Caballero *et al.* (2020) along several dimensions. First, the period under analysis is from 2010-2020, encompassing all measures from SMP to PEPP. Second, we include risks arising from private purchase programmes (covered bonds, ABSs and corporate bonds) and ELA. Third, we employ detailed data on exposures with monetary policy counterparties and their collateral in credit operations. Fourth, we use a 'double default' model, whereby losses on refinancing operations are estimated conditionally on the joint default of both the counterparty and the collateral issuers. Last, our approach for the estimation of the Student *t* copula with a three-year rolling window of weekly data results in out-of-sample (instead of in-sample) risk estimates, thus providing a more accurate measure of risk over time.

Risk is also regularly monitored by the ECB on an aggregate Eurosystem basis, as well as at the level of each National Central Bank (NCB).[6] The ECB approach to risk measurement hinges on the default and rating migration probabilities of the issuers of the assets held outright, of the counterparties in refinancing operations (or open market operations, OMOs) and of the issuers/obligors of the collateral pledged (ECB, 2015). Default and rating migration probabilities are derived from the studies published by the major

5 Risks originating from the holding of foreign reserves and own funds are not considered.

6 In addition, each of the Eurosystem's central banks reports internally on the risks associated with the specific exposures contained in their balance sheet, not necessarily on the basis of the same methodology and assumptions used by the ECB, although they can serve as a benchmark.

rating agencies and, as such, they are rather stable over time. Their sluggish reaction to short-term changes in the market's perception of financial risk is an intended feature of the model, which protects against possible procyclical reactions from the central bank. In this respect, the ECB approach results in through-the-cycle risk estimates that tend to be lower in periods of severe credit stress and higher otherwise compared with the point-in-time, market based estimates, like those that will be shown in the remainder of this paper. In this respect, our approach can be considered complementary to that of the ECB, as it is more responsive to real-time market developments and provides an up-to-date, forward-looking view of credit risk in the short term (such as the 1-year horizon typically considered for risk reporting).

Our main findings may be summarized as follows. First, while from 2010 to 2020 the Eurosystem exposure from monetary policy operations grew more than threefold (from around €2,000 to over €6,000 billion), at the end of 2020 financial risk estimated with our model is slightly above its average value in 2010 and corresponds to 23 percent of the same measure at the peak of the sovereign debt crisis in 2011-2012 (€43 billion *vs* €185 billion). We interpret this finding to be an outcome of the launch of OMT. With this programme the ECB has made it clear that it considers supporting sovereign issuers that experience financial distress as being, under well-defined conditions, within its mandate.[7] This clarification has filled a void that previously existed in the institutional set-up of the euro area. It seems to have had a long lasting effect in lowering sovereign risk in the euro area. Since the OMT, sovereigns' CDS-I-EDFs, both over a 1-year horizon (the measure that we directly use for risk estimation) and a 5-year horizon (the measure that may be seen as more representative of the sovereign credit risk profile underlying official credit ratings) have never attained a level near their peak in 2011-2012.

Second, while risk arising from credit operations can be managed by appropriately selecting collateral and calibrating valuation haircuts (whereby the central bank can effectively gauge the maximum level of risk that it is prepared to bear), the credit risk arising from securities purchased outright is practically unmitigated and the central bank is directly exposed to financial market distress; in turn, the latter is also affected by the central bank's actions (see next point). Therefore, the Eurosystem financial risk mainly accrues from outright purchase holdings (APP and PEPP), which produce over 90 percent of total risk at the end of 2020. Risk from public sector purchases accounts for 62 percent of total risk.

Third, financial risks in the market and in the Eurosystem's balance sheet reached their peaks before or shortly after the ECB's announcement of OMT and PEPP, after which they receded. Our interpretation of this result is that during particularly distressed periods financial risks appear as largely endogenous for the central bank. We also show that not all monetary policy measures are equally effective in reducing risk due to the communication of the central bank, the external economic conditions and the EU political scene. In this regard, OMT and PEPP have been powerful circuit breakers activated amid severely deteriorating market conditions. The SMP might have been of like kind, however the effectiveness of the programme was undermined by a hesitant and uncertain commitment to act. The APP was launched in a relatively calm market environment to counter the de-anchoring of inflation expectations.[8]

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7 Draghi (2012), ECB (2012).

8 Our evidence is consistent with the argument put forward by Danielsson and Shin (2003), that in normal conditions, when expectations are heterogeneous, thus resulting in heterogeneous trading strategies, treating risk as exogenous is

Recognizing the different nature of uncertainty in a crisis environment, especially when sovereign debt is involved, is essential for central banks. They are not constrained by liquidity or capital motives and, by making their balance sheet promptly available to absorb the risks that the private sector cannot bear, they can act to prevent the sovereign debt market from settling in a bad equilibrium.[9]

Fourth, our high frequency estimates lend themselves to an analysis of the risk efficiency of the monetary policy measures. The notion of risk efficiency implies that a certain expected policy impact should be achieved with the minimum level of balance sheet risk (ECB, 2015). Our proxies for the policy impact of the different measures are the long-term inflation expectations (inferred from the swap market) and financial stability risks (as measured by the Composite Indicator of Systemic Stress, or CISS, developed by the ECB). By comparing these variables with the change in Eurosystem risks around the time of some major policy announcements in the last decade, we find that OMT and PEPP have been highly risk efficient, especially with reference to financial stability (the result for OMT being broadly in line with Caballero *et al.*, 2020). The risk efficiency of the APP is relatively smaller and mainly connected to the price stability objective. The SMP does not appear to be risk efficient in comparison with the subsequent purchase programmes.

Finally, a consideration of the financial strength of the Eurosystem is in order. The notion of solvency for a central bank is not appropriate, in the sense that the central bank is not liquidity constrained in the currency of issue (unless this endangers the price stability objective), and it may even operate with negative capital. Still the question arises as to whether the Eurosystem capital buffers are capable of withstanding the materialization of an extreme ES99-sized credit loss. We find that the Eurosystem as a whole has relatively large capital buffers, defined as the sum of capital and reserves (i.e., paid-up capital, legal reserves and other reserves), revaluation accounts (i.e., unrealized gains on certain assets like gold), and risk provisions. These buffers increased from €430 billion in 2010 to €737 billion in 2020.[10] At

appropriate, for the statistical relationships among asset prices are assumed to depend on the underlying fundamentals and not on the actions of other market agents, which behave as price takers. In this case, the standard roulette-wheel view of risk is a useful approximation of the uncertainty surrounding asset values; hence, the use of quantitative tools for risk measurement, based on the probability densities inferred from past data, is a sound practice. However, when there is a prevailing view concerning the direction of market outcomes and such uniformity leads to broadly similar trading strategies, as occurs during a crisis, the standard risk measurement tools may no longer be adequate. In such circumstances, the uncertainty around asset values not only depends on external financial and economic conditions but, to a large extent, it is also affected by the response of individual agents to the unfolding events: market distress can feed on itself. As a matter of fact, when asset prices fall and traders get closer to their trading limits, they are forced to sell. In turn, the selling pressure sets off further downward pressure on asset prices, which induces a further round of selling, and so on. This endogenous effect on market prices may be caused by commercial banks trying to reestablish adequate levels of capital after a financial loss. The depletion of bank capital diminishes banks' ability to bear risks and may induce them to deleverage further, and in doing so reinforcing the downward trend in asset prices (Brunnermeier and Pedersen, 2009; Danielsson, Shin and Ziegrand, 2012). Danielsson, Shin and Ziegrand (2010) argue that banks' balance sheet capacity, risk constraints and market risk premiums should all be determined simultaneously in an equilibrium model.

9 In particular, with reference to government debt markets, the presence of self-fulfilling defaults is widely studied in the academic literature. In light of the multiplicity of self-fulfilling equilibria in sovereign debt markets, within a wide range of fiscal fundamentals, the fiscal position of a sovereign may support both equilibria without default and equilibria with default. Calvo (1988) addresses the issue on a theoretical level. De Grauwe and Yuemei (2012 and 2013), Corsetti and Dedola (2016) and Orphanides (2017) apply this notion to the euro area.

10 In this paper data regarding the financial buffers of the central banks of the Eurosystem are drawn from the Statistical Data Warehouse of the ECB.

individual NCB level, comparing the buffers with our risk estimates, for the major NCBs the buffers were a multiple of the ES99-sized credit loss arising from monetary policy and ELA operations in all years, including at the peak of the sovereign debt crisis and of the pandemic crisis. We note however that the buffers should cater for all risks in the central bank balance sheet, not simply for those related to monetary policy implementation, i.e. including risks on foreign exchange reserves, investments, etc.

The remainder of this paper is organized as follows. Section 2 describes the methodology underlying our estimates. Sections 3 and 4 describe the data used for the estimation of the exposures and the probabilities of default, respectively. Section 5 presents the results and examines the evolution of Eurosystem risks, the long term inflation expectations and the conditions of financial stress around some key ECB announcements. Section 6 concludes. The Appendix provides further details on the methodology.

2. Methodology

We estimate the financial risks[11] of the Eurosystem over a 1-year horizon by means of a Monte Carlo simulation in which more than 100,000 scenarios are drawn at any date, with the exact number (which may be as high as 200,000) depending on the fulfilment of a convergence criterion.[12] In any scenario, losses arising from purchase programmes and monetary policy and ELA refinancing operations are computed and aggregated. Risks are computed as the expected shortfall at the 99 percent confidence level (ES99), i.e. taking the average of the 1 percent most adverse losses realized in the simulated scenarios at any particular date. Section C in the Appendix provides a graphical representation of the entire process.

We focus on default risk, which is the most relevant risk component in the Eurosystem's balance sheet, since the holdings of purchase programmes are held-to-maturity with very few exceptions and market risk in refinancing operations can materialize only subordinately to the default of the counterparty. This means that we calculate losses only conditional to the default of one or more debtors to whom the Eurosystem is exposed.[13]

With reference to purchase programme portfolios, loss is zero for those assets whose issuers do not default, while in case of default the loss is computed as the difference between the book value[14] and a fixed percentage of the nominal value, as follows:

$$L = \sum_{a} \delta_{issuer(a)} \cdot (BV_a - RR_a \cdot FV_a)$$

11 Financial risk refers to potential losses due to financial events, such as issuers' defaults. It does not consider, for example, potential losses due to operational or legal reasons.

12 After the first 50,000 scenarios, we estimate risk by adding 10,000 scenarios at a time and we stop the simulation when the change in the estimated risk is below 1 percent for five consecutive times (i.e., in the last additional 50,000 scenarios estimated risk changes by less than 1 percent).

13 Potential losses arising from market prices movements are therefore not considered.

14 This takes into account the fact that purchase programme holdings are not marked-to-market.

where L is loss, a is the asset index, δ is a binary default indicator (1 if issuer defaults, 0 otherwise), BV and FV are, respectively, the book and the face value of the asset, RR is the recovery rate.

Our recovery rate assumptions are 60 percent for structured finance instruments (covered bonds and ABSs) and 30 percent for all the other assets.

The calculation of losses arising from monetary policy credit operations takes into account the double layer of protection offered by the counterparty and the collateral pledged. First, the counterparty risk is simulated: if the counterparty does not default, then the loss is zero. Otherwise, each asset in its collateral pool is simulated as well, and the loss is computed as the difference, if positive, between the exposure-at-default (EAD) and the sum of all collateral asset values. The value of each collateral asset is set equal either to a fixed percentage of its nominal value, if the issuer defaults, or to its value before the haircut, if the issuer does not default,[15] as follows:

$$L = \sum_{c} \delta_c \cdot max\left(0, EAD_c - \sum_{a\ in\ collateral(c)} (\delta_a \cdot FV_a \cdot RR_a + (1 - \delta_a) \cdot BH_a)\right)$$

where c is the counterparty index, a is the collateral asset index, EAD is the assumed exposure-at-default, δ are the binary default indicators for both the counterparties and the collateral asset issuers, BH are the values before haircut, FV are the face values and RR are the recovery rates.

The estimation of EAD is not straightforward since banks, under the regime of full allotment that has been in place throughout the sample period, might increase their monetary policy exposure during a crisis. Current exposure thus generally is an underestimate of the potential EAD. We make a conservative assumption and set EAD equal to the current collateral value after haircuts,[16] assuming that banks under stressful conditions would increase their monetary policy exposure up to the maximum allowed amount, given by the value of collateral they have pledged (net of the haircuts).[17] Therefore, our assumed EAD may be significantly higher than the amount of money actually lent to each counterparty at any date. As an example, on the reference date of 25 December 2020 the total refinancing exposure was €1,800 billion, while the total net collateral value – which we use as EAD - was €2,600 billion (+46 percent).

With this assumption, losses arising from monetary policy credit operations are computed as:

$$L = \sum_{c} \delta_c \cdot max\left(0, \sum_{a\ in\ collateral(c)} (AH_a - \delta_a \cdot FV_a \cdot RR_a - (1 - \delta_a) \cdot BH_a)\right)$$

where AH are the values after haircut.

Since collateral value before haircuts is always larger than collateral value after haircut ($BH > AH$), collateral assets that do not default add a negative contribution to losses, which offsets the positive

[15] Since our analysis focuses on default risk, the market risk of collateral (i.e., the possibility that its price goes down during the liquidation process) is not considered.

[16] Excluding cash collateral (if any), since it does not carry risk.

[17] In principle, this approach could lead to an underestimation of EAD as well, since banks could also decide to increase their collateral pool (i.e., to pledge more assets). However, such a hypothesis would require an estimation of eligible unencumbered assets for each counterparty, which is difficult to obtain.

contribution originated by collateral assets that do default. Thus, both the diversification effect in the collateral pool and the protection offered by the haircuts are taken into account.

Regarding ELA operations, in theory losses could be calculated with the same formula reported above for the monetary policy credit operations, since ELA has the same financial structure (it is a collateralized loan). However, in the case of ELA, exposures are likely to be of worse quality than exposure through regular OMOs due to the lower credit quality of the counterparties accessing ELA and the wider collateral set typically eligible for ELA operations. In addition, data regarding the exact amount and composition of collateral are generally not available. Finally, the potential role of the government, as the ultimate effective guarantor, should be taken into account in case of a systemic banking crisis. In practice, risk from ELA exposures should be modelled with some suitable assumptions, depending on the type of the operations conducted in the sample period (see the Appendix, Section C for more details).

In the above formula exposures (book values, face values, values before haircuts, values after haircuts) are static data, and do not change from one scenario to another. Default events (δ), on the contrary, must be simulated. In particular, we simulate three sets of obligors for each scenario:

i. issuers of assets held in the purchase programme portfolios;

ii. counterparties in monetary policy and ELA operations;

iii. issuers of assets pledged as collateral by counterparties.

These debtors are jointly simulated according to a multivariate Student *t* distribution, whose parameters are estimated as described in the Appendix, Section B.[18]

Once the random deviates (X_i) are drawn from the multivariate Student *t* distribution, they are compared with a given threshold (T_i) in order to determine if a default happens:

$$\delta_i = \begin{cases} 1, & if\ X_i < T_i \\ 0, & otherwise \end{cases}$$

The thresholds are set equal to the (univariate) Student *t* quantile of the probability of default (PD):

$$T_i = Q(PD_i)$$

This guarantees a simulated default rate equal to the PD, up to the Monte Carlo error.

The PDs used in our exercise are described in Section 4.

We note that, while issuers in the purchase programme portfolios and counterparties are simulated over a 1-year horizon (namely, the risk horizon),[19] collateral is simulated over a much shorter horizon (typically a few weeks), since it is assumed to be swiftly liquidated by the Eurosystem in the event of a

[18] Our distribution is symmetric. According to Caballero *et al.* (2020), which use a similar dataset to calibrate a skewed *t* copula, the introduction of an asymmetric term has a small effect on the expected shortfall estimates.

[19] In principle, purchase programme holdings with maturity below one year should be simulated over a horizon equal to their maturity. We do not take this into account, which is fair if one considers the practice of reinvestment which has taken place so far.

counterparty default. In practice, this means that PDs must be scaled down for collateral assets. For more details see the Appendix, Section C.

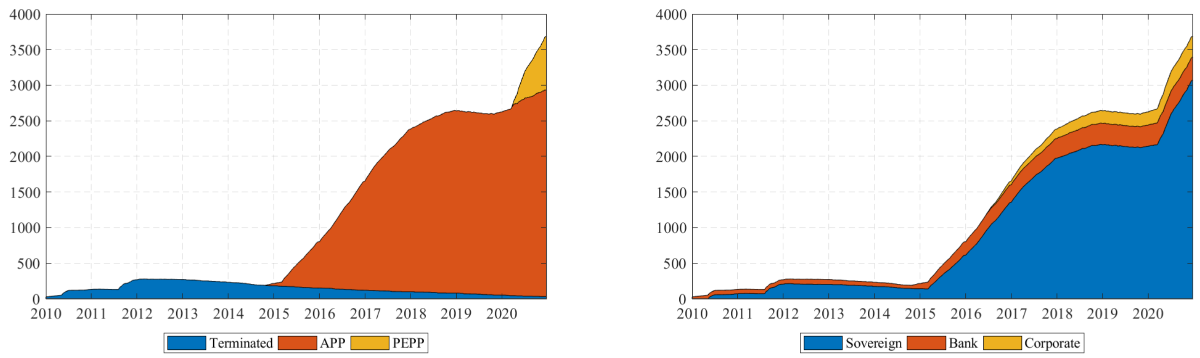
Notwithstanding the large number of input parameters and methodological assumptions, our results exhibit a high degree of robustness, as shown in the Appendix, Sections A and B.

3. Exposure

For purchase programme portfolios, exposures (book and face values) are retrieved from our internal database. The first available date is 5 July 2013. For the period September 2010 – June 2013, exposures of Covered Bond Purchase Programmes 1&2 (CBPP1 and 2) and Securities Market Programme (SMP) have been estimated from the total (publicly available) outstanding portfolio. We assume the same composition by issuer as that observed on 5 July 2013 for CBPP1 and 2. For the SMP we take into account the different country composition during the two waves of the programme.[20]

Figure 1 plots the evolution of the monetary policy securities holdings between September 2010 and December 2020, which significantly increased after the launch of the APP at the end of 2014, and especially during its first three years of operations (with monthly net purchases of €60-80 billion). The left panel shows the composition by category: the terminated programmes (CBPP1&2, SMP), the Asset Purchase Programme (APP, which includes the Covered Bond, ABS, Public Sector and Corporate Sector Purchase Programmes), and the Pandemic Emergency Purchase Programme (PEPP). As of December 2020, the APP represents 78 percent of total exposure. The right panel shows the breakdown by sector: public, corporate and bank (covered bonds and ABSs). As of December 2020, the exposure towards the public sector amounts to 84 percent of the total.

Figure 1. Monetary policy securities holdings (book value, € billion)

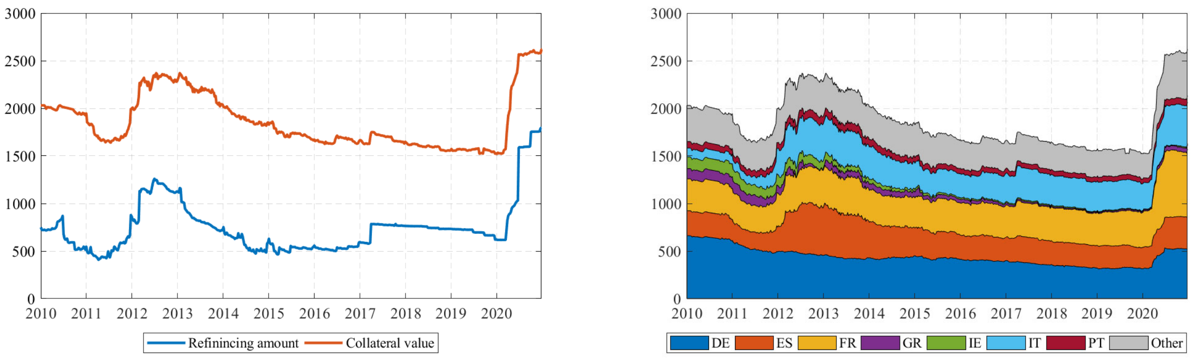


Source: ECB and own calculations.

[20] SMP purchases were conducted by Eurosystem central banks in two main waves. The first one (May 2010 - March 2011) dealt with government bonds from the secondary markets of Greece, Ireland, and Portugal. The second one (which started on 7 August 2011 and ended in February 2012) also dealt with government bonds from Italy and Spain.

For credit operations, exposures (collateral face value, collateral value before haircuts and after haircuts) are retrieved from our internal database.[21] Figure 2 plots the evolution of credit operations between September 2010 and December 2020. The left panel compares the value of collateral (after haircut), which is our assumed EAD (see Section 2), with the actual refinancing amount.[22] Both quantities significantly increased after the outbreak of the pandemic and the related collateral easing measures approved by the ECB in the second quarter of 2020. While the over-collateralization[23] is 46 percent as of December 2020, on some dates in the first half of 2011 it was close to 300 percent. The right panel shows the distribution of collateral by jurisdiction.

Figure 2. Credit operations (refinancing amount and collateral value, € billion)



Source: ECB and own calculations.

For ELA operations, exposures are derived from confidential data.[24]

[21] The first available date is 17 September 2010. For the period 1 January 2010 – 17 September 2010, data have been estimated from the total collateral value per asset class, as reported in several internal sources. Within each asset class, we assume the same composition by issuer as that observed on 17 September 2010.

[22] For simplicity, the blue line ('refinancing amount') only includes the monetary policy refinancing operations denominated in euro. The estimation of risks, however, also takes into account the monetary policy operations in other currencies (US dollar liquidity providing operations), since it is based on the total collateral pledged by monetary policy counterparties (see Section 2), which covers all the outstanding operations.

[23] Computed as: (collateral value)/(refinancing amount) - 1.

[24] Some public information regarding ELA may be found on the website of the relevant NCB. More detailed evidence regarding ELA exposures of the Eurosystem is reported in Mourmouras (2017). As of May 2017, qualitative information has been provided by the ECB with the publication of the *'Agreement on emergency liquidity assistance'*, a document that describes the allocation of responsibilities, costs, and risks for ELA operations within the Eurosystem (ECB, 2017). A thorough discussion of the lender of last resort role of the Eurosystem and other central banks is provided by Calomiris, Flandreau and Laeven (2016).

4. Probability of default

We use the 1-year probabilities of default (PDs) computed by Moody's (as expected default frequencies, EDFs).[25] They are widely employed in the financial sector as input in counterparty assessment, early warning systems and portfolio monitoring, internal risk rating systems, and loss provisioning. These market-driven EDFs, which are independent from agency ratings, enable us to investigate the behaviour of financial risks around some major monetary policy announcements of the last decade.

For financial and non-financial corporates, EDFs are produced with a proprietary model (known as KMV), which uses equity prices and balance sheet indicators as input data. For sovereign issuers, absent the latter input, EDFs are derived from CDS premia (CDS-I-EDF), with a methodology described in the Appendix, Section A. Both EDFs, for corporates and sovereigns, can be considered 'physical' PDs (as opposed to 'risk neutral' PDs), and thus do not require any adjustment to disentangle the quantity of risk from the market price of risk for use in credit risk estimation.[26]

High yield EDFs are used for credit claims pledged as collateral with non-investment grade credit quality.[27]

Our sample comprises 364 debtors, distributed by sector as reported in Table 1.

Table 1. EDF sample: number of debtors

Sovereign & Supra	19
Bank	126
Corporate - Invest. Grade	151
Corporate – High Yield	68

Such sample clearly does not cover all the entities in our risk estimation, which amount to around 7,000 distinct debtors (including counterparties, purchase programme issuers and collateral issuers). In order to make this large number tractable, we create country-sector EDF indices, which are assigned to debtors without an EDF in our sample. More specifically, we cluster debtors by country and sector, and for each cluster we compute the median of all available EDFs, which is then assigned to all the entities in the

25 Moody's Analytics (2010).

26 When deriving default probabilities from market prices (equity prices, bond yield spreads, CDS premia), it is important to distinguish between physical and risk-neutral default probabilities. While risk-neutral default probabilities adjust for investors' risk aversion, physical default probabilities, which can be thought of as 'real world' default probabilities, do not. Market prices, including CDS premia, reflect the expected loss – equal to the product of the probability of default (PD) times the loss given default (LGD) – and the risk premium, but frequently PDs extracted from market prices fail to remove the risk premium, thus largely overstating actual default rates, especially among higher rated entities. Moody's EDF measures are physical PDs; since they filter out the premium demanded by investors to compensate for risk inherent in the CDS contract, they reflect only the risk of the underlying credit. See Hull, Predescu and White (2005).

27 The credit claims accepted as collateral under the Additional Credit Claims (ACC) regime belong to this category.

cluster without an EDF. Since there is a single sovereign for each country,[28] sovereign indices correspond to the individual EDF time series (and not to a median of several EDFs).

We chose the median rather than the average EDF since the former is less sensitive to outliers, in line with Caballero *et al.* (2020).

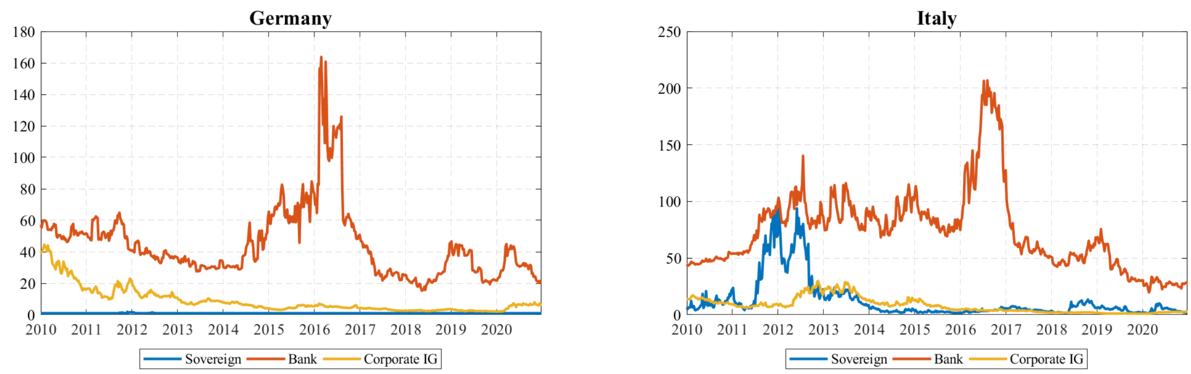
In all, we calculate 36 indices, as reported in Table 2. These EDF indices are also used for the estimation of the parameters of the multivariate Student *t* distribution (see the Appendix, Section B).

Table 2. Country-sector EDF indices

Sovereign & Supra (19)	Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Portugal, Slovakia, Slovenia, Spain, Netherlands,[29] Others
Bank (8)	Austria, Germany, Spain, France, Greece, Ireland, Italy, Others
Corporate - Invest. Grade (7)	Belgium, Germany, Spain, France, Italy, Netherlands, Others
Corporate – High Yield (2)	Euro Core, Euro Peripheral

Figure 3 shows the EDF indices for Germany and Italy.

Figure 3. Country-sector EDF indices (basis points)



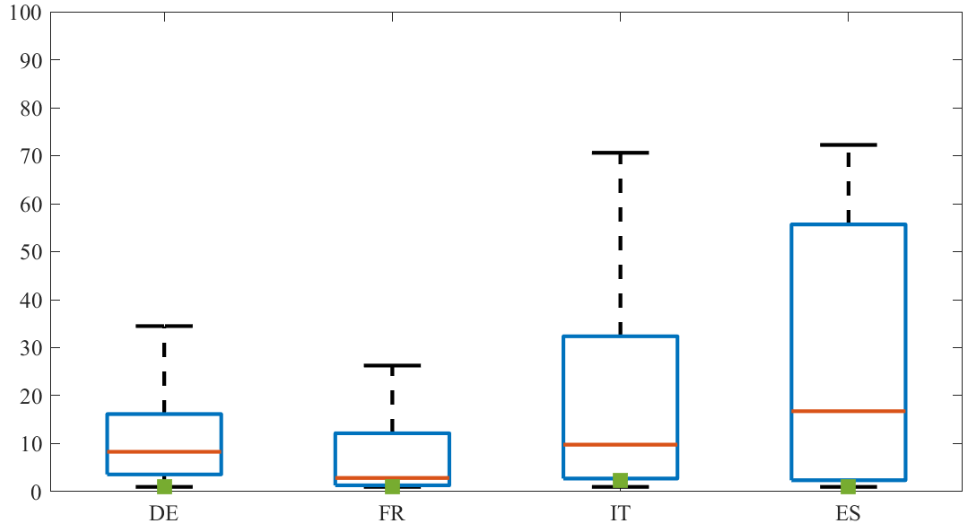
Source: Moody's Credit Edge and own calculations.

[28] While distinct EDFs are available for central governments and local governments, we only consider central government EDFs, which we apply to local government issues as well.

[29] We proxy the (unavailable) EDF of Luxembourg with the one of the Netherlands.

A robustness check of CDS-I-EDFs is challenging, because very few sovereign defaults are available. A possible course of action is verifying that the sovereign CDS-I-EDF is consistent with domestic corporate (financial and non-financial) EDFs, under the assumption that the former should be lower, since the sovereign is normally perceived as less risky than the safest firms in its jurisdiction. Figure 4 shows that this is indeed the case for the largest countries of the euro area.

Figure 4. Sovereign (green squares) and corporate (boxplots) EDFs for the major jurisdictions in the euro area (average in Q4 2020; basis points)



Source: Moody's Credit Edge and own calculations.

We also verify the consistency of sovereign CDS-I-EDFs and their implied ratings (also provided by Moody's Analytics) with the actual ratings assigned by Moody's Investors Services (a separate legal entity of the Moody's group, in charge of the rating business; see Table 4 in the Appendix, Section A). We show that, on average, the ratings implied by the 5-year CDS-I-EDFs are in line with the actual ratings issued by Moody's Investors Services. The appropriate comparison has been made with 5-year EDFs (instead of 1-year EDFs) as rating agencies claim that their ratings represent an assessment of the credit risk profile of an issuer over a medium term perspective.

5. Results

Figure 5 plots risk (left y-axis) and exposure (right y-axis) at weekly frequency from 1 January 2010 to 25 December 2020. Risk is estimated for the entire Eurosystem as the expected shortfall at the 99 percent confidence level (ES99) with the methodology described in Section 2. Risk reaches local highs on the following occasions: a) the sovereign debt crisis in the first half of 2012; b) the ELAs to Greek banks in 2015; c) the political tensions in Italy surrounding the formation of the new government in May 2018; d) the outbreak of the pandemic in March 2020, followed by a split among EU members on the extraordinary relief package and the German constitutional court pronunciation on the illegality of the PSPP, in April-May 2020.

Risk reached an overall maximum around €185 billion in June 2012, even though monetary policy exposure widely increased since then, following the APP in 2014 and PEPP in 2020.

Figure 5. Risk and Exposure (€ billion)

Source: own calculations.

The contribution to risk of monetary policy credit operations is rather small and less sensitive to financial market developments, due to the collateralized nature of refinancing to commercial banks. The risk profile of the Eurosystem has changed since the launch of the purchase programmes, becoming more similar to the risk profile of institutional investors that hold diversified portfolios of marketable assets and are directly exposed to financial market volatility. Finally, the risk contribution of ELA operations is quite significant.

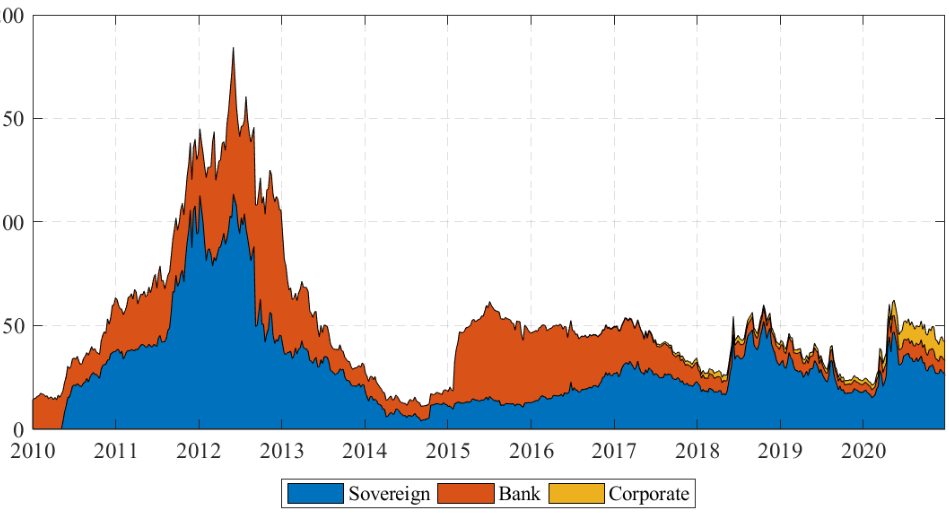
Figure 6 plots the risk contribution by sector. The sovereign sector and the corporate sector take into account the risk of the corresponding purchase programmes. In addition to risks arising from purchase programmes (covered bonds and ABSs), the bank sector also includes the risk of monetary policy refinancing and ELA operations. As of December 2020 the public sector accounts for 62 percent of total risk, while the corporate sector and the bank sector account for 21 and 17 percent, respectively.

Next we examine what would happen if an ES99-sized credit loss materialized: would capital buffers withstand this event?

For this purpose we compare the maximum risk borne by the individual NCBs with the financial buffers in each year. Financial buffers include capital and reserves (paid-up capital, legal reserves and other reserves), revaluation accounts (i.e., unrealized gains on certain assets like gold), and risk provisions.

We find that for all major NCBs the buffers were a multiple of the ES99 loss arising from monetary policy and ELA operations, even at the peak of the sovereign debt crisis in 2011-2012 and during the pandemic crisis in 2020.

Figure 6. Risk breakdown by sector (€ billion)



Source: own calculations.

The picture at the aggregate Eurosystem level is also reassuring as the buffers increased from a minimum of 430 billion in 2010 to a maximum of 737 billion in 2020.[30] We recall however that the buffers should cater for all risks in the central bank balance sheet, not simply for those related to monetary policy implementation.

Next we analyze in more detail the evolution of risk during four time periods encompassing the launch of the major purchase programmes for sovereign bonds: SMP, OMT, PSPP and PEPP. In order to assess the monetary policy measures under a comprehensive cost-benefit perspective, we also report two indicators related to the central bank price stability mandate and financial stability: a) the 5-year, 5-year forward euro inflation swap rate, which is commonly used as a proxy for the market's long term inflation expectations in the euro area; b) the Composite Indicator of Systemic Stress (CISS), which is computed by the ECB as the equally weighted average of 15 market-based financial stress measures from the financial intermediaries sector, money market, equity market, bond market and foreign exchange market

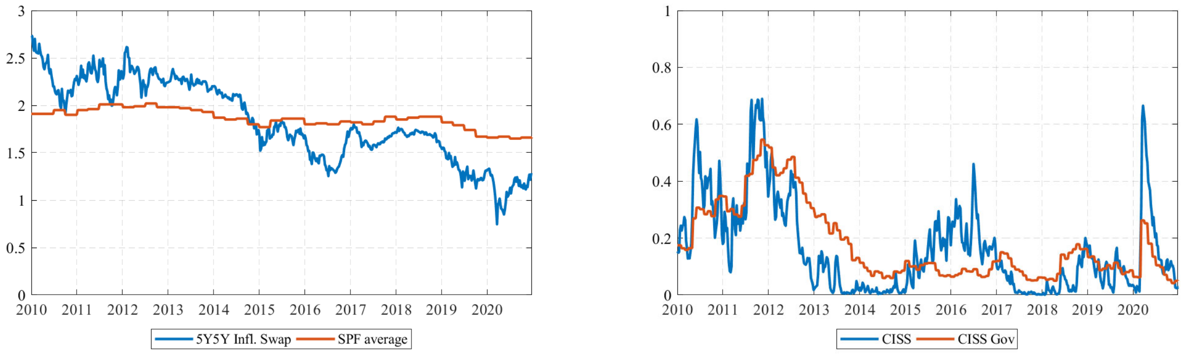
[30] The financial buffers in 2010 (430 billion) do not include the NCBs of Lithuania and Latvia, which joined the euro in 2014.

(this indicator ranges between 0 and 1).[31] The left panel of Figure 7 plots the 5-year, 5-year forward euro inflation swap rate (left y-axis) and, for comparison, the long term inflation expectations from the Survey of Professional Forecasters. The right panel of the same figure plots the CISS index and its sovereign component.

We cannot perform a proper event study analysis. Such an approach relies on the assumption that markets are informationally efficient. In our context, this would require that the impact of the ECB's unconventional policies materializes on the *exact date* of announcement, while in the cases under consideration expectations are more likely to have been shaped over a period of time, during which views and actions of financial market participants, including the central bank, have interacted with each other in a continuous *process*. A case in point is the APP, which had been fine-tuned according to financial and economic developments and communicated to the market on different occasions during the second half of 2014.

Therefore, we focus on the main events and narratives that have accompanied the four monetary policy announcements, including some major statements by policy makers.

Figure 7. Inflation expectations and Systemic stress indicator



Source: ECB.

SMP

The first time window of interest is related to the Securities Market Programme, launched on 10 May 2010 and involving the purchase of sovereign bonds in secondary markets as a monetary policy tool for the first time since the introduction of the euro in 1999. To many commentators, the decision seemed behind the curve and taken without much conviction, coming only a few days after the conclusion of a scheduled meeting of the Governing Council, during which the possibility of purchasing sovereign bonds was not even discussed.[32] Yet the market tensions that led to the launch of the SMP had been going on

[31] Garcia-de-Andoain and Kremer (2018), Holló, Kremer and Lo Duca (2012).

[32] ECB (2010a).

since the end of 2009, when difficulties with public finances in Greece had come into the focus of financial market participants.

In launching the SMP, as well as in subsequent official speeches by the President of the ECB, the communication was very cautious.[33] On 10 May the ECB did not announce any key features of the SMP, such as which securities it targeted, the amount that would be purchased, and how long the programme would last.[34] Moreover, it was evident that the ECB was not acting decisively also because of diverging views within the Governing Council.

At the German-French summit of 19 October 2010 in Deauville, Chancellor Merkel and President Sarkozy called for a permanent crisis resolution mechanism in Europe *'comprising the necessary arrangements for an adequate participation of the private sector'*. Private investors interpreted the announcement as an official signal that sovereign debt restructuring would henceforth be considered acceptable in EU countries. Bond yields of vulnerable sovereign issuers steeply increased on the news.

During the summer of the following year the financial contagion spread to Spain and Italy. On 7 August 2011 the ECB stated that it would have actively implemented the SMP on the assessment that the governments of Italy and Spain were committed to reforms in the areas of fiscal and structural policies, aimed at enhancing the competitiveness and flexibility of their economies and at rapidly reducing public deficits.[35]

The sovereign crisis did not abate after the launch of the second wave of the SMP, as shown in Figure 8, which plots the evolution of risk for the Eurosystem (left and right panels) plus the inflation expectations (left panel) and the systemic stress indicator (right panel) around the two relevant SMP dates, 10 May 2010 and 7 August 2011.[36]

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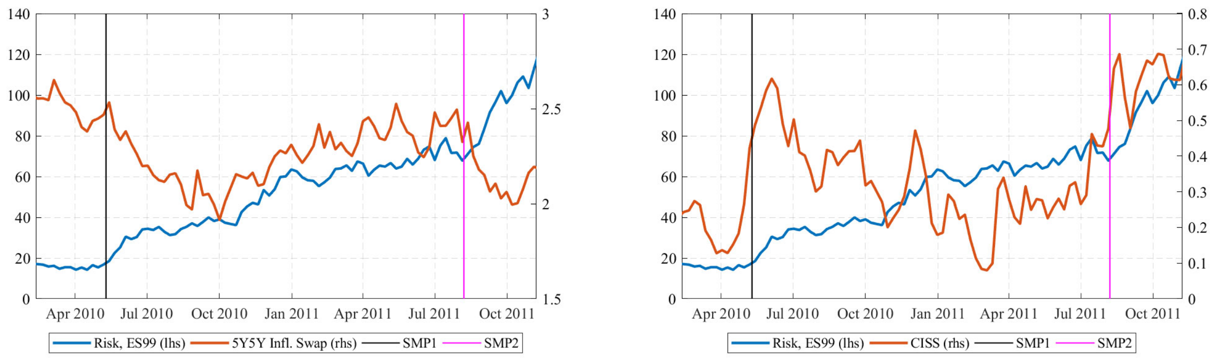
[33] It was made very clear that 'the ECB was not printing money', the purchases made on the secondary market were 'not meant to help Governments to circumvent the fundamental principle of budgetary discipline' and, even more importantly, purchases would be decided by the Governing Council at its discretion. ECB (2010b).

[34] Fairly soon, bond traders learned about the ECB's actual presence in the market under SMP. As evidence accumulated about the likely size and time profile of the official interventions in the distressed jurisdictions, investors grew concerned that the programme might fall short of the minimum scale that, in their assessment, would be necessary to decisively eradicate the fear that was gripping the sovereign bond market (Rostagno *et al.*, 2019). At the press conference following the Governing Council meeting of 10 June 2010, in response to a question about the size and jurisdictions of purchases, President Trichet replied: *'You could see that the first week we withdrew approximately 16.5 billion euros, the second week 10 billion more, the third week an additional 8.5 billion, in the fourth week 5.5 billion. So you have this information. We withdraw exactly the level of liquidity that we inject. No other indication.'*

[35] ECB (2011).

[36] After the August 2011 decision, the spread between 10 year Italian and German government bond yields decreased from around 400 basis points to 270 basis points. This positive market reaction was short lived and the spread climbed to 500 basis points at the beginning of November 2011 and again in January 2012.

Figure 8. Risk (€ billion), Inflation expectations (percentage values) and Systemic stress indicator around the two SMP announcements (10 May 2010 and 7 August 2011)



Source: ECB and own calculations.

OMT

The two three-year Very Long-Term Refinancing Operations (VLTRO) launched by the ECB in December 2011 and February 2012, respectively, had limited and short lived effects on the sovereign market conditions. In mid-2012 the tensions in the euro area government bond markets reached new peaks and spread to the banking sector.

During the sovereign debt crisis, at their summits in the first half of 2012 European leaders took several decisions to break the circle between banks and sovereigns, the most relevant being the set-up of the European Stability Mechanism (January) and of the Single Supervisory Mechanism (June).

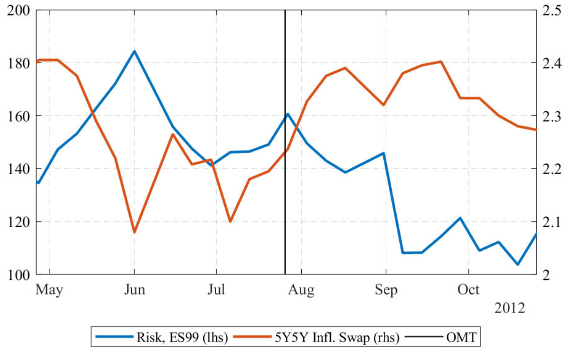
As a further intervention to avoid impairments in monetary policy transmission, in the period from July to September 2012 the Governing Council announced that the ECB might have engaged in Outright Monetary Transactions (OMTs) in the secondary markets for government bonds. In particular, on 26 July 2012, during a conference in London, President Draghi said that the ECB was ready to do *'whatever it takes'* to preserve the euro within the limits of its mandate.[37] On 2 August 2012, at the press conference after the Governing Council meeting, it was announced that the ECB *'may undertake outright open market operations of a size adequate to reach its objective'*.[38] On 6 September the ECB eventually announced a number of technical features of the OMT programme.

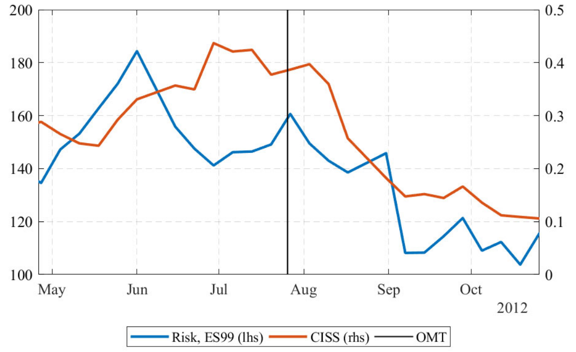
[37] Draghi (2012). The irreversibility of the euro made the premia on sovereign bonds (owing to the so called convertibility risk) unwarranted, as they derived from the wrong perception that a sovereign in financial difficulty would abandon the euro and return to its domestic currency. To the extent that the size of these sovereign premia was hampering the functioning of the monetary policy transmission channel, addressing them was in the remit of the ECB.

[38] ECB (2012). Although the operational details would have been communicated over the following weeks, during the Q&A session with journalists, it was made clear that the new programme would have been *'very different from the previous Securities Market Programme'*. The following aspects were mentioned: i) explicit conditionality; ii) full transparency about the countries where OMT would be undertaken and about the amounts; iii) focus on the shorter part of the yield curve; iv) review of the issue of the seniority of the Eurosystem claims.

The announcement of the OMT signaled determination and strength; indeed it succeeded in calming market tensions (Figure 9). The effectiveness of the announcement of OMT in influencing financial market conditions (especially if compared with the SMP) is probably related to the fact that purchases are in principle unlimited, subject to conditionality on compliance with a macroeconomic adjustment programme, and have greater transparency.[39] In the following years risk has never reached the level of 2012, despite the huge increase of the Eurosystem's balance sheet.

Figure 9. Risk (€ billion), Inflation expectations (percentage values) and Systemic stress indicator around the *'whatever it takes'* statement (26 July 2012)





Source: ECB and own calculations.

Although successful, the OMT was politically controversial. The commitment to preserve the euro as a stable currency was unanimous within the Governing Council. Still, there was no mystery that the Bundesbank had expressed its reservations about purchasing sovereign bonds.[40] The decision to launch the OMT was later challenged before the German constitutional court by members of the German Bundestag.

APP

The Eurosystem Asset Purchase Programme (APP) started in the last quarter of 2014 with the purchases of covered bonds and asset-backed securities under the CBPP3 and ABSPP, respectively. In the face of weaker than expected inflation dynamics and signs of decrease of inflation expectations even at long horizons, on 22 January 2015 the Governing Council decided to adopt further quantitative measures to expand the size and change the composition of the Eurosystem's balance sheet, supplementing the previous two programmes with additional purchases of securities issued by euro area governments,

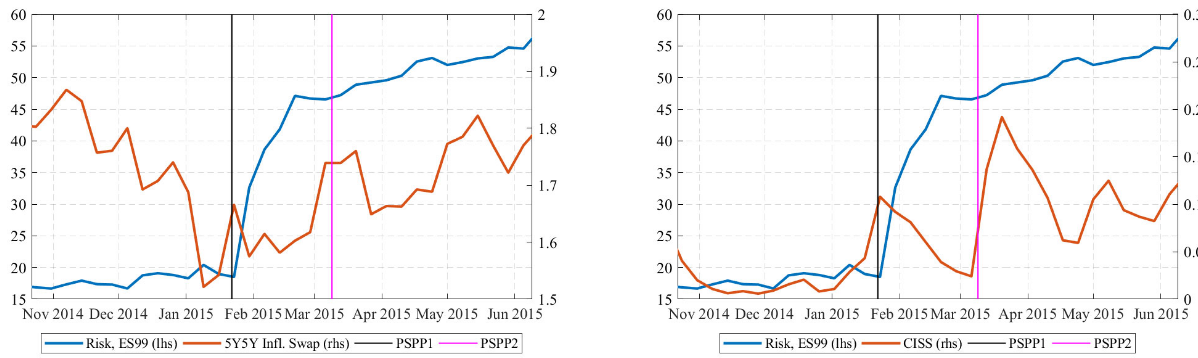
[39] Altavilla, Giannone and Lenza (2016) find evidence that the OMT announcement significantly lowered yield spreads of sovereign bonds, especially for stressed euro area countries. Acharya *et al.* (2018), and Krishnamurthy, Nagel and Vissing-Jorgensen (2017) show significantly positive effects on banks' equity prices after the OMT announcement.

[40] These diverging views were explicitly acknowledged on 6 September 2012 during the press conference in which the President of the ECB announced the details of the OMT.

agencies and EU institutions (Public Sector Purchase Programme, PSPP). The programme was further extended to the corporate sector (CSPP) in June 2016.

In contrast to the OMT, the APP was not launched in a period of market tension, so its limited impact on financial stability risk does not come as a surprise. Figure 10 shows the evolution of risks, price stability and financial stability indicators around the announcement of the extension of APP to public sector (22 January 2015) and the actual start of the purchases (9 march 2015). The evolution of risk around 22 January 2015 is affected by the large ELA operations in Greece, that started just few days later.

Figure 10. Risk (€ billion), Inflation expectations (percentage values) and Systemic stress indicator around the extension of APP to the public sector (22 January 2015 and 9 March 2015)



Source: ECB and own calculations.

As with the OMT, also the launch of the APP was challenged in court.[41]

PEPP

Soon after the outbreak of the Covid-19 pandemic throughout Europe at the beginning of March 2020, the expectations built up in the market about a strong and quick reaction from the ECB in view of the fast deterioration of the economic outlook. However, in the face of increasing turmoil in the euro sovereign debt market, in early March an official statement by the President of the ECB did not point to any concrete action and merely signaled that the central bank *'stands ready to take appropriate and targeted measures, as necessary and commensurate with the underlying risks'*.[42] The first measures to address the effect of the pandemic were announced on 12 March. These included additional LTROs,

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[41] The complainants — a group of about 1,750 people, led by German economists and law professors — first brought their case in 2015. They argued that the ECB was straying into monetary financing of governments, which is illegal under the EU treaty. The case was referred to the European Court of Justice, which ruled in favor of the ECB in 2018; the case went back to the German constitutional court, which on 5 May 2020 formally rejected the plaintiff's case (there was no monetary financing) but ruled the essential aspects of PSPP to be unconstitutional under German law.

[42] ECB (2020a). On 3 March the Federal Reserve lowered the target range for the federal funds rate by 0.5 percentage points (to 1-1.25 percent) and the discount rate from 2.25 to 1.75 percent.

more favourable terms applied to TLTRO III operations and a temporary envelope of additional net asset purchases for the APP by €120 billion until the end of 2020.[43]

After some measures of stress in the euro money market had reached levels close to the historical highs of 2008 and 2012, on 18 March 2020 the Pandemic Emergency Purchase Programme (PEPP) announcement came as a strong positive surprise, with most commentators acknowledging that it was a game changer, supporting tighter intra-EMU spreads. The details of PEPP, released in the legal acts a week after the announcement, reinforced the perceived determination to act of the ECB. The package was strengthened on 22 April with the ECB decision to grandfather the eligibility of marketable assets used as collateral, in order to mitigate the impact of possible rating downgrades on collateral availability for euro area counterparties.[44]

However, after an initial positive market response, intra-EMU credit spreads suddenly started to increase again. The tightening in the euro area financial conditions — largely offsetting monetary and fiscal efforts — had been sparked by a split among EU countries over how additional public spending would have ultimately been funded.[45] PEPP started to be seen as unable to address reemerging concerns on sovereign debt sustainability and the long-term viability of the single currency area was again perceived at risk.

The period of market turmoil came to an end on 18 May, after a press conference in which Chancellor Merkel and President Macron outlined a plan to create additional €500 billion of spending power. Italian and Greek government bonds sharply rallied after the announcement, sending their yields to three-month lows. Before then, Eurosystem risks had peaked at 62 billion on 15 May 2020.

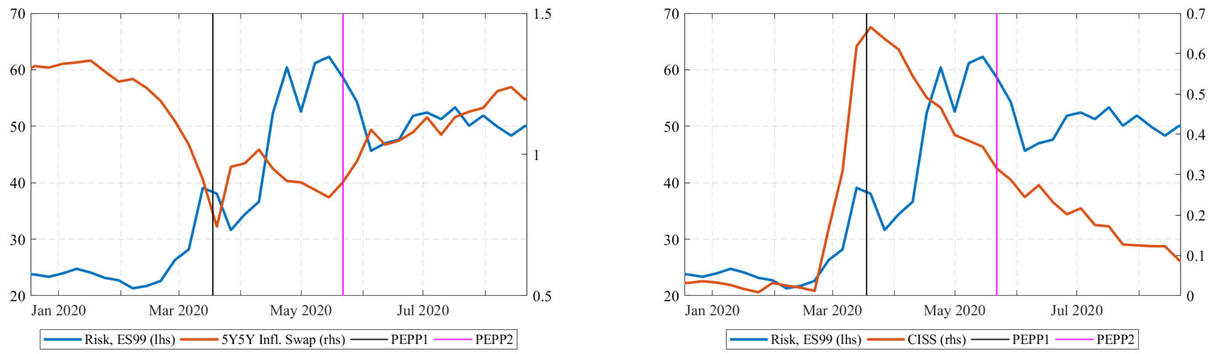
On 22 May 2020 the publication of the minutes of the Governing Council meeting held on 30 April confirmed that the ECB would *'stand ready'* to expand the PEPP response to the pandemic, if needed to tackle the economic and financial turmoil. Finally, on 4 June 2020 the ECB announced that it will buy an extra €600 billion of bonds, a move larger than most economists' expectations, taking the PEPP to €1.35 trillion in total. Italian and Greek government bonds rallied after the announcement (see Figure 11 and Figure 12).

[43] ECB (2020b).

[44] ECB (2020c). The ECB also said it *'may decide, if and when necessary, to take additional measures to further mitigate the impact of rating downgrades, particularly with a view to ensuring the smooth transmission of its monetary policy in all jurisdictions of the euro area'*. Investors were particularly concerned by a potential downgrade of Italy's sovereign debt ratings, with Standard & Poor's set to announce a decision about that on Friday 24 April 2020. S&P later confirmed the rating and the negative outlook.

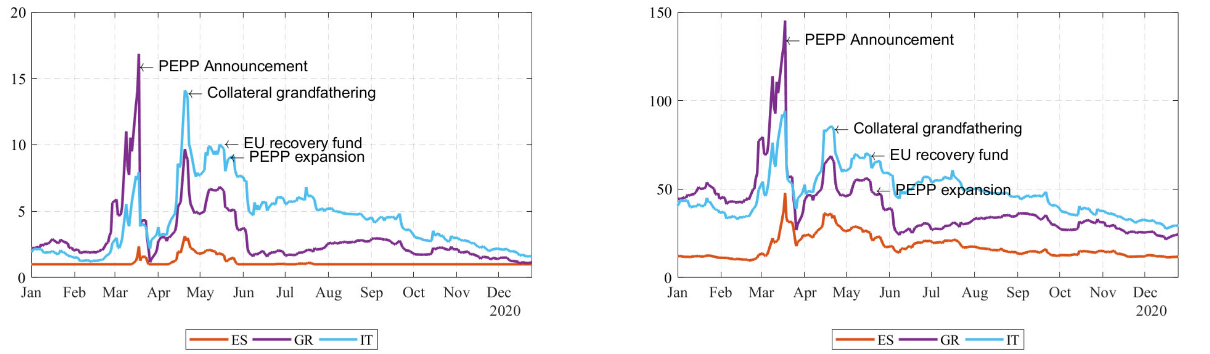
[45] It is also worth recalling the unexpected downgrade of Italy's credit rating by Fitch Ratings late on 28 April and the German Federal Court ruling that the PSPP partly violates the German constitution on 6 May 2020. The latter made it highly likely that German critics of the ECB would challenge the PEPP, too.

Figure 11. Risk (€ billion), Inflation expectations (percentage values) and Systemic stress indicator around the PEPP announcement and follow-up (18 March and 22 May 2020)



Source: ECB and own calculations.

Figure 12. 1-year and 5-year CDS-I-EDF of Spain, Greece and Italy (basis points) during 2020



Source: Moody's Credit Edge.

Table 3 summarizes the change in risk, inflation expectations and the financial stability indicator three weeks after the monetary policy announcements analyzed in this Section.

Table 3. Change in Risk, Inflation expectations and Systemic stress indicator after the monetary policy announcements

	3 weeks after announcement		
	ΔRisk (%)	ΔInfl (bp)	ΔCISS (%)
SMP1 (10 May 2010)	+56	-14	+33
SMP2 (7 August 2011)	+14	-18	+3
OMT (26 July 2012)	-12	+16	-29
PSPP1 (22 January 2015)	+123	-6	-36
PSPP2 (9 March 2015)	+5	-8	+106
PEPP1 (18 March 2020)	-6	+21	-14
PEPP2 (22 May 2020)	-20	+13	-13

Source: own calculations.

6. Conclusions

We show the evolution of financial risk on the monetary policy operations of the Eurosystem over the last decade using a methodology that relies on probabilities of default over a 1-year horizon inferred from real-time market data.

While from 2010 to 2020 the Eurosystem exposure arising from monetary policy operations grew more than threefold, financial risk estimated with our model at the end of the period is much lower than that measured at the peak of the sovereign debt crisis in 2012. The launch of the OMT succeeded in quelling market turmoil and reducing the risk of the Eurosystem. These effects seem to be long lasting.

Financial risk mainly accrues to the Eurosystem from outright purchase holdings (as part of APP and PEPP) rather than from credit operations, as the risk on the latter is attenuated by collateral and valuation haircuts, whereas risk on the bond holdings is unmitigated and directly exposes the central bank to financial market distress.

During the episodes of severe market tensions, financial risk appears as largely endogenous for the central bank, although to an extent that is admittedly difficult to assess with accuracy. This would call for a risk management mind-set that complements the use of standard quantitative methods for risk measurement with other economic considerations of more general nature.

A closer look at the events surrounding some key monetary policy decisions reveals that the decrease in financial risk brought about by the announcement of OMT and PEPP is associated with an improvement in inflation expectations and the mitigation of the stress index in financial markets. The APP announcement managed to stop at least temporarily the ongoing trend in deflationary expectations. These findings, together with the broader pattern of the Eurosystem risk from 2012 onwards, seem to provide a clear indication about the risk-efficiency of the above monetary policy measures.

To conclude, we show that a market-driven measure of default risk offers an important perspective on two issues, namely the risk endogeneity and the risk efficiency of different monetary policy decisions. Our findings raise important questions concerning the methodology for and interpretation of the estimates of financial risk for the central bank. Risk estimates based on point-in-time, market-driven, 1-year PDs and current exposures represent an accurate picture of risk over a short-term period based on all available information. These risk measures might be complemented with through-the-cycle estimates, which adopt a longer term perspective and could corroborate risk management decisions. A further analysis of these issues is left for future research.

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Glossary

ABS	Asset-Backed Security
ABSPP	Asset-Backed Securities Purchase Programme
AH	After Haircuts
APP	Asset Purchase Programme
BH	Before Haircuts
BV	Book Value
CBPP	Covered Bond Purchase Programme
CDS	Credit Default Swap
CDS-I-EDF	CDS-Implied-EDF
CISS	Composite Indicator of Systemic Stress
CSPP	Corporate Sector Purchase Programme
EA	ECB Approach (for risk estimation)
EAD	Exposure-at-Default
ECB	European Central Bank
EDF	Expected Default Frequency
ELA	Emergency Liquidity Assistance
ES99	Expected Shortfall at 99 percent confidence level
EU	European Union
EUREP	Eurosystem repo facility for non-euro area central banks
FV	Face Value
KMV	Moody's proprietary model originally developed by Kealhofer, McQuown and Vasicek
L	Loss
NCB	National Central Bank (member of the Eurosystem)
OMO	Open Market Operations
OMT	Outright Monetary Transactions
PD	Probability of Default
PELTRO	Pandemic Emergency Longer-Term Refinancing Operations
PEPP	Pandemic Emergency Purchase Programme
PSPP	Public Sector Purchase Programme
RR	Recovery Rate
SIO	Scorecard-Indicated Outcome (an intermediate rating provided by Moody's)
SMP	Securities Market Programme
TLTRO	Targeted Longer-Term Refinancing Operations
UP	Unconventional Policies
VLTRO	Very Long-Term Refinancing Operations

Appendix

A. Moody's CDS-implied EDF

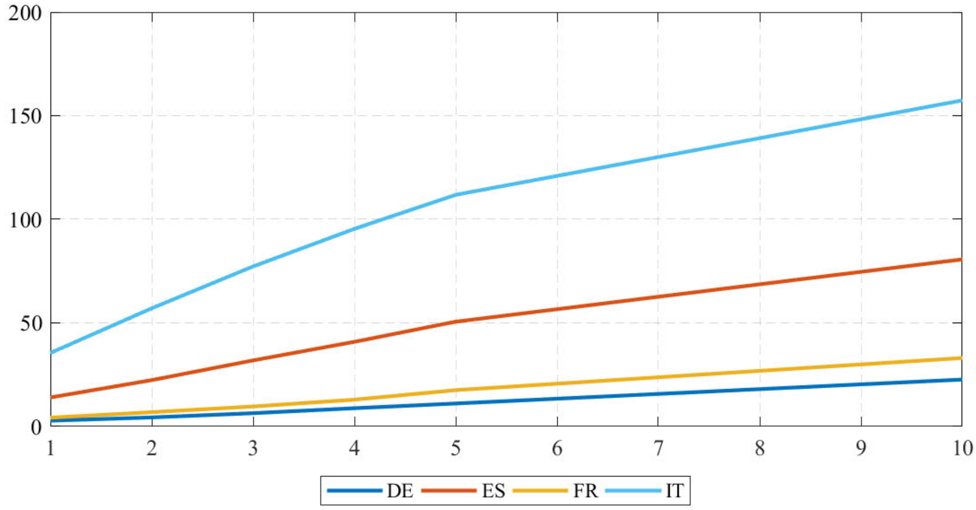
CDS-implied EDF (CDS-I-EDF) are physical PDs provided by Moody's and calculated using CDS quotes.[46] Moody's methodology relies on two equations:

1. the spread valuation equation, which converts CDS premia into risk-neutral PDs;
2. the translation equation, which converts risk-neutral PDs into physical PDs.

The first equation requires a formula for the pricing of CDS contracts. They contain two legs: i) the first leg, including the periodic coupons paid by the protection buyer until the maturity of the contract or the credit event, whichever comes first; ii) the protection leg, consisting in the principal amount being paid by the protection seller in case of a credit event. The value of both legs depends on the PD of the reference entity which the contract is linked to. The risk-neutral PD are obtained by equating the present values of the premium and protection leg under the risk-neutral assumption (i.e., using the risk-free rate to discount cashflows).

In general, the pricing of a CDS requires the entire term structure of risk-neutral PDs, from time zero to the maturity of the contract. Even though several CDS contracts may be written on the same entity for different maturities (Figure 13), they are not sufficient to fully specify the term structure.

Figure 13. CDS term structure of Germany, Spain, France and Italy (average in Q4 2020; basis points)



Source: CMA.

[46] This section draws from Moody's Analytics (2010).

To solve this issue, a parametric specification of the probability of default curve is typically considered. In particular, Moody's employs the Weibull distribution:

$$Q_t = 1 - e^{-\frac{t}{\alpha}^{\beta}}$$

where Q_t is the risk-neutral PD, t is the maturity, α and β are the parameters of the Weibull distribution, which are calibrated in order to fit the available CDS quotes.

The CDS term structure of distinct entities has an impact on the estimated probability of default, which may be similar on short horizons (e.g. 1-year), but diverge for longer ones (5-years), as shown in Table 4 below.

Since in the CDS pricing the cashflows of both legs are discounted at the risk-free rate, the resulting risk-neutral PDs contain a component linked to the market price of risk, and thus generally overestimate the actual (physical) PDs. In order to remove this component, the following translation equation is applied:

$$P_t = N\left(N^{-1}(Q_t) - \lambda\rho\sqrt{t}\right)$$

where P_t is the physical PD, N is the cumulative normal distribution, λ is the market Sharpe ratio[47] and ρ is the correlation between the asset return of the reference entity and that of the market. The derivation of the formula requires several assumptions, since it involves the Merton's model for structural credit risk and the Capital Asset Pricing Model (CAPM).

Two key parameters are required for the estimation of CDS-I-EDFs:

1. the LGDs, which are required for the pricing of the protection leg of CDS contracts (for each LGD assumption, a different risk-neutral PD term structure is derived);
2. the market Sharpe ratios (λ).

Moody's calibrates these parameters on equity-based EDF measures, so that CDS spreads can be converted into EDF levels and vice versa. Sharpe ratios are estimated by geographic region and asset class (either investment grade or high yield) to account for the fact that for similar EDF levels, CDS spreads may differ across regions and asset classes (e.g., Japanese companies tend to have lower CDS spreads than companies in other regions for the same EDF level; investment grade companies tend to have lower CDS spreads than high yield companies for the same EDF level, etc.). LGDs are estimated by geographic region and industry sector.

The calibration is performed in two steps. First, Sharpe ratios are calibrated for all combinations of regions and asset classes using a flat LGD of 60 percent for all companies. Second, LGDs are calibrated for each region and sector, using the previously estimated Sharpe ratios, to ensure consistency between spreads and EDF measures also at sector level.

By construction, LGDs are centered on 60 percent for each region, which is typically assumed by market participants for corporate issuers. Therefore, the estimated LGDs essentially capture the relative

[47] The Sharpe ratio is defined as the ratio between excess return and volatility.

differences of LGDs among sectors, not their absolute value (which is captured by the Sharpe ratio, if it significantly differs from 60 percent).

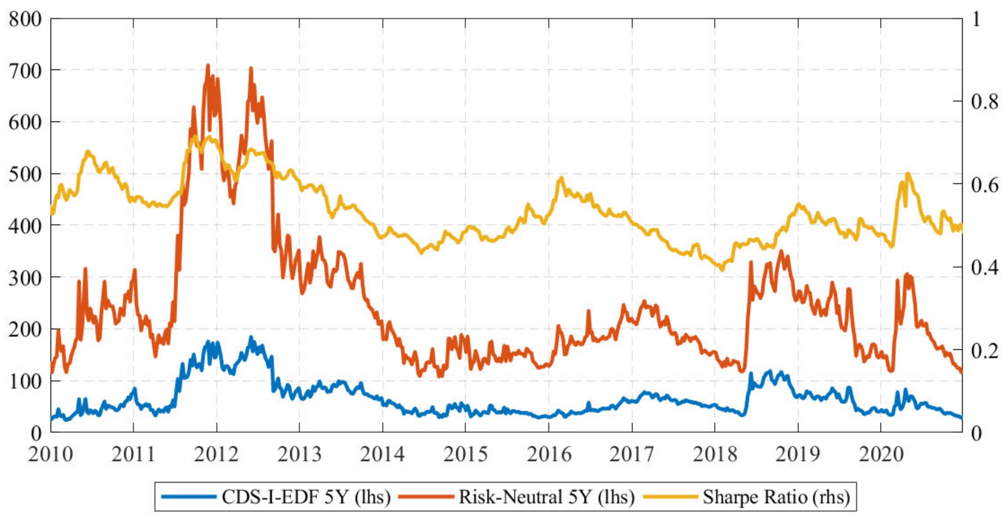
Since equity-based EDFs are not available for sovereign issuers, Sharpe ratios and LGDs cannot be directly derived as described above. For sovereign issuers, Moody's applies the following assumptions:

1. Sharpe ratios are taken from the North American corporate sample (whose market prices are deemed as relatively more reliable): investment grade governments receive the Sharpe ratio of investment grade American corporates; high yield governments receive the Sharpe ratio of high yield American corporates;
2. LGDs are set equal to 75 percent, that is most often used for sovereign CDS pricing (rather than 60 percent, used for corporates) and which takes into account the peculiar nature of a sovereign default (greater uncertainty, 'willingness to pay' rather than 'ability to pay', liquidation cannot be forced, etc.).

This methodology is applied to derive the 5-year CDS-I-EDFs. The EDFs for different horizons, such as the 1-year horizon that is used in this paper, are derived from the 5-year ones following an approach that models the relationship between credit risk and time horizons with three components: an asymptotic default tendency, a systemic factor and a firm-specific factor (see Moody's Analytics, 2017 for further details).

Figure 14 plots the estimated Sharpe ratio for euro area governments, which is used to convert the risk-neutral PDs into the CDS-I-EDF (right y-axis). The same figure also compares the 5-year CDS-I-EDF with the 5-year risk-neutral PD for Italy (left y-axis).

Figure 14. 5-year CDS-I-EDF and 5-year risk-neutral PD for Italy (basis points) and Sharpe ratio

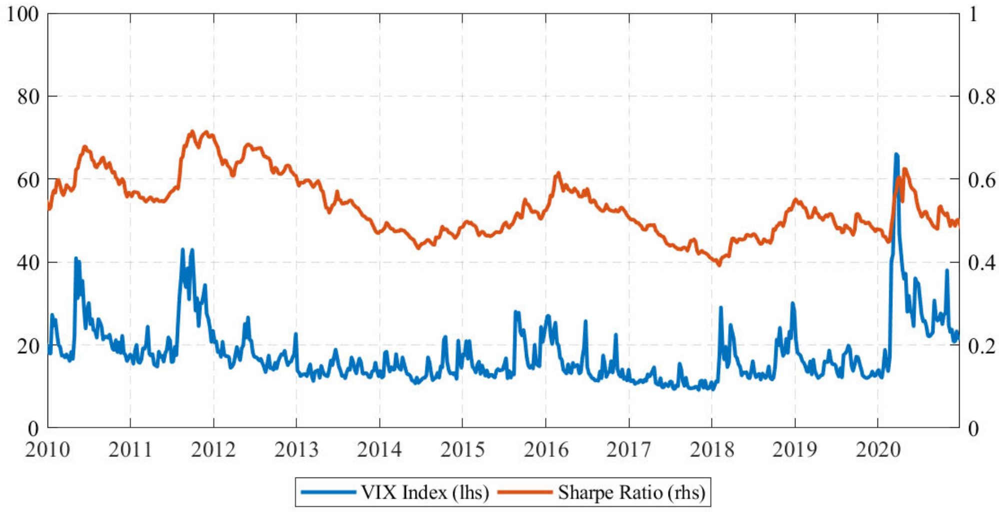


Source: Moody's Credit Edge.

We note that the market price of risk, measured by the Sharpe ratio, reaches local lows in June 2014 and January 2018, while in 2020 it is close to its long-term average. This implies a moderate correction to the risk-neutral PDs and contributes to explain the low CDS-I-EDF levels of euro area sovereigns observed in recent times.

Figure 15 compares the market Sharpe ratio with the VIX index, which measures the implied volatility of the American equity market and can be viewed as a further indicator of the market price of risk. In 2020 the VIX index was above its long-term average, thus confirming the high level of the market price of risk estimated with the Sharpe ratio.

Figure 15. Market Sharpe ratio and VIX index



Source: Moody's Credit Edge, Bloomberg.

As a further robustness check of the sovereign CDS-I-EDFs, we verify the consistency of the implied rating in these CDS-I-EDFs, a piece of information also provided by Moody's Analytics through the Credit Edge platform, with the actual rating assigned by Moody's Investors Service, a separate legal entity of the Moody's group in charge of the rating business, to the senior unsecured debt of the issuer (i.e., the official rating). In addition, we compare the implied ratings also with the so called Scorecard-Indicated Outcomes (SIO), provided by Moody's Investors Service as a simple reference tool that can be used to approximate the credit profile of the sovereign issuer and to explain the four most important factors underlying its credit rating: Economic Strength, Institutions and Governance Strength, Fiscal Strength and Susceptibility to Event Risk. Scorecard-Indicated Outcomes (SIOs), are the first building block of the credit analysis for sovereign issuers. Official ratings are then obtained by incorporating additional analytical judgments on other factors, such as environmental and social considerations, regulatory, litigation, liquidity, technology and reputational risk.[48]

[48] Moody's Investors Service (2019). Scorecard-indicated outcomes may not closely map into actual ratings as credit loss and recovery considerations, which become more important as an issuer gets closer to default, may not be fully captured in the scorecard.

Table 4 reports CDS-I-EDFs and CDS-I-EDF implied ratings for both the 1-year and 5-year horizon, and compares them with Moody's ratings. We note that ratings are related to the credit risk profile assessed over a medium-term horizon; therefore their comparison with 5-year CDS-I-EDF implied ratings (not to 1-year CDS-I-EDF) is more appropriate.

Table 4. CDS-I-EDF (basis points), CDS-I-EDF implied ratings and Moody's actual ratings (25 December 2020)

	CDS-I-EDF (basis points)		**CDS-I-EDF implied rating**		**Rating**		**5-year impl. rating vs SIO/official rating (difference in notches)**	
	1-year	5-year	1-year	5-year	SIO (mid point)	Official	SIO (mid point)	Official
Austria	1.00	1.88	Aaa	Aaa	Aa3	Aa1	3	1
Netherlands	1.00	2.09	Aaa	Aaa	Aa2	Aaa	2	0
Germany	1.00	2.13	Aaa	Aaa	Aa1	Aaa	1	0
Finland	1.00	2.73	Aaa	Aaa	Aa2	Aa1	2	1
Belgium	1.00	3.02	Aaa	Aaa	Aa3	Aa3	3	3
Ireland	1.00	3.46	Aaa	Aaa	Aa2	A2	2	5
France	1.00	3.78	Aaa	Aaa	Aa3	Aa2	3	2
Portugal	1.00	9.91	Aaa	A1	Baa1	Baa3	3	5
Spain	1.00	11.80	Aaa	A2	A2	Baa1	0	2
Slovakia	1.00	12.52	Aaa	A2	A1	A2	-1	0
Estonia	1.00	14.54	Aaa	A3	Aa3	A1	-3	-2
Lithuania	1.00	17.29	Aaa	A3	A2	A3	-1	0
Latvia	1.00	17.69	Aaa	A3	A3	A3	0	0
Slovenia	1.00	20.52	Aaa	Baa1	A3	A3	-1	-1
Greece	1.15	24.52	Aaa	Baa2	Ba3	Ba3	4	4
Cyprus	1.32	26.67	Aa1	Baa2	Baa2	Ba2	0	3
Italy	1.62	29.55	Aa1	Baa2	Baa2	Baa3	0	1
Malta	4.33	52.32	Baa1	Ba1	A1	A2	-6	-5
						Average	**0.6**	**1.1**
						Standard deviation	**2.5**	**2.5**

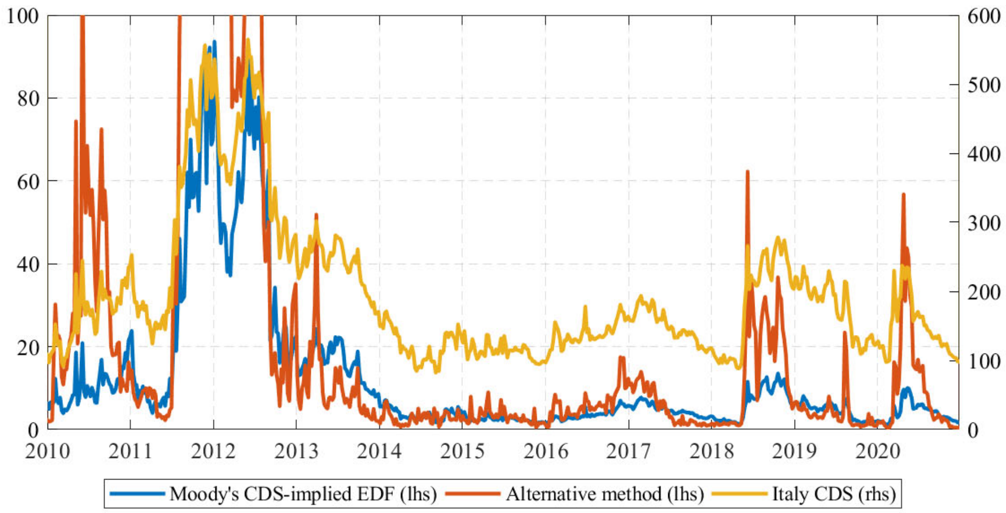
Source: Moody's Credit Edge, Moody's Investors Services.

Table 4 shows that CDS-I-EDFs mirror the positively sloped term structure of CDS premia shown in Figure 13: while the 1-year probability of default is around 1 basis point for all sovereign issuers, 5-year probabilities of default range from 2 to 30 basis points and are higher for the issuers whose CDS slope is steeper. We also note that the 5-year CDS-I-EDF implied ratings are consistent with Moody's ratings: the Italian 5-year CDS-I-EDF is 29.55 basis points, corresponding to an implied rating of Baa2, in line with the Scorecard-Indicated Outcome (Baa2) and one notch above Moody's official rating (Baa3).

On average, Moody's ratings are 1 notch worse than 5-year CDS-I-EDF implied ratings, even though some significant discrepancies can be detected in both directions (e.g. for Ireland, Greece, Portugal, and Malta). Moody's Scorecard-Indicated Outcomes are more in line with the 5-year CDS-I-EDF implied ratings, since the average difference is half notch.

Figure 16 plots the 1-year CDS-I-EDF for Italy, and compares it with the physical PD computed from CDS quotes using the methodology proposed by Heynderickx *et al.* (2016), which is also employed by Caballero *et al.* (2020). The PDs produced with this alternative method exhibit a much higher volatility than Moody's EDFs. We attribute this to the fact that the latter benefit from daily updates of the Sharpe ratio, which allows adjustments (from risk-neutral to physical PD) of different magnitude depending on market conditions, possibly filtering out some of the volatility in the underlying CDS quotes. On the other hand, the parameters proposed by Heynderickx *et al.* for converting risk-neutral PDs into physical PDs are constant over time, hence market noise incorporated in risk-neutral PDs is filtered to a lesser extent.

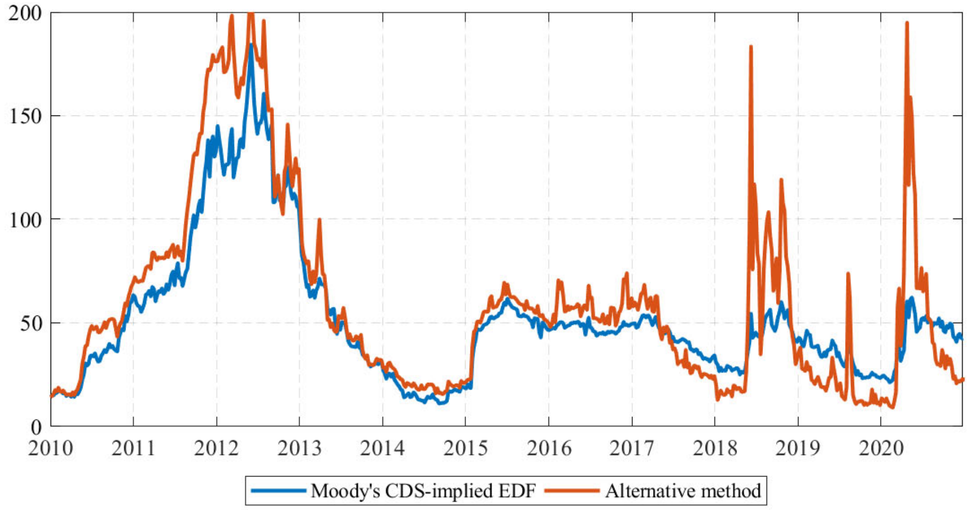
Figure 16. 1-year probability of default of Italy and Italy's CDS (basis points)



Source: Moody's Credit Edge, CMA, own calculations.

Figure 17 shows the impact on risk of two different PD specifications for the sovereign: a) Moody's EDF, which we used (the blue line corresponds to the risk reported in Section 5); b) an alternative specification based on Heynderickx *et al.* (2016). The volatility of the PD with the latter method affects the volatility of the corresponding risk estimate, with a larger peak-to-trough difference.

Figure 17. Risk (€ billion)



Source: own calculations.

B. Estimation of the Student *t* distribution

The defaults of issuers and monetary policy and ELA counterparties are simulated with a multivariate Student *t* distribution whose parameters are (i) the correlation matrix and (ii) the degrees of freedom.

The choice of the multivariate distribution does not have an impact on the simulated default rates of individual issuers, which are by construction equal to the assumed PDs (up to the Monte Carlo error, see Section 2). Nevertheless, they determine the simulated 'joint' default rates (i.e. the number of scenarios where many debtors jointly default, leading to the largest losses).

We use the log-changes of the country-sector EDF indices defined in Section 4 as input data for the estimation of the parameters of the multivariate distribution, as described below. The idea of using the correlation between (a monotonous transformation of) the probability of default as a proxy for the correlation between the debtors is quite common (it is also used by Caballero *et al.*, 2020). The log-changes function maps the domain of the EDF, which is the [0, 1] interval, to the real axis, where the Student *t* distribution is defined. We also check that other transformations have negligible impacts on the resulting estimates.[49]

The estimation is performed in two steps. First, the correlation matrix is estimated. The correlations between debtors are set equal to the correlations between the log-changes of the country-sector EDF indices (out of the diagonal). As an example, the correlation between any Italian bank and any German corporate is set equal to the correlation between the log-changes of the Italian bank EDF index and the log-changes of the German corporate EDF index. If two debtors belong to the same country-sector group, than the correlation is set equal to either 100 percent, if they are sovereigns (since we have a single sovereign for each country), or to the maximum correlation among those previously estimated for the sector. For instance, the correlation between two Italian banks is set equal to the maximum correlation between the log-changes of the Italian bank EDF index and the log-changes of the EDF indices of all the other banks. Second, the degrees of freedom are obtained by means of maximum likelihood estimation, conditionally on the previously estimated correlation matrix:

$$dof = argmax_{\theta} \sum_{i=1}^{N} log\ f(\theta; \rho, \Delta logEDF_i)$$

where f denotes the multivariate Student t density function, N is the number of observations, θ denotes the degrees of freedom (to be estimated), ρ is the correlation matrix (estimated in the first step).

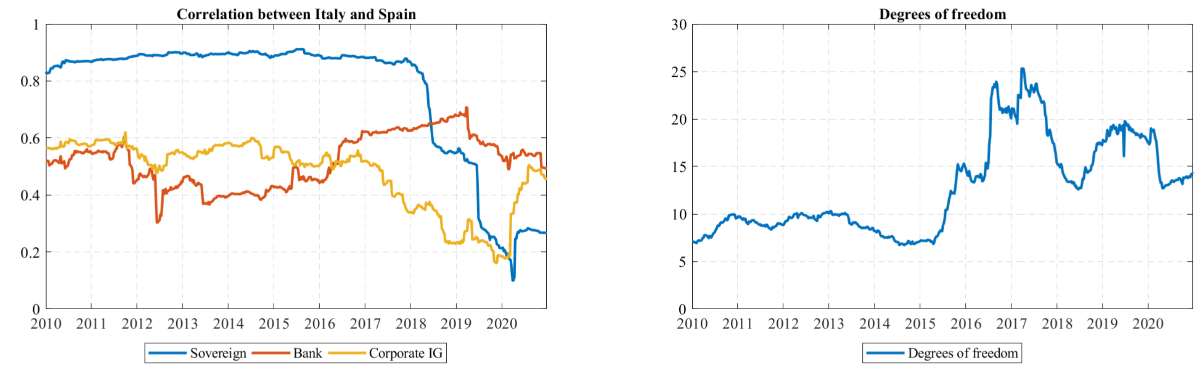
These parameters are estimated with a moving average rolling approach using the last three years of weekly data (156 observations). This means that on each date risks are estimated using a different correlation matrix and a different value for the degrees of freedom (Figure 18). The resulting risk estimates are thus fully out-of-sample, i.e. more reflective of the actual market risk perception at any point in time.

Figure 18 plots the estimated correlations between Italy and Spain for the sovereign sector, the bank sector and the (investment grade) corporate sector (left panel) and the degrees of freedom (right panel).

[49] More specifically, we perform an estimation based on the changes in normal quantiles of the EDF indices.

We find that the estimated degrees of freedom are below 10 until 2016 and larger in the following years, implying a higher deviation from normality in the first half of our period (we recall that the Student *t* distribution approaches the Gaussian distribution as the degrees of freedom grow).

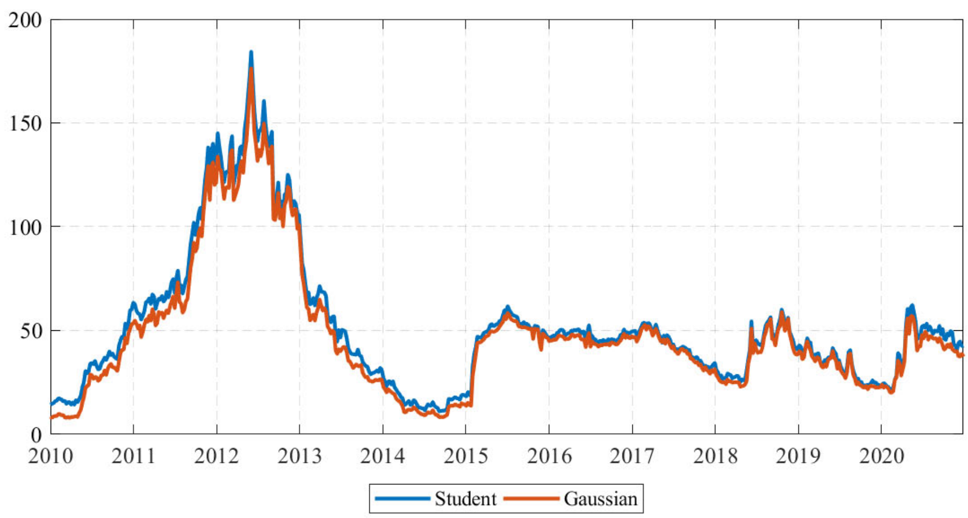
Figure 18. Time-varying Student *t* parameters



Source: own calculations.

In order to gauge the sensitivity of the results to some of the modelling assumptions used in this paper, Figure 19 shows the impact on risks of different copula specifications, namely comparing the proposed fat-tail approach (Student *t*) with the Gaussian approach. The Student *t* copula implies an average increase of risks by 14 per cent with respect to the Gaussian copula, with peaks above 40 percent in some periods.

Figure 19. Risk (€ billion)



Source: own calculations.

While accounting for fat tails leads to higher estimated risk, the risk profile is substantially equivalent, with a peak in June 2012 and a level four times smaller at the end of 2020. This confirms the robustness of our conclusions. Finally, Figure 20 shows that the choice of different rolling window lengths, namely the proposed 3-year window versus the alternative 2-year and 1-year windows, does not affect our results in a significant way.

Figure 20. Risk (€ billion)

Source: own calculations.

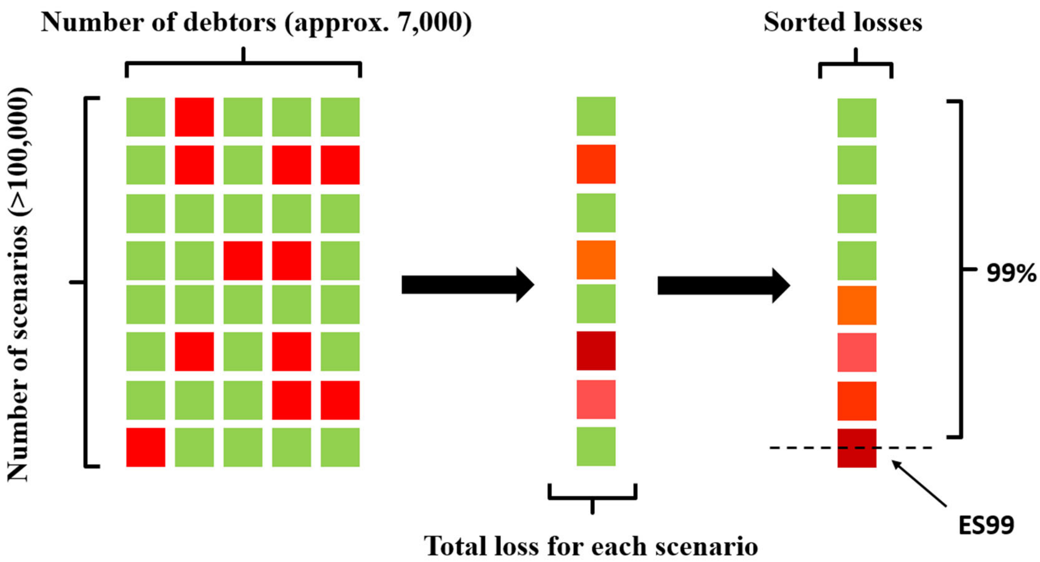
C. Further methodology details

1. Simulation process

Figure 21 below represents a stylized picture of the simulation process. For each date and scenario, the financial state of each debtor is simulated in order to establish if it has defaulted (red = in default; green = solvent). Each default might result in a loss, the severity of which depends on the type and amount of the exposure. For example, the default of an issuer of purchased securities always generates a loss, while the default of an issuer of collateral assets typically does not generate a loss, unless the monetary policy or ELA counterparty jointly defaults and the applied haircuts are found to be insufficient.

Losses realized within a scenario are then aggregated. Finally, risk is computed as the expected shortfall at the 99 percent confidence level (ES99), i.e. taking the average of the 1 percent most adverse losses realized in the simulated scenarios at any particular date.

Figure 21. Simulation process and calculation of risk



2. Simulation of collateral

While risks on purchase programme holdings and counterparties are simulated over a 1-year horizon, collateral is simulated over a much shorter horizon, since it is assumed to be swiftly liquidated by the Eurosystem in the event of a counterparty default. More specifically, collateral is simulated over the time horizon that is deemed necessary for its smooth liquidation (time-to-liquidation, T2L). Table 5 reports the T2Ls used in our exercise, which are based on expert judgement. In most cases, a few weeks are considered sufficient to liquidate collateral. Noticeable exceptions are own-used assets,[50] simulated over a 1-year horizon to align their outcome to that of the counterparty, and credit claims, simulated over a 1-year horizon as well, to take into account their non-marketable nature and possible operational hurdles.

Table 5. Assumed time-to-liquidation for collateral (number of weeks)

Central governments	1
Local governments	2
Agencies & Supranational	2
Covered bonds	3
ABSs	6
Uncovered bank bonds	6
Corporate & other	6
Own-used collateral	52
Credit claims	52

In order to simulate collateral over a time horizon equal to the assumed T2L, the default thresholds (T_i, see Section 2) must be on the T2L PDs (e.g., the default threshold of a government bond pledged as collateral is given by the Student *t* quantile of the 1-week PD). We inferred T2L PDs from 1-year PDs with the following formula, which assumes constant conditional default probabilities:

$$PD_{T2L} = 1 - \left(1 - PD_{1-year}\right)^{T2L}$$

We note that the same asset might be included in the purchase programme holdings as well as collateral. In such case, two different thresholds are considered: one for the purchase programme holdings (based on the 1-year PD of the issuer) and one for the collateral (based on the T2L PD of the issuer).

Finally, we aggregate credit claims pledged as collateral in order to reduce the computational burden. For each counterparty, we aggregate all credit claims into two different groups: one containing credit claims with credit quality comparable to investment grade, and one containing the remaining ones.[51] These two groups are simulated as if they were a single instrument (i.e. as if they had the same debtor), with a PD equal to the weighted average of the individual PDs. By doing so the number of credit claim debtors shrinks from above 100,000 (the actual number of distinct debtors) to below 1,000. The approximation leans on the conservative side, since it reduces the degree of diversification within the collateral pool.

[50] Own-used assets are those assets for which issuer and counterparty are either the same or have close links. Currently, only covered bonds are accepted as own-used collateral.

[51] The credit claims accepted under the Additional Credit Claims regime fall under this second category.

3. ELA operations

In theory, losses arising from ELA operations could be calculated with the same formula reported for the monetary policy credit operations (see Section 2). In practice, however, risks from ELA exposures have to be modelled with some suitable assumptions, as the data regarding the amount and composition of collateral are not available and the potential role of the government as the ultimate guarantor in case of a systemic crisis, or ELA granted to systemic relevant banks, should be taken into account.

As a first assumption, we set EAD equal to the current exposure. This makes sense since in the ELA operations the exposures is decided by the NCB and cannot be arbitrarily increased by the counterparty, even if abundant collateral is available. In addition, we conservatively assume no over-collateralization:

$$EAD = \sum\nolimits_{a\ in\ collateral} AH_a = actual\ exposure$$

With regard to the composition of collateral, we distinguish between idiosyncratic ELA, where a single non-systemic bank is involved, and systemic ELA, where a relevant bank and/or a larger number of banks in the same jurisdiction resort to ELA. Both types are in turn divided into two different subtypes. More specifically we consider:

i. Idiosyncratic ELA – suspension. This is the case of a bank that relies on ELA after having been suspended from the monetary policy operations because of financial soundness issues. In this case we use for ELA the same collateral composition as that observed in the monetary policy operations right before the suspension;

ii. Idiosyncratic ELA – liquidity crisis. This is the case of a bank facing liquidity problems that resorts to ELA as an additional financing source while not being suspended from monetary policy operations. In this case we assume that ELA collateral entirely consists of credit claims, assuming that the most liquid assets – such as investment grade debt securities – are already pledged as collateral for the monetary policy operations;

iii. Systemic ELA – government support. This is the case of ELA granted to a systemic relevant bank or to a large number of banks in a jurisdiction, where an explicit support of the government is present, for example in the form of promissory notes and/or guarantees. In this case, we assume that collateral consists of a government guarantee, which covers the entire ELA exposure. For the calculation of risk, we only simulate the counterparty and the government: if they both default, then a loss is realized; otherwise, the loss is zero;

iv. Systemic ELA – government crisis. This is the case of ELA granted to an entire banking system, which is facing a severe crisis because of a simultaneous sovereign debt crisis. In this case, we only simulate the sovereign: if it defaults, we assume that both the counterparty and the collateral automatically default, generating a loss in the ELA operations; otherwise, the loss is zero.

In the case of systemic ELA (type iii. and iv. above), where the collateral composition is not considered, the loss (if any) is computed as:

$$L = EXP \cdot \left(1 - \frac{30\%}{1-H}\right)$$

where EXP is the actual exposure, 30 percent is the recovery rate and H is the average haircut.

4. Probability of default for covered bonds and ABSs

For covered bonds and ABSs[52] an adjustment is required to account for the fact that they exhibit a higher credit quality than their issuers. Since they are the least risky among the Eurosystem exposures,[53] we apply a simplified approach and divide the issuer's EDF by a predefined number, equal to 8.07 for covered bonds and 3.06 for ABSs. Such numbers are obtained by comparing the long-term default rates implied in the rating of these assets (as reported by rating agencies in their annual Default Studies)[54] with those implied by the rating of their issuers. In spite of the same average level of rating, we estimated a lower divisor (3.06) for ABSs than for covered bonds since ABS default rates are generally higher than non-ABS default rates, for any given rating level.

52 By ABS we mean 'senior tranches of ABS', which are the only type of ABS eligible as collateral and for purchases.

53 Covered bonds and ABSs have almost always an AA rating.

54 For covered bonds we use the 'Global Corporates' default rates, since no covered bonds default was ever experienced in the past. For ABSs, we use the 'Structured Finance' default rates.

D. Dataset and software

We build a unique dataset for this study. It is made up of four tables:

1. purchase programme holdings table: each record contains the face and book value for any given combination of date/portfolio/issuer. The number of dates is 574, the number of portfolios ranges from zero to nine,[55] depending on the date; the average number of issuers for any portfolio is 100, yielding a total number of records approximately equal to 260,000;
2. monetary policy credit operations table: each record contains the face value, before haircut and after haircut, for any given combination of date/counterparty/collateral issuer/collateral type. The number of dates is 574; the average number of counterparties per date is 1,500; the average number of collateral issuers for any date/counterparty is 15. Collateral type is a categorical variable that depends on the type of instrument, required for the assumptions on the recovery rates (e.g., covered bonds vs. uncovered bank bonds) and time-to-liquidation (e.g., market placed covered bonds vs. retained covered bonds). The total number of records is around 12 million;
3. ELA operations table: each record contains the face value, before haircut and after haircut, for any given combination of date/counterparty/collateral issuer/collateral type. The total number of records is around 8,000;
4. probabilities of defaults table: each record contains the PD for any given combination of date/debtor. The number of dates is 574, the number of debtors (either issuers or monetary policy counterparties) is approximatively 7,000, yielding a total number of records around 4 million.

Risk estimates are obtained with a C++ object-oriented program, while the calibration of the multivariate Student *t* parameters is performed with a Matlab script.

[55] CBPP1&2, SMP, CBPP3, ABSPP, PSPP, CSPP, PEPP-Covered, PEPP-Public, PEPP-Corporate.

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